

~~ENVIRONMENTAL GUIDELINES~~

WWU 401

THE WORLD BANK

OFFICE OF ENVIRONMENTAL AFFAIRS

ENVIRONMENTAL GUIDELINES

JUNE 1983

TABLE OF CONTENTS

	Page
FOREWORD.....	iii
1. ALUMINUM INDUSTRY.....	1
2. CANE SUGAR INDUSTRY.....	7
3. CEMENT INDUSTRY.....	18
4. CHLOR-ALKALI INDUSTRY.....	27
5. DAIRY PRODUCTS INDUSTRY.....	39
6. DUST EMISSIONS.....	46
7. EFFLUENTS, DISPOSAL OF INDUSTRIAL WASTES.....	54
8. EFFLUENTS, LIQUID, LAND DISPOSAL & TREATMENT.....	63
9. ELECTROSTATIC PRECIPITATORS (ESP'S).....	65
10. ETHANOL PRODUCTION.....	66
11. FERTILIZER MANUFACTURING WASTES.....	76
12. FISH AND SHELLFISH PROCESSING.....	86
13. FRUIT AND VEGETABLE PROCESSING.....	95
14. GEOTHERMAL DEVELOPMENT.....	103
15. GLASS MANUFACTURING.....	105
16. IRON & STEEL INDUSTRY - GENERAL CONSIDERATIONS.....	116
17. IRON & STEEL INDUSTRY - BLAST FURNACE.....	124
18. IRON & STEEL INDUSTRY - BY-PRODUCT COKE OVENS.....	130
19. IRON & STEEL INDUSTRY - ORE PREPARATION, SINTERING AND PELLETIZING	137
20. IRON & STEEL INDUSTRY - ROLLING AND FINISHING OPERATIONS.....	143
21. IRON & STEEL INDUSTRY - STEEL MAKING PROCESS.....	155
22. LEAD SAMPLING AND ANALYSES.....	169
23. MEAT PROCESSING AND RENDERING.....	177
24. MINING - STRIP SURFACE MINING OPERATIONS..... (SEDIMENT & EROSION CONTROL - LAND RECLAMATION)	183
25. MINING - UNDERGROUND (COAL).....	189
26. NITROGEN OXIDE EMISSIONS.....	198
27. NITROGEN OXIDE SAMPLING AND ANALYSES.....	204
28. NOISE.....	211
29. NON-FERROUS METALS INDUSTRY - ALUMINUM.....	219
30. NON-FERROUS METALS INDUSTRY - COPPER & NICKEL.....	228
31. NON-FERROUS METALS INDUSTRY - LEAD & ZINC.....	240
32. NON-FERROUS METALS INDUSTRY - SILVER, TUNGSTEN, COLUMBIUM AND TANTALUM	251
33. OFFSHORE HYDROCARBON EXPLORATION AND PRODUCTION PROJECTS.....	263
34. OIL PIPELINES.....	275
35. OIL SHALE OPERATIONS.....	281
36. PALM OIL INDUSTRY.....	295
37.* PESTICIDE MANUFACTURE - SAFETY AND ECOLOGY.....	303
38.* PESTICIDES - GUIDELINES FOR USE.....	306
39. PETROLEUM REFINING.....	312
40. PLATING AND ELECTROPLATING.....	323

	Page
41. PLYWOOD MANUFACTURING.....	332
42. POULTRY PROCESSING.....	341
43. PULP AND PAPER INDUSTRY.....	348
44.* RODENTICIDES.....	364
45. RUBBER PRODUCTION (CRUMB).....	367
46. SECONDARY ENVIRONMENTAL EFFECTS.....	372
47. SLAUGHTERHOUSES I - INDUSTRIAL WASTE DISPOSAL.....	374
48. SLAUGHTERHOUSES II - DESIGN ARRANGEMENT.....	379
49. SULFUR DIOXIDE EMISSIONS - GENERAL POLLUTION SO ₂	385
50. SULFUR DIOXIDE SAMPLING AND ANALYSES.....	392
51. LEATHER TANNING AND FINISHING.....	399
52. TEA AND COFFEE PRODUCTION.....	408
53. TEXTILE AND SYNTHETIC FIBER INDUSTRIES.....	413
54. WOOL SCOURING.....	421

* Denotes Environmental and Occupational Health and Safety.

INDUSTRIAL WASTE CONTROL GUIDELINES

As an integral part of its appraisal and supervision functions, the World Bank is required to evaluate the adequacy and effectiveness of pollution control measures for projects involving industrial operations. These evaluations are concerned not only with effects on environment, but with effects on the occupational health and safety of industrial workers as well.

To assist Bank's missions, the Office of Environmental Affairs has developed a series of guidelines covering industries and pollutants most frequently, or considered most likely, to be encountered in the Bank lending programs.

Each industry, or major pollutant, which may be common to a number of industries, is treated separately. Guidelines are designed to present only an overview of a particular industry or pollutant rather than exhaustive coverage.

Each guideline covers a number of aspects, including: environmental factors, permissible pollutant levels, and principal control methods. If applicable, the guideline includes a discussion of gaseous, liquid and solid waste aspects of the same industry or pollutant.

Application of these guidelines must be adjusted to each specific situation. Permissible pollutant levels given, are considered to be achievable at reasonable costs by existing treatment and control technology. Where these performance levels cannot be achieved, the appraisal and/or supervisory mission should fully document deviations and reasons for these deviations, be they technical, regulatory or other. Where local regulations regarding permissible pollutant levels differ from those presented in these guidelines, the stricter regulations should prevail.

Individual guidelines will be revised periodically by the Office of Environmental Affairs as sufficient new knowledge becomes available to warrant changes. Additional guidelines covering specific industries will be written as required. While these guidelines were prepared primarily for use by Bank staff, their use by others is welcomed and encouraged. Further information concerning environmental activities of the World Bank are available by writing to:

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OFFICE OF ENVIRONMENTAL AFFAIRS

GUIDELINES

ALUMINUM INDUSTRY WASTES

1. Aluminum is considered to be the most abundant metal in the earth's crust. The aluminum industry is international in scope, and its manufacture, fabrication, and use are currently worldwide. The wastes resulting from the industry's operations are of significant proportions, and hence their effects must be considered in environmental impact assessments.

MANUFACTURING PROCESS

2. The basic material used in the manufacture of aluminum metal is bauxite ore. Major sources of the mineral are South America, the Caribbean and Australia. Specific sources include Jamaica, Haiti, Costa Rica, Surinam, Guyana, French Guiana, Brazil, Ghana, Guinea, Sierra Leone, Cameroon, Sumatra, Java and Borneo.

3. The most commonly used method for the production of aluminum metal from bauxite ore is the Bayer Process, followed by the Hall-Heroult Process. Thus, aluminum production may be considered a two-step process.

4. In the Bayer Process the bauxite is digested with hot, strong alkali solution (generally sodium hydroxide) to form a solution of sodium aluminate, and a mud residue (commonly referred to as "red mud"). The solution is then cooled and the mud residue removed by settling and/or filtration. The hydrated aluminum is calcined to produce alumina (Al_2O_3), following carbon dioxide injection.

5. The alumina is then reduced electrolytically by the Hall-Heroult Process, to produce aluminum, involving the electrolysis of alumina dissolved in a fused salt electrolyte consisting of cryolite ($\text{Na}_3\text{Al F}_6$) with minor additions of other fluoride salts. The process is carried out in a cell (pot) — consisting of a carbon anode, a cathode, and the electrolyte — contained in a carbon-lined steel box. This is followed by alloying and casting into ingots. The ingots are then shaped for final use by casting, rolling, forging and/or extrusion.

6. The industry is currently investigating the possibility of producing alumina from alumina-bearing raw materials, as an alternative to the Bayer Process. Recycling is also a source of aluminum metal, with material coming mainly from new scrap, aluminum cans, and discarded automobile bodies.

ENVIRONMENTAL ASPECTS

A - BAUXITE MINING

7. The major environmental concerns in bauxite mining operations are land reclamation, runoff water control, dust control and infrastructure impacts.

8. It is generally accepted that in cases of mining and related operations the land should be restored to an equal or more useful state than existed before the start of such operations. Reclamation measures and costs should be carefully assessed and included in the projected mining costs.

9. Rainwater runoff control can be both difficult and costly under certain conditions. Runoff waters should be carefully considered in terms of suspended solids, pH, dissolved solids, and metals. Dust problems may arise from the mining, handling, and shipping of bauxite ore. Ore operations can also generate unwanted noise from blasting and the use of heavy excavation and transportation equipment. Infrastructure needs can include access roads and facilities, personnel housing, and community services.

B - BAUXITE PROCESSING AND REFINING

10. In the processing of bauxite to produce aluminum, the principal environmental concerns include: (1) disposal of the bauxite residue (red mud); (2) dirt losses; (3) emissions from fuel burning; (4) waste liquid and slurry streams, other than bauxite residue; (5) noise; and (6) infrastructure impacts.

11. The amount of bauxite residue can vary from a half to one ton dry weight per ton of alumina produced; depending upon the type of bauxite and the manner in which it is processed. The mud normally contains 20 to 30 percent of solids. While the chemical composition can vary widely, a representative sample will generally range as follows:

<u>Component</u>	<u>% (Dry Basis)</u>
Fe ₂ O ₃	30-60
Al ₂ O ₃	10-20
SiO ₂	3-20
Na ₂ O	2-10
CaO	2-8
TiO ₂	Trace-10
Loss On ignition	10-15
pH	12-12.5 (Sol. Fraction)

12. While a number of disposal methods for these residues have been investigated, some form of dumping is currently considered to be the best method, including (1) land impoundment; (2) ocean dumping by ships, barges, or pipelines; and (3) seashore reclamation.

13. Land impoundment in a diked impervious area is most frequently used, and is the method to be generally employed for Bank-supported projects. Care must be taken to avoid contamination of ground waters. The settling ponds can remove 30 to 60 percent of the solids. In some cases, water from the impoundment area can be returned to the process as make-up water.

14. Sea disposal is practiced in a number of areas. At some sites in the Mediterranean, the residue is discharged via pipelines into underwater canyons at depths of over 2,000 meters. In Japan sea dumping is permitted, but only to areas and by methods specified by government regulations, with disposal areas being located over 300 kilometers from shore. Use of bauxite residue for seashore reclamation is permitted in Japan on a limited basis, but has been found to be very costly.

15. For Bank-sponsored projects sea disposal may be used in special cases only, under carefully controlled conditions, and with the assurance that there will be no harmful effects on sea life.

16. The handling of bauxite from its transportation source through storage and processing can generate significant fugitive dust emissions, as can the handling of aluminum from processing to shipping. Although both bauxite and aluminum are inert materials, their escape into the atmosphere can create a nuisance problem. Exhaust gases from aluminum calcination may also be a source of undesirable dust emissions. Abandoned bauxite impoundment areas can also lead to appreciable dust generation if allowed to become entirely dry.

17. Fuel burning for steam generation and aluminum calcination can produce emissions of sulfur dioxide and oxides of nitrogen. Stacks for these facilities should be designed to meet applicable ambient air quality standards.

18. Infrastructure effects may extend some distance from the plant site itself. Consideration should be given to access roads, bauxite unloading and aluminum shipping facilities, water supplies, power needs, housing for the work force, and community facilities.

C - ALUMINA REDUCTION

19. The emissions resulting from the primary reduction process are both gaseous and particulate in character. The gaseous portions consist mainly of hydrogen fluoride (HF), with traces of other fluoride compounds. The particulate material is chemically ill defined, but does contain substantial quantities of fluoride. The proportion of gaseous to particulate fluorides will vary considerably, depending upon the type of cell being operated.

20. While fluorides are the principal substance of concern, attention must be given to other potential waste problems. Scrap carbon, used pot linings, and precipitator dusts should also be considered. The use of wet scrubber systems may require liquid waste treatment.

STANDARDS AND CONTROLS

21. The contaminants of principal concern in the production of aluminum metals are the fluorides, in various forms. Standards defining allowable levels have been established in various countries. On the basis of these and of the currently available technology, the Bank has established limits which are to be adhered to for its projects involving this type of industrial development. These limitations are as follows:

A. Bauxite Mining

1. There is to be no disposal of mine tailings to waterways or to the sea, except under very special circumstances and very carefully controlled conditions.
2. A reclamation program is to be established for handling mine tailings. The project sponsor is to submit a proposed plan of action, which will be evaluated as part of the project appraisal.
3. The reclamation program is to be initiated within three (3) years of the start of project operations.

B. Bauxite Processing and Refining

There is to be no disposal of red mud into either the waterways or into the sea.

C. Primary Aluminum Smelting

1. Liquid Effluents

<u>Contaminant</u>	<u>Kg. Al. Produced</u>	<u>per Mg*</u>
Fluorides (Total)	0.05	
TSS	0.01	
pH	6 to 9	

2. Gas Effluents

Stack heights and stack releases should be such that air concentration both inside and outside the plant will conform to the following limits:

* 1 Mg = 1 megagram = 1 metric ton.

a. Annual Mean

Fluorides (as HF)	10 $\mu\text{g}/\text{m}^3$
Fluorides (Insol.)	30 $\mu\text{g}/\text{m}^3$

b. Eighty-Hour Peak

Fluorides (as HF)	100 $\mu\text{g}/\text{m}^3$
Fluorides (Insol.)	300 $\mu\text{g}/\text{m}^3$

c. Total Emissions

Total fluoride discharge is to be no greater than 1 Kg. per Mg of aluminum produced, and the discharge of total particulate is to be no greater than 5 Kg. per Mg of aluminum produced.

In applying these standards it is essential that currently recognized and accepted methods of analysis be used to measure concentrations of the contaminants of interest. Standard methodology is generally available, and may be found in the literature.

BIBLIOGRAPHY

1. "The Aluminum Industry and the Environment." UNEP Industry Sector Seminars, Aluminum Meeting, Paris, 6 to 8 October 1975. Papers and Documents. (1975).
2. "Environmental Aspects of the Aluminum Industry-An Overview." UNEP Industry Programme. Paris (May 1977).
3. "Environmental Recommendations for Siting and Operation of New Primary Aluminum Industry Facilities." International Primary Aluminum Institute. London (1977).
4. "Environmental Considerations of Selected Energy Conserving Manufacturing Process Options." Alumina/Aluminum Report. U.S. Environmental Protection Agency. Doc. EPA 600/7-76-034 h. Washington (December 1976).
5. "Air Pollution Control in the Primary Aluminum Industry." Singmaster & Breyer. New York (1973).
6. "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Bauxite Refining Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category." U.S. Environmental Protection Agency. Doc. EPA 440/l-74/019-c (March 1974).
7. "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Primary Aluminum Smelting Subcategory of the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA -440/l-74-019-d (March 1974).
8. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Secondary Aluminum Smelting Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA-440/l-74-019-e (March 1974).
9. Bauxite, Alumina and the Environment (ISSN. 0378-9993. UNEP, Industry and Environment Office. July/ August/September, 1981.. Vol. 4 No. 3 17 Rue Margueritte, 75017, Paris, France.

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GUIDELINES

CANE SUGAR INDUSTRY

1. On the basis of general manufacturing practices, cane sugar production falls into one or the other of two groupings - raw cane sugar processing and cane sugar refining. These represent separate major steps in the process and are frequently carried out at separate locations. For the purposes of these guidelines each grouping will be discussed separately under each of the principal headings. Although in a few cases raw cane and refined sugar are produced in the same plant, the two types are treated separately since physically separate production facilities are generally utilized. There are substantial differences in the processes, as well as in the quality and quantity of waste effluents.

2. In each case organics and solids are the pollutant of significance. Pollution loadings are generally expressed in terms of biochemical oxygen demand (BOD_5) and total suspended solids (TSS). The hydrogen ion concentration (ph) is also important in measuring pollutional effects of these wastes.

MANUFACTURING PROCESSES

Raw Cane Sugar Processing

3. Sugar cane is a giant perennial grass, containing varying amounts of sucrose in the juice of the mature plant. The exact sucrose concentration depends upon the variety of cane, agricultural practices, and other factors. The harvested cane will typically contain 15 percent fiber and 85 percent juice, by weight. In turn, the juice will average 80 percent water, 12 percent sucrose, and 8 percent invert sugars and impurities.

4. The harvesting and loading of sugar cane on transport vehicles may be accomplished either manually or mechanically, depending upon the availability and cost of labor. The methods used will appreciably affect the amounts of dirt, trash and mud entering a mill. High loads of these materials are undesirable from both the processing and waste water handling viewpoints, and are generally higher where mechanical harvesting and loading are utilized.

5. The manufacturing process consists of cane washing and cleaning, milling or extraction of the juice from the stalk, clarification, filtration, evaporation and crystallization. Washing is generally employed when mechanical harvesting and loading are used. After cleaning, the cane is cut into chips, shredded and fed into a series of mills for crushing and extraction of 40 to 50 percent of the juice. The cane fiber from the final mill, known as "bagasse", is usually fed to a boiler and used to produce steam.

6. The juice from the mills contains large amounts of impurities. Screening removes the coarser shreds, which are returned to the mills. Lime, heat and a small amount of phosphate are used to remove much of the remaining impurities through precipitation, settling and decantation in continuous clarifiers. Following clarification the juice is divided into the clarified and precipitated mud portions. Rotary vacuum or other types of filters are used to thicken the precipitated materials and recover a part of the juice. The liquid from the clarification system is about 85 percent water and 15 percent soluble solids. Before crystallization, the solution is reduced by evaporation to obtain a syrup containing about 60 percent soluble solids.

7. The concentrated juice from the evaporation is crystallized, gently agitated and discharged to high-speed centrifuges to separate the crystal from the syrup. Crystals remaining in the centrifuge are washed with hot water to remove remaining syrup and the crystalline sugar transferred to storage for subsequent shipping of further processing.

8. A typical process flow diagram is presented in Figure 1.

Cane Sugar Refining

9. The raw material for refining consists of the crystalline sugar produced by the raw cane factories. The raw sugar contains a film of molasses, as well as various impurities such as bagasse particles, organics, inorganic salts and microorganisms. The refining process involves the removal of most of this film and the associated impurities. The steps generally followed include affination and melting, clarification, decolorization, evaporation, crystallization and finishing. A typical process flow diagram is presented in Figure 2. Processes will vary in detail from refinery to refinery. Such differences are particularly evident in decolorization methods, where the medium may consist of bone char, granular activated carbon, powdered activated carbon, vegetable carbon, ion-exchange resins or other materials.

10. In some cases a refinery may produce liquid sugar only, or both liquid and crystalline sugar. For liquid sugar the affination, decolorization, and evaporation steps are usually the same. After evaporation, the sugar solution is filtered, cooled and stored in the liquid form for later distribution. A typical process for liquid sugar refining is presented in Figure 3.

SOURCES AND CHARACTERISTICS OF WASTES

Raw Cane Sugar Processing

11. In raw cane sugar processing, water is used for cane washing, cooling of vapors from barometric condensers, slurrying of filter cakes, boiler bottom ash and boiler fly ash, boiler makeup, maceration, floor wash and clean up and miscellaneous cooling.

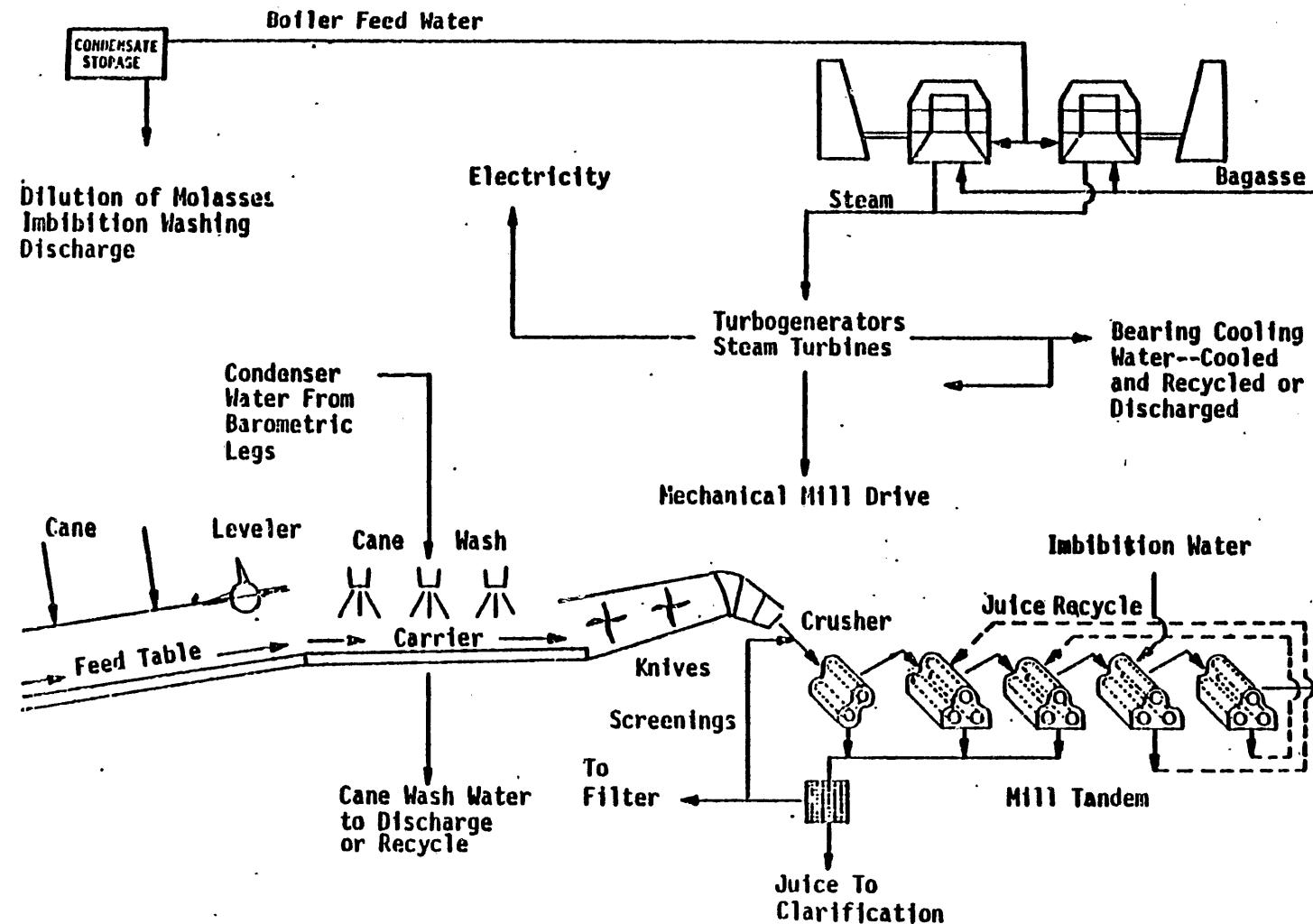


Figure 1 - Typical Process Flow Diagram for Raw Cane Sugar Production

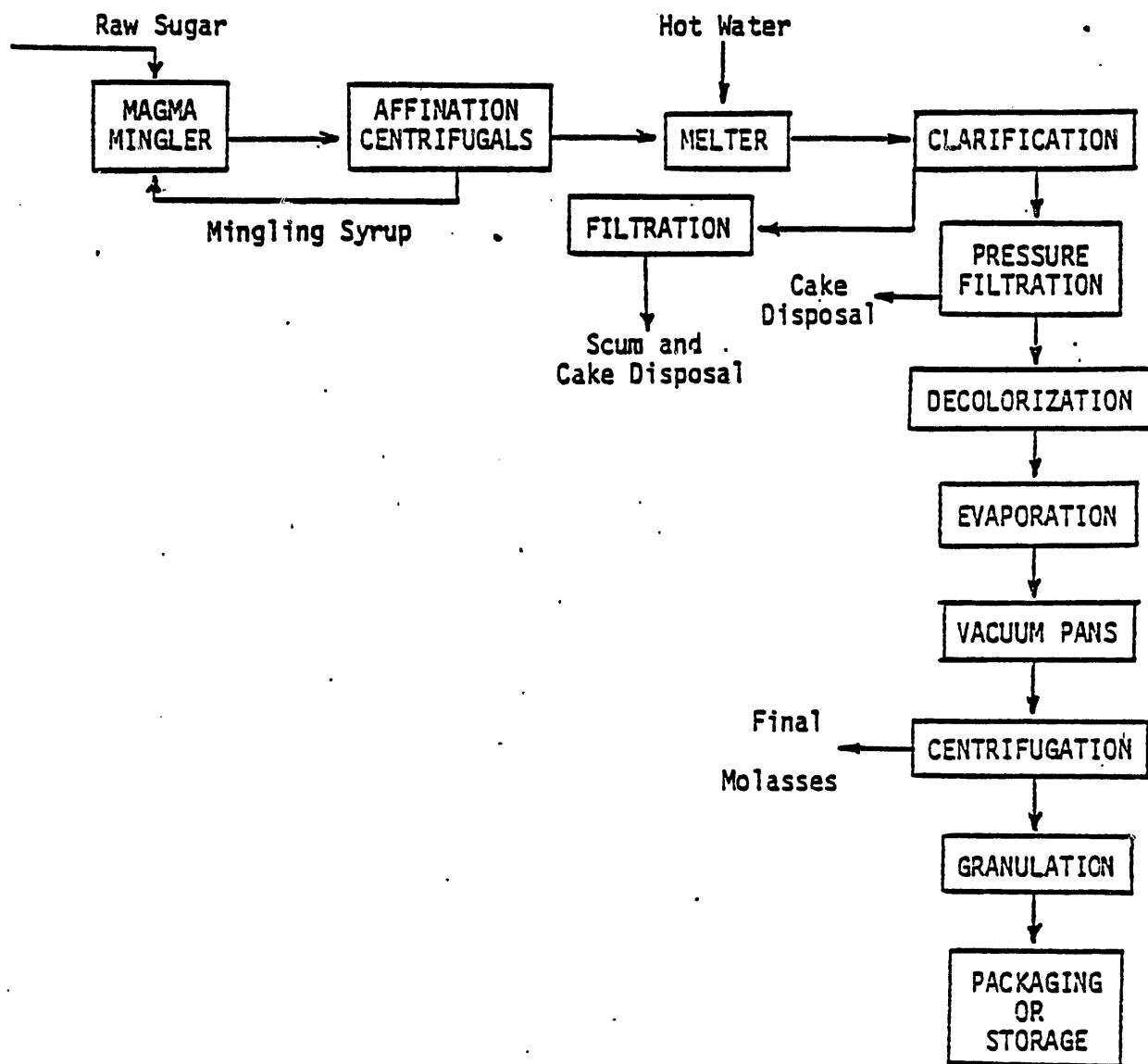


Figure 2 - Typical Process Flow Diagram for Refined Crystalline Sugar Production

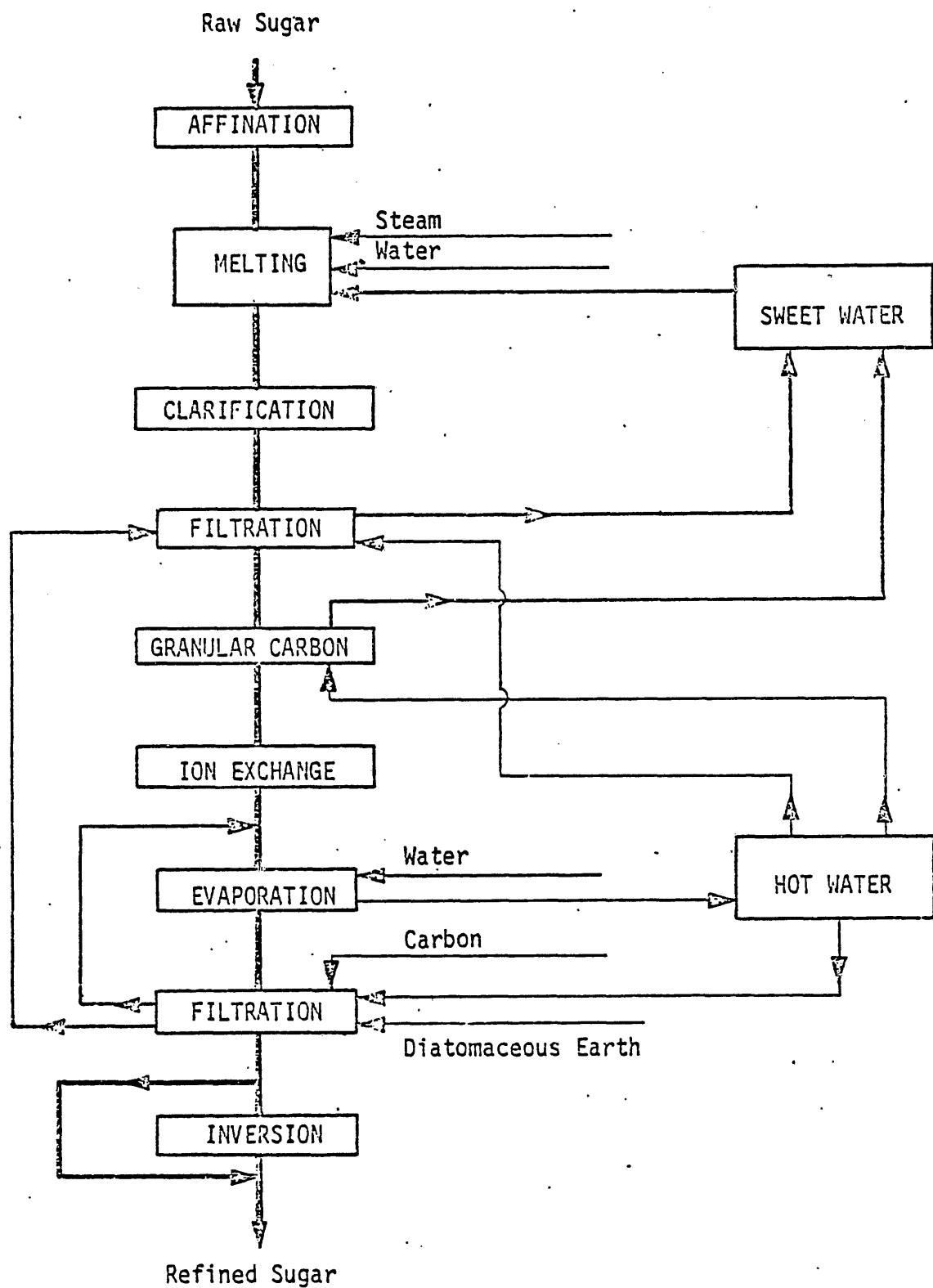


Figure 3. - Typical Process Flow Diagram for Refined Liquid Sugar Production

12. Water use will vary considerably between plants, due to differences in water conservation and recirculation practices. The quantities of waste water generated in a plant may not correspond to the total water intake because of moisture content of sugar cane, amounting to 70 to 75 percent; a portion of the fresh water added in the process enters into the filter cake and bagasse; and a portion of the fresh water is lost through evaporation.

13. Waste water production will be affected by (1) the condition of the cane upon arrival at the factory in terms of the mud and trash content; (2) harvesting technique, whether by hand, mechanically, or a combination of the two; (3) the availability of land for waste water treatment of disposal; (4) length of processing season; (5) climatic variations; (6) size of plant; (7) nature of soil; (8) process variations; (9) nature of water supplies.

14. The character of the total waste water discharges will depend not only upon the characteristics of the component streams, but also upon the extent of in-plant waste reduction practices. The principal sources are the filter mud, barometric condenser cooling waters, and cane wash water. Some pollution is added by numerous small streams originating in the process. In general, purely hazardous or toxic pollutants (such as heavy metals and pesticides) will not be found in wastes discharged from cane sugar factories.

15. While a number of parameters may be considered in evaluating the effects of these wastes, it has been found that three are of principal significance: (1) BOD_5 , for measuring the organic oxygen-consuming materials; (2) TSS for measuring the loading of suspended materials which could interfere with water supply and other legitimate stream use; and (3) pH for assessing the acidity or alkalinity of the wastes.

Cane Sugar Refining

16. As in the case of raw cane sugar plants, water use will vary widely due to differences in processes, water reuse, conservation techniques, and other aspects. Water supplies are usually taken from two sources. One will be a low quality water, generally from a nearby surface supply, for condenser cooling. The other will be a high quality water, such as from a municipal source, for process, washing and related purposes. Water intake for a crystalline refinery is about double that for a liquid sugar refinery.

17. Waste water discharges may originate from condensers, filter backwash, truck and equipment washing, floor drains, boiler fed blowdown, and miscellaneous cooling.

18. Although waste water volumes and quality from refineries will vary widely, the sources may be generally grouped as follows:

- (1) Crystalline refinery using bone char for decolorization - principally char wash water and barometric condenser cooling water.
- (2) Crystalline refinery using carbon for decolorization - principally barometric condenser cooling water, process waste, ion-exchange regeneration solution, and carbon slurries.
- (3) Liquid refinery utilizing affination and remelt - similar to a carbon crystalline refinery but with a lower barometric condenser cooling water flow.
- (4) Liquid refinery not using affination, remelt and vacuum pans - similar to number (3) but with a lower barometric condenser cooling water flow.
- (5) Combination crystalline and liquid refiner, by separate process-discharge is a combination of numbers (2) and (3).

19. The parameters of principal pollutional significance for cane sugar refining wastes are BOD₅, TSS and pH. On an individual basis, chemical oxygen demand (COD), temperature, sucrose, alkalinity, total coliforms, fecal coliforms, total dissolved solids, and nutrients may be of significance. Based on available evidence cane sugar refining wastes are not known to contain hazardous or toxic substances.

EFFLUENT LIMITATIONS

20. As has been previously stated, for both raw sugar processing and cane sugar refining plants, the BOD₅, TSS and pH are the pollution parameters of principal concern, and should therefore receive principal consideration by appraisal and supervision missions. The effluent limitations presented below are considered to be economically achievable by the use of best available technology for new plants.

Raw Sugar Cane Processing

21. The quality and quantity of plant discharges will be influenced by several factors. Such factors include raw materials, harvesting techniques, length of grinding season, climatic variations, growing cycle, topography, precipitation, irrigation practices, and other relevant aspects.

22. Generally the most significant factor influencing operations and waste water characteristics will be the mud, dirt, and trash content of the cane upon arrival at the factory. Harvesting techniques—whether mechanical, hand, or a combination of the two—will determine the amounts of these materials entering the plant. The levels of undesirable materials will affect processing operations in terms of : the presence or absence of cane washing and the quality of spent cane wash water; the efficiency of sucrose production; and the amounts of filter muds and bagasse produced. Factories processing hand harvested cane generally do not utilize cane washing, and thus should more readily produce a high quality effluent.

23. Table 1. lists the permissible effluent concentrations for maximum daily average discharges, expressed in terms of kilograms of pollutant per megagram of field cane.* Field cane is defined as the cane crop as harvested, including field trash and other extraneous materials.

24. As an approximation for relating pollutant discharges to output of finished product, experience indicates that on the average 1 megagram net cane will produce 75 kg. of raw cane sugar. Field cane may contain from zero to as high as 50 percent field trash and extraneous materials, depending upon the location, harvesting methods, and other local factors. Net cane is defined as field cane minus the weight of extraneous materials.

Table 1. -- Effluent Limitations for Raw Sugar Can Processing Plants.

Harvesting Method	BOD ₅ Max. Daily	TSS Max. Daily	pH
Mech. or combined hand/mech.	0.20	0.48	6 - 9
Hand	0	0	6 - 9

Cane Sugar Refining

25. For purposes of applying effluent standards, cane sugar refineries are grouped according to whether producing crystalline or liquid sugar. Current limitations to be applied to Bank projects are given in Table 2, expressed as kilograms of pollutant per megagram of melted sugar.

26. As an approximation for relating pollutant discharges to finished product, experience has shown that on the average 100 kg of raw cane sugar will yield about 93 kg of crystalline sugar, at 96° Brix. Degrees Brix is defined as the percentage of sucrose, by weight, in a pure sugar solution.

* 1 megagram = 1 metric ton
1 Mg = 1 MT

Table 2 -- Effluent Limitations for Crystalline and Liquid Sugar Refining Plants 1/

Category <u>2/</u>	BOD ₅	TSS	pH
	Max. Daily	Max. Daily	
Crystalline	0.18	0.11	6 to 9
Liquid	0.30	0.09	6 to 9

CONTROL AND TREATMENT

27. Flows resulting from the production of sugar, spanning from the harvesting of cane to the refined product, are amenable to a number of techniques for reducing or eliminating waste discharges. This includes both in-plant and end-of-pipe procedures.

Raw Cane Sugar Processing

28. Treatment and disposal at cane sugar factories may range from essentially no treatment to complete land retention (by irrigation or other means) for eliminating all discharges to surface waters. In-house measures could include development of new harvesting methods for reduction or elimination of cane wash waters; dry hauling or impoundment of filter muds and bottom ash; recirculation or reduction of various cooling water flows; and improved plant housekeeping practices.

29. Existing end-of-pipe technology is considered rudimentary. The procedures currently employed include: (1) impoundment of all contaminated waters; (2) recirculation of can wash waters; (3) dry hauling or complete containment of ashes and filter mud slurries; (4) recirculation of condenser waters or use for irrigation; (5) screening and disposal of leafy trash; and (6) elimination of excess bagasse discharges.

1/ Assumes cooling and recycling of barometric condenser cooling water.

2/ For combined crystalline - liquid refineries applicable limitation may be determined by taking weighted average of crystalline to liquid production.

30. A number of potential end-of-pipe technologies are currently under investigation, including: (1) biological treatment (stabilization ponds, activated sludge and others); (2) the use of tube settlers and other means for removing solids without the use of coagulants; (3) modification of cane washing systems to reduce soil loadings in the waste waters; and (4) the use of polymers to accelerate settling of waste water discharges.

Cane Sugar Refining

31. Current technology for the control and treatment of cane sugar refining waste waters consists principally of process control (i.e. recycling and reuse of water, prevention of sucrose entrainment in barometric condenser cooling water, and recovery of sweet waters), impoundment (land retention), and disposal of process waters to municipal sewerage systems. In-plant control measures are important in the total pollution control effort. A principal purpose of these measures is to prevent sugar losses, which may be looked upon as profit losses by the refiner and as organic pollutant contributions by the environmentalist.

32. In addition to reducing sugar losses, other measures would include effective dry-handling techniques for sludges and filter cakes, maximum recovery and reuse of various process streams, and improved housekeeping.

33. A number of end-of-pipe techniques are available, ranging from preliminary to advance waste treatment systems. These would include (1) flow equalization; (2) chemical treatment (pH adjustment, chlorination); (3) primary treatment (settling, sedimentation, and clarification); (4) biological treatment (activated sludge, trickling filters, stabilization ponds and lagoons); (5) advance waste treatment (carbon adsorption, micro-screening, reverse osmosis); and (6) ultimate disposal (evaporation lagoons, spray irrigation).

34. When land disposal of waste water is practiced, contamination of ground water resources must be prevented, whether such disposal is by seepage beds or by deep well injection.

BIBLIOGRAPHY

1. Meade, G.P. "Cane Sugar Handbook". 10th Ed. John Wiley & Sons, New York, (1977).
2. "Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Raw Cane Sugar Processing Segment of the Sugar Processing Point Source Category", U. S. Environmental Protection Agency, Doc. EPA 440/1-75/044 (February 1975).
3. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Cane Sugar Refining Segment of the Sugar Processing Point Source Category". U. S. Environmental Protection Agency. Doc. EPA 440/1-74/002-c (March 1974).
4. "Sugar Manual". Hawaii Sugar Planters Association. Honolulu (1972).
5. "A System Approach to Effluent Abatement by Hawaii's Sugar Cane Industry". In Proceedings Fourth National Symposium on Food Processing Wastes. Doc. EPA 660/2-73-031, U. S. Environmental Protection Agency. Washington, (December 1973).
6. "Consumptive Use of Water by Sugar Cane in Hawaii", University of Hawaii, Water Resources Research Center, Technical Report No. 37 (1978)
7. Biaggi, N. "The Sugar Industry in Puerto Rico and Its Relation to the Industrial Waste Problem". J. Water Pollution Control Federation. 40, 8 (August 1968).
8. Miller, J. R. "Treatment of Effluent from Raw Sugar Factories". In Proceedings of the International Society of Sugar Cane Technologists, (1969).

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MARCH 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

CEMENT MANUFACTURING

GUIDELINES FOR DISPOSAL OF WASTE

1. Cement manufacturing plants vary widely in volume and composition of pollutants discharged. Differences arise from process variations, in-plant practices, housekeeping, and other factors.

2. Three basic steps are normally utilized in cement manufacture: (1) raw material grinding and blending, (2) clinker production, and (3) finish grinding.

3. Raw materials include lime (calcium oxide), silica, aluminum, and iron. Lime, the largest single ingredient normally comes from limestone, cement rock, oyster shell, marl, or chalk - all of these sources consist primarily of calcium carbonate. Other raw materials are introduced as sand, clay, shale, iron ore, and blast furnace slag. These materials may be added initially, with feed to the process, or further in the process sequence such as in the clinker grinding stage.

4. Two types of processes are available, nominally termed "wet" or "dry". In the wet process, raw materials are ground, mixed with water and the slurry fed to the kiln. With the dry process raw materials are dried before or during grinding. Dry ground materials are fed to the kiln.

5. The kiln is a long cylindrically shaped oven, internally lined with refractory brick. It rotates slowly on a axis slightly inclined from the horizontal. The slight axis inclination allows kiln contents to drop forward as the kiln rotates. High temperature combustion gas produced at the lower end of the kiln flows upward, counter current to solid material moving down the kiln. Coal, gas, or oil may be used to generate this combustion gas. Most kilns are equipped to fire more than one type fuel. As material moves down the kiln, its temperature increases to about 1400° C, at which point it fuses to form hard, small pieces termed "clinker". Upon leaving the kiln, clinker is rapidly air cooled, combined with a small amount of gypsum* and ground into fine powder. Ground cement is further and shipped to market either in bulk or bags.

* Gypsum level of the final cement product, regulates cement setting time at the site of its use.

6. Flow sheets for typical wet and dry manufacturing processes are shown in Figure 1.

7. Cement plants are categorized as "leaching" and "non-leaching". Kiln dust leaching systems are used in leaching plants to avoid loss of high alkali dusts. Dry dust is mixed with water to make a slurry about 10% solids. In the slurry, alkali from the dust dissolves into the water phase. The slurry then flows to a clarifier. Clarifier underflow, containing 40 to 60 % solids returns to the kiln, while overflow is discharged. Clarifier overflow is the most severe source of water pollution for the cement industry. An alternative for reducing this problem is to use low alkali raw materials.

SOURCES OF WASTE

8. Cement manufacture can result in pollution of air, water, and land resources.

Air

9. Air pollution can originate at several operations in cement manufacture. These sources and their associated emissions are as follows:

<u>Sources</u>	<u>Emissions</u>
Raw Materials - Grinding, Handling	Particulates (dust)
Kiln Operations and Clinker Cooling	Particulates (dust), CO, SO _x , NO _x , Hydrocarbons, Aldehydes, Ketones
Product Grinding, Handling, Packaging, Shipping	Particulates (dust)

10. A major source of particulate matter (or dust) at most cement plants is the kiln. Kiln rotation and high-velocity flow of combustion gases entrain large quantities of dust (as much as 10 to 20 % of the kiln feed) out the feed inlet of the kiln.

Water

11. Highest levels of water pollution occur when water is allowed to contact collected kiln dusts. Three most significant sources where this contact may occur are: (1) the leaching operation (most important) which removes soluble alkali and recovers solid insoluble portions for reuse, and

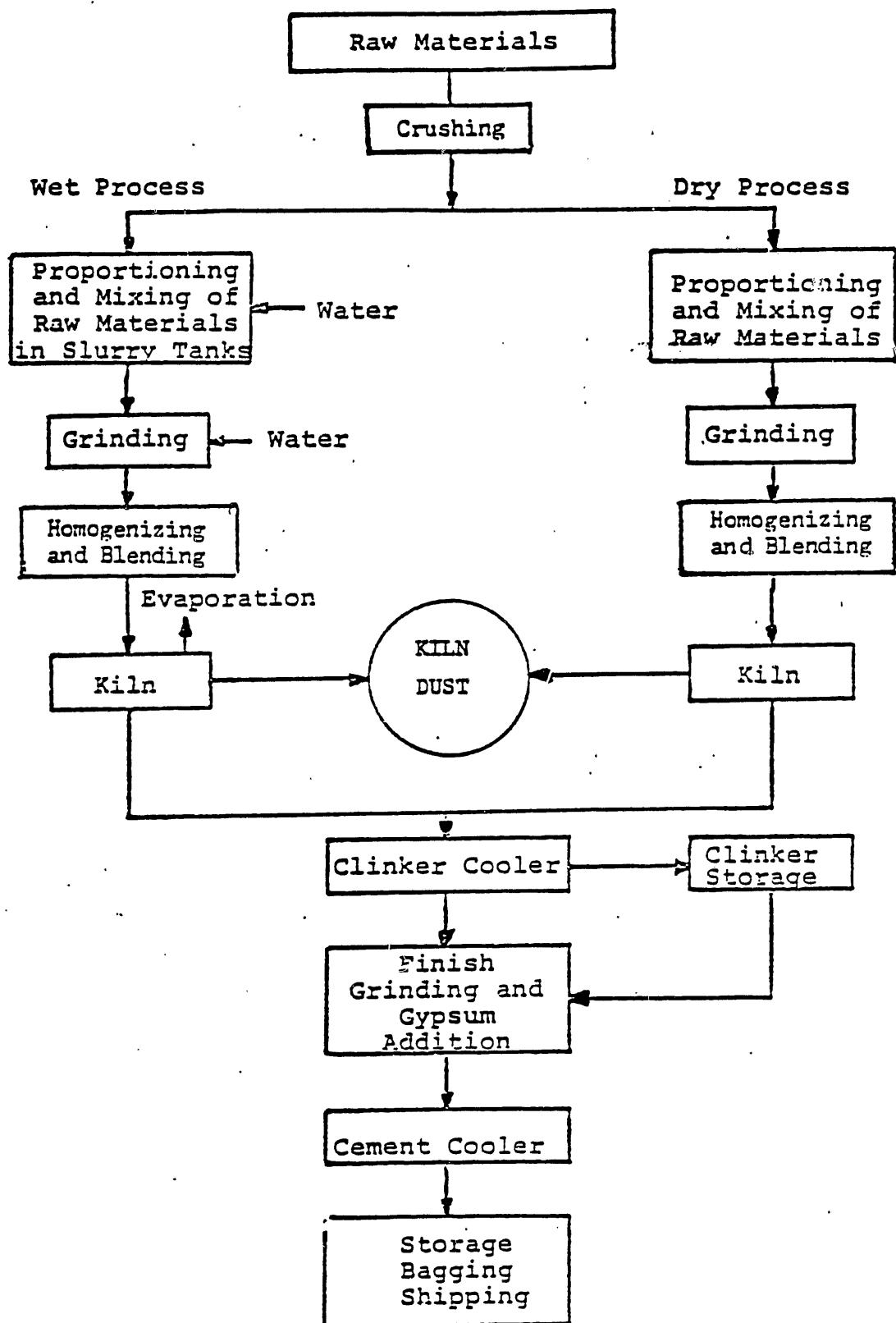


Figure 1 - Flow Sheet for Typical Wet and Dry Cement Manufacturing Processes.

discharges overflow (leachate) as waste, (2) disposal of entire wet dust slurry with no recovery or reuse (slurry is fed to a pond, solids settle and overflow is discharged), and (3) aqueous effluents from wet scrubbers are used to wash dusts from kiln gas emissions.

12. Process cooling is the major use for water in dry process cement manufacture (drying equipment and air compressor operation, and cooling of kiln bearings, burner pipes, etc.). Therefore, dry process water effluents should not normally be contaminated unless poor water management is practiced. Slurry water used to feed raw materials into the kiln for the wet process evaporates (dissipates in the air as vapor) so it does not become a water effluent discharge.

13. Auxiliary activities such as electric power generation (with a steam boiler), slurry tank cleaning, washing of bulk hauling trucks, cooling tower blow-down, and raw material washing are wastewater sources, but normally of minor significance.

Land

14. Kiln dust, raw materials, clinker, coal, and other substances are frequently stored in piles on plant property. Unless proper measures are taken, rainfall may percolate through these piles, dissolve (or leach) soluble pollutants and carry them with the surface runoff waters. Also water polluted in this manner can migrate through the subsurface layers beneath the material storage piles and contaminate groundwater sources.

CHARACTERIZATION OF WASTES

15. Dust removed from kiln gases is primarily a mixture of raw material, and clinker particles. These gases also contain alkalies (from the raw materials) and fuel which volatilized in the kiln. While raw material alkalies are insoluble in their natural state, high kiln temperatures, chemically modifies the alkali component of its mineralogical matrix so that alkali becomes both volatile at high temperatures and water soluble at low temperatures.

16. Plants which produce low alkali cement and use high alkali raw materials do not recycle dust to the kiln. Disposal of this dust is a serious plant problem. In addition to dust, cement plant emissions also contain significant quantities of CO, SO_x, (sulfur oxides) and NO_x, (nitrogen oxides), as well as lesser quantities of hydrocarbons, aldehydes, and ketones.

17. The seven most significant parameters for evaluating water pollution of cement industry effluents are: pH, total dissolved solids, total suspended solids, alkalinity, potassium, sulfate, and temperature. Average values for these parameters which are in water effluents created by scrubbing kiln dusts are shown in Table 1.

Table 1 - Average Values of Pollution Parameters for Leaching and Non-Leaching Plants.

Parameter	Leaching	Non-Leaching
pH (no units)	9.9	8.2
TDS	6.6 mg/Mg (a)	0.27 mg/Mg
TSS	0.9 "	0 "
Alkalinity	1.38 "	0.09 "
Potassium Salts	3.3 "	0.08 "
Sulfates	6.7 "	0 "
Temperatures increase (b)	+3.0°C	+3.0°C

(a) Milligrams per megagram of product.

(b) Typical temperature rise in cooling water discharges.

18. Surface water runoff from rain may be contaminated with dust accumulated at the plant site. Runoff from dust piles, coal piles, and raw material storage may also add to this problem. The pollution potential of runoff waters from these sources are highly variable. Coal pile runoffs, for example, may frequently show pH values of 4.0 or less.

EFFLUENT LIMITATION

19. Permissible levels of gaseous, liquid, and solid waste discharges for both leaching and non-leaching plants are given below. If these cannot be met, appraisal or supervisory missions must thoroughly document any variation and reasons for not meeting these limitations.

Air Pollutants

20. Air pollutants originate in kiln gases, clinker cooler exhaust gases, and (to a much lesser extent) in the boiler flue gas. Stack gases should be analysed for SO_x , NO_x , and particulates. If coal that contains mercury is used for kiln heating, flue gas should also be analyzed for mercury. Ambient air pollution levels will depend not only on pollution concentrations in the effluent, but also on stack height, local atmospheric conditions and local terrain.

21. The following pollutant limits for the most important emissions are to be adhered to in all but unusual circumstances:

SO₂ - At Ground Level

Inside Plant Fence	Annual Arith. Mean:	100 $\mu\text{g}/\text{m}^3$
Outside Plant Fence	Max. 24-hr Peak	1000 $\mu\text{g}/\text{m}^3$
	Annual Arith. Mean:	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr Peak	500 $\mu\text{g}/\text{m}^3$

Particulates (dry basis)

from kiln	150 g/Mg. Feed
from clinker cooler	50 g/Mg Feed
ground level outside plant fence	80 $\mu\text{g}/\text{m}^3$
Stack discharge*	50 mg/m ³

Liquid Pollutants

22. Based on currently available technology, liquid effluent disposal should be within the following limitations:

- * This limit may replace combined kiln and clinker cooler discharge if it appears more acceptable.

All Plants

- No cooling water discharge. If recycling is not feasible, cooling waters may be discharged provided its temperature rise is not over 3° C.
- No water discharge to slurry waste dusts.
- No discharge of slurry spills or slurry tank wash water.
- Maintain pH level of effluent discharge between 6.0 and 9.0.

Non-Leaching Plants

- Suspended solids under 5g/mg Product.
- Total dissolved solids no greater than levels in water incoming to the plant.

Leaching Plants

- Suspended solids less than 150 g/Mg Product.
- Total dissolved solids less than 1.5 Kg/Mg Product. TDS may be adjusted to reflect composition of raw materials.

Material Storage Piles

- No rainfall allowed to percolate through piles and runoff in uncontrolled fashion.

Equipment Washing, Road Washing, Etc.

- Not over 150 g/Mg Product during equipment cleaning operations, or during periods of rainfall.

Solid Wastes/Material Storage

23. Kiln dust, coal, and other materials piles should be so arranged as to avoid any arbitrary rainfall runoff. Where such runoff cannot be avoided, the effluent should be channelled, centrally collected, and subjected to sedimentation and any other necessary measures for reducing or eliminating pollution. Also, if any rainwaters can migrate under storage piles to contaminate a groundwater resource, storage areas may have to be lined.

CONTROL AND TREATMENT OF WASTES

24. Kiln operation is the major source of dust and gaseous pollutants. Larger dust particles can be removed by cyclones or other mechanical devices. Small dust particules can be removed by electrostatic precipitators, bag filters, or wet scrubbers. In most cases, collected dust is recycled to the process for reuse as raw material. Dusts from other sections of cement production are generally removed through local exhaust systems combined with some form of mechanical collection.

25. Both wet process and dry process plants achieve essentially complete waste water reuse with available technology, except in certain dust contact operations. In all wet process plants, except those leaching collected dust, effluents from ancillary operations (plant clean-up, truck washing, cooling, etc.) can be used to prepare slurry feed to the kiln. This water evaporates in the kiln, any organic matter is burned off, any nonvolatile inorganic material remains with the product, thus, no water effluent is produced. Cooling towers or ponds may be necessary to recycle excess water.

26. Use of waste waters for feeding the kiln is not possible in dry process plants. Here, however, virtually complete recycling of liquid effluents is possible if cooling towers or ponds are used. The only discharge is normally a small volume of cooling tower "blow-down" or bleed water that is required to prevent buildup of dissolved solids in the recirculating water. In some cases, these small volumes can be evaporated. Cooling streams can be segregated and steps taken to prevent dust entry into cooling water systems.

27. For leaching plants, the water is necessarily exposed to contaminants and recycling is generally not feasible. Principal pollution parameters of leaching basin effluents are pH, alkalinity, suspended solids, and total dissolved solids (primarily potassium and sulfate). Treatment is effected by neutralization and carbonation. Although removal of dissolved solids is generally not practiced for leachate streams, results indicate that evaporation, precipitation, ion exchange, reverse osmosis, and electrodialysis, individually or in combination, can be quite effective.

28. Laboratory analyses for any liquid effluent should include pH, total dissolved solids, total suspended solids, alkalinity, potassium, salts, sulfate, and temperature rise.

29. Solid materials, including wastes, are generally stored in piles on plant property. These can be contained or treated (diking, latex spraying, etc.) to prevent rain runoff into adjacent waters. Diked areas should be of sufficient size to contain an average 24-hour rainfall.

ENERGY CONSIDERATIONS

30. Application of these guidelines and control mechanisms should ensure optimum utilization of raw materials and result in some reduction of energy requirements. Major factors in minimizing energy consumption will be the plant design and operation.

31. Fuel requirements of a cement plant should vary from 6.23 to 6.91 gigajoules per megagram of product* for the wet process and from 3.14 to 4.0 gigajoules/megagram of product for the dry process. Fuel consumption for new plants should be at the lower limit, and it should fall below the upper limit for existing plants. Conformance to these limits should minimize any impact on the environment. Where fuel consumption for a new plant is estimated to be at or near the higher value, the reasons must be fully explained by the appraisal mission.

* One gigajoule = one billion joules.
One gigajoule/megagram = 238.9 calories/gm

BIBLIOGRAPHY

1. "Information Sources on the Cement and Concrete Industry". UNIDO Guides to Information Sources, No. 2. United Nations Industrial Development Organization. New York (1977).
2. "Emission Measurement Techniques for Particulate Matter from Power Plants, Cement Manufacturing and the Iron and Steel Industry". Organization for Economic Cooperation and Development. Paris (1975).
3. Development Document for Effluent Limitations, Guidelines and New Source Performance Standards for the Cement Manufacturing Point Source Category". U.S. Environmental Protection Agency. Doc. No. EPA/440/1-74-005-a.
4. "Papadakis, M. and M. Venuat. "Industrie de la Chaux, du Ciment, et du Platre", from Collection "Les Industries, Leurs Productions, Leurs Nuisances". Industrie-2. DUNOD. Paris (1970).

THE WORLD BANK

FEBRUARY 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

CHLOR-ALKALI PLANTS

(CHLORINE AND CAUSTIC SODA)

1. Chlorine and caustic soda (NaOH) production constitute important segments of the inorganic chemicals industry. The largest world producers of chlorine include Canada, France, the Federal Republic of Germany, Italy, the United Kingdom, and the United States. Annual production by individual countries for 1979 varied from 0.87 to 11 million metric tons.
2. Except for the United Kingdom the same countries, along with Romania and Russia, are the largest world producers of caustic soda. For 1979, the annual production varied from 0.7 to 11.3 million metric tons in the individual countries, as 100 percent NaOH.
3. Chlorine and its co-product, caustic soda, are used in large quantities in the production of plastics, organic and inorganic chemicals, in the pulp and paper industry, in water supply and wastewater treatment, and in several other industrial processes.

MANUFACTURING PROCESSES:

4. Chlorine and caustic soda are produced almost entirely from the electrolysis of a sodium or potassium chloride solution (brines) by one of two major processes — the mercury cell or the diaphragm cell. These two processes differ in cell design and in the quality and quantity of wastes generated. Other processes, such as the membrane process, have been developed through the pilot plant stage but operating data are not currently available. To avoid any discharges of mercury to the environment, new World Bank projects involving chlor-alkali plants should not utilize the mercury cell process.
5. In the purification of the brine, the sodium chloride solution (brine or salt dissolved in water) is treated with sodium carbonate and sodium hydroxide to precipitate impurities such as calcium, magnesium, and iron. The precipitated hydroxides and carbonates are then settled in a clarifier and the underflow, referred to as brine mud, goes to a lagoon or to filtration.
6. Brine muds from mercury cell plants usually contain small amounts of mercury, because of recycling of the spent brine from the cells. Before transfer to the cells, treated brine is evaporated if necessary to remove the excess water and then pH-adjusted. Spent or depleted brine from the cells is acidified and dechlorinated (using vacuum and/or air stripping) before being saturated with salt and recycled.

Mercury Cell Process

7. The mercury cell consists of two sections: the electrolyzer and the decomposer or denuder. A general process flow diagram is shown in Figure 1. The electrolyzer consists of an elongated steel trough slightly inclined from the horizontal. Mercury flows in a thin layer at the bottom, acting as the cathode of the cell, and the brine flows concurrently on top of the mercury. Parallel graphite or metal anode plates are suspended from the cover of the cell. Electric current flowing through the cell decomposes the brine, liberating chlorine at the anode and sodium metal at the cathode. The metallic sodium forms an amalgam with the mercury. The amalgam from the electrolyzer flows to a denuder. The spent brine is recycled to the brine purification process.

8. In the denuder, the sodium-mercury amalgam is the anode and the cathode is iron or graphite. De-mineralized water is added, and this reacts with the amalgam to form hydrogen and caustic soda. The mercury is returned to the electrolyzer. The hydrogen gas can be vented or cooled by refrigeration to remove water vapor before sale or before use as a fuel.

9. The chlorine from the cell is cooled to remove water and other impurities. The condensate is usually steam stripped and then either returned to the brine system or discharged as a waste. The chlorine gas, after cooling, is further dried by scrubbing with sulfuric acid. The diluted acid is regenerated for reuse, sold, or used for pH control. The chlorine gas is then compressed and liquified.

10. The liquefying procedure results in a residual mixture of noncondensable gases known as tail or sniff gases. This residue is usually scrubbed with caustic or lime, generating a hypochlorite solution, which is decomposed, used on site, sold, or discharged as a waste.

11. The caustic soda formed at the denuder has a concentration of 50 percent NaOH. Some of the impurities present in the solution can be removed or reduced by the addition of certain chemicals, followed by filtration of the caustic. In most cases the caustic is sent to storage or evaporated if a more concentrated product is required.

Diaphragm Cell Process

12. The process flow diagram for the diaphragm cell process is presented in Figure 2. In this process, the treated brine solution is electrolyzed to form chlorine, hydrogen and sodium hydroxide. The cell contains an asbestos diaphragm separating the anode from the cathode. Chlorine is liberated at the anode, while hydrogen and hydroxyl ions are produced at the cathode. The negatively charged hydroxyl ions (anions) will react with the positively charged sodium ions (cations) to form caustic. In the past graphite, with lead to provide the electrical contact and support, was generally used for the anode. In recent years the graphite anodes have been replaced by titanium anodes, having a platinum or ruthenium oxide coating. The advantages of the metal anodes include increased

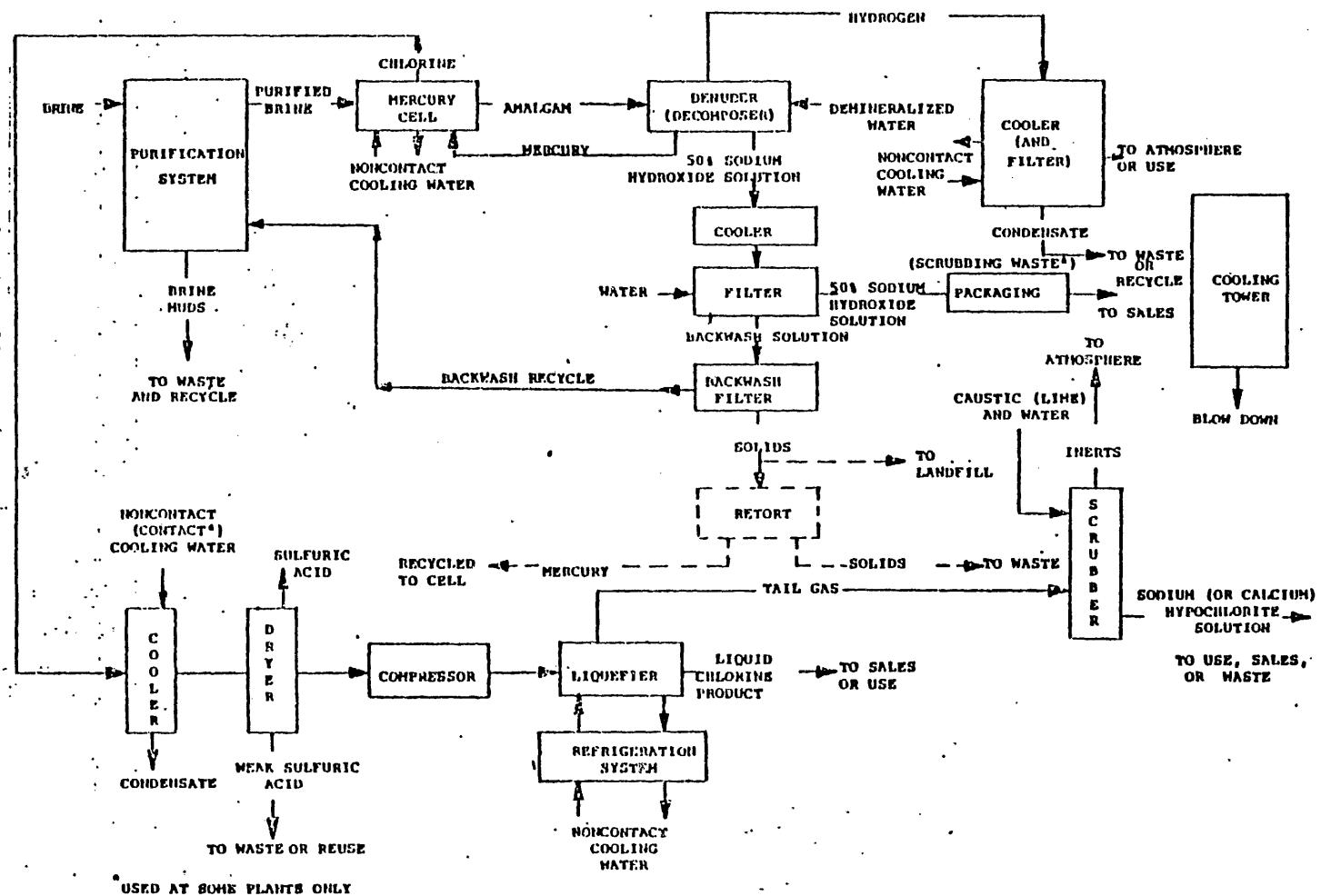
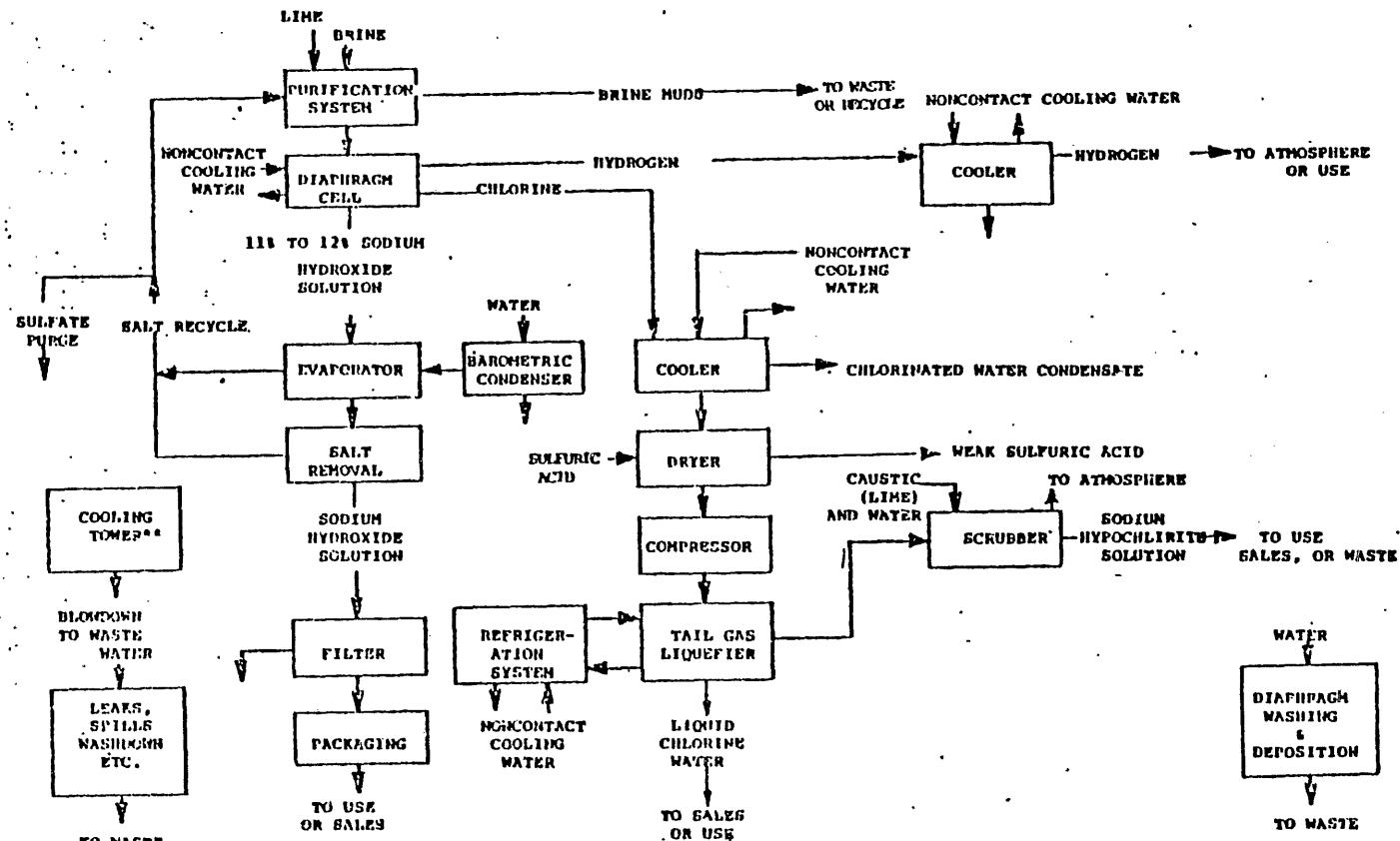


Figure 1 - General process diagram for production of chlorine/caustic by mercury cells.
(From Document EPA 440/1-79/007)



* USED SOME PLANTS ONLY

** DEPENDS UPON PLANT DESIGN

Figure 2 - General process flow diagram for production of chlorine/caustic by diaphragm cells. (From Document EPA 440/1-79/007)

power efficiencies, longer anode life, and a reduction in potential pollutant loads of lead and chlorinated organics. Cathodes are generally made of metal. In the Hooker "S" cell, for example, the cathode is made of crimped steel wire directly covered with asbestos. When in use, the cathode unit is completely submerged. The asbestos covering then functions as the diaphragm, separating the anode from the cathode.

13. The chlorine gas is processed in the same way as in the mercury cell process, and produces the same residuals. The hydrogen gas can be vented or cooled to remove the water vapor, and either marketed or used as a fuel.

14. The resulting caustic (or sodium hydroxide) has a concentration of about 14 percent NaOH and a sodium chloride content running as high as 17 percent. The caustic is usually filtered to remove some of the impurities and then evaporated to 50 percent NaOH in multiple effect evaporators. The vapor resulting from the last of the evaporators is condensed in barometric condensers, by contact with cooling water, or in surface condensers using non-contact cooling water. Sodium chloride remains as a solid salt, and this is returned to the brine system. Further purification of the caustic is sometimes necessary for certain applications (such as rayon production). Extraction or adsorption techniques are effective in removing small amounts of impurities.

WASTE SOURCES AND CHARACTERISTICS

Air Emissions

15. Emissions from mercury and diaphragm cell plants include chlorine gas, carbon dioxide, carbon monoxide, and hydrogen. Gaseous chlorine is present in the gas from liquefaction, from vents in tank cars and tank containers during loading and unloading, and from storage tanks and process transfer tanks. Other emissions include mercury vapor from mercury cathode cells and chlorine from compressor seals, header seals, and the air blowing of depleted brine in mercury cell plants.

Liquid Effluents - Mercury Cell Process

16. Brine mud, produced from purification of the brine, usually contains magnesium, calcium, iron and other trace metals such as titanium, molybdenum, chromium, vanadium, and tungsten. Calcium and iron are removed as oxides. Small amounts of mercury also are found in the mud, from the recycling of the unconverted brine to the purification unit after dechlorination.

17. Cell room wastes include leaks, spills, area wash down, and cell wash waters. The volume depends upon housekeeping practices, and may vary from 0.01 to 1.5 cubic meters per metric ton of chlorine produced. This is the major stream requiring treatment because of the high levels of mercury present. If graphite anodes are used, the wastes may also contain lead and chlorinated organics.

18. Condensation from the cell gas is contaminated with chlorine. In most cases the condensates are recycled to the process after chlorine recovery. Both contact and non-contact water are utilized for chlorine cooling and for removal of water vapor. Concentrated sulfuric acid is used in the dryer to remove residual water from the chlorine gas after first stage cooling. The acid is used until it is reduced in concentration to 50 to 70 percent. Then it is regenerated, used for pH control in a treatment system, or marketed.

19. The tail gas containing the uncondensed chlorine gas from the liquefaction stage, along with some air and other gases, is scrubbed with sodium/calcium hydroxide to form sodium/calcium hypochlorite solution. Additional hypochlorite solution is produced when the equipment is purged for maintenance. The hypochlorite can be used on site in another process, sold, or treated before discharge. Tail gas scrubber discharges will vary from 0.04 to 0.58 cubic meters per metric ton of chlorine produced.

20. The 50 percent caustic produced at the denuder is filtered to remove salt and other impurities. The filters are backwashed periodically as needed. The backwash water can be discharged to treatment, or filtered with the filtrate which is recycled to the brine system. The filtered solids may either be disposed of to land or reprocessed for recovery of mercury.

21. Cooling of the hydrogen results in a condensate, which can either be sent to treatment facilities or to mercury recovery and returned to the denuder.

22. In summary, the total waste flow from mercury cell plants is reported to average 2.1 cubic meters per metric ton of chlorine produced. This does not include brine mud waters, which are reused instead of discharged and hence do not affect total flow.

23. The pollution parameters of importance in the mercury cell plants are total suspended solids (TSS), mercury, and hydrogen ion concentrations (pH). Other toxic metals which may be present, besides mercury, include arsenic, antimony, cadmium, chromium, copper, lead, nickel, silver, thallium and zinc. The principal sources of these metals are considered to be the raw salt or brine and the corrosion reactions between chlorine and the materials in the process equipment. Other than mercury, the levels of the other toxic metals found in the wastes are not considered to be significant.

Liquid Effluents - Diaphragm Cell Process

24. Brine purification produces the brine mud as a waste, consisting of precipitated hydroxides and carbonates of calcium, magnesium, iron, and other metals. The muds are filtered or settled in lagoons, with the filtrate or overflow either discharged or recycled to the brine systems. The filtrate volume will average about 0.42 cubic meter per metric ton of chlorine produced.

25. Cell room wastes include leaks, spills, area washdown and cell wash waters. The cell wash waters contain high levels of asbestos. Where graphite anodes are used in the cells, the wastes may also contain significant quantities of lead. Waste flows from cell room operations will vary widely, and will average about 0.38 cubic meters per metric ton of chlorine produced from metal anode plants. Graphite anode plants will average 1.2 cubic meters per metric ton of chlorine produced.

26. Condensation from the indirect cooling of cell gas is contaminated with chlorine. The chlorine is removed and/or recovered from the liquid stream before discharge or recycle. Flows will average 0.49 cubic meter for metal anode plants and 0.78 cubic meter per metric ton of chlorine produced for graphite anode plant.

27. Concentrated sulfuric acid is used to dry the chlorine gas after the first cooling stage. When the concentration is reduced to 50 to 70 percent, the spent acid is regenerated, sold, or used for pH control, as is the case in mercury cell plants.

28. Uncondensed chlorine gas from the liquefaction stage is scrubbed with sodium or calcium hydroxide to produce the corresponding hypochlorite. The hypochlorite can be used in other processes, sold, or discharged with or without treatment. Waste flows from this source average 0.17 for metal anode plants and 0.11 for graphite anode plants, in terms of cubic meters per metric ton of chlorine produced.

29. Backwashing of filters used to clarify the caustic product may produce significant quantities of wastewaters. These are wholly or partially recycled to the process. Caustic filter backwashing is necessary to remove sodium sulfate at graphite anode plants, since the accumulation of sulfate ions can interfere with cell performance.

30. Hydrogen gas cooling produces a stream which is usually discharged. The volume of flow is very small and not considered to be of significance.

31. Where vapors from caustic evaporators are water-cooled, a significant amount of wastewater can be generated in "once through" installations. Recirculation of the cooling water will greatly reduce this discharge, but will require a cooling step and a blowdown discharge. Average wastewater flows from the individual units in the diaphragm cell process are given in Table 1. The total plant flow in any specific case will depend upon the practices (such as recirculation, by-product recovery, etc.) employed at the particular plant.

32. The pollution parameters of significance include total suspended solids (TSS), hydrogen-ion concentration (pH), chromium, copper, lead, nickel and zinc. Asbestos, used for the diaphragm separating the anode from the cathode, is a major toxic pollutant also found in these process wastewaters. However, due to the lack of a standardized analytical procedure there is as yet no general agreement on acceptable limitations. As a rough approximation, a concentration of 300,000 fibers per liter is considered to be an acceptable limit at this time. Other toxic metals may also be present in these wastes but the levels are generally not considered to be of significance.

Table 1. Average Wastewater Flows from Diaphragm Cell Plants.

Source	<u>Flow-m³ per Metric Ton Chlorine</u>	
	Metal Anode Plant	Graphite Anode Plant
Cell room wastes and cell wash	0.38	1.2
Chlorine Condensate	0.49	0.78
Spent Sulfuric Acid	0.01	NA*
Tail Gas Scrubber	0.17	0.11
Caustic Filter Wash	NA*	5.4
Brine Filter Backwash	NA*	0.45
Caustic Cooling Blowdown	0.86	NA*
Brine Mud	0.42	NA*

* NA = Not Available

Solid Wastes

33. The major sources of solid wastes in chlorine plants, for both the diaphragm and mercury cell processes, are the brine muds. The solids concentration in the filter backwashing can vary from 2 to 20 percent, and range in volume from 0.04 to 1.5 cubic meters per metric ton of chlorine produced. Solids are also present in the caustic filter washdown and the cell room wastes. In a diaphragm cell plant, the waters will contain significant quantities of asbestos, originating from washdowns and cell repair or cleaning. Total mercury loss from mercury cell operations averages 7.5 grams of Hg per ton of chlorine liquefied. Some portion of this can be expected to be present in the solid wastes discharged from the plant.

EFFLUENT LIMITATIONS

Air Emissions

34. Air emissions, when discharged to the atmosphere should be maintained within the following limitations:

Carbon Monoxide (CO)

Max. 8-hr. Aver.	10 $\mu\text{g}/\text{m}^3$
Max. 1-hr. Aver.	40 $\mu\text{g}/\text{m}^3$

Carbon Dioxide (CO_2)

20 mg/m³

Chlorine Gas (as Cl^-)

Max. 30-min. Aver.	0.3 mg/m ³
Max. 24-hr. Aver.	0.1 mg/m ³

Sodium Hydroxide (Na OH)

Max. 15 minutes 4 mg/m³

Mercury (Hg)

Per ton of chlorine produced: 3 grams

Liquid Effluents

35. Liquid effluents from plants using the mercury cell process, are to be maintained within the following limits:

	Max. 24 hr. Aver. Kg per Metric Ton of Chlorine Product.	Max. 30 day Aver. Kg per Metric Ton of Chlorine Product.
TSS	0.64	0.32
Mercury	2.8×10^{-4}	1.4×10^{-4}
pH	6 to 9 units	6 to 9 units

36. For plants using the diaphragm cell process, effluents should meet the following limitations:

	Max. 24-hr. Aver.	Max. 30-day Aver.
	<u>Kg. per Metric Ton of Chlorine Product.</u>	
TSS	1.1	0.51
Chromium	2.3×10^{-3}	8.8×10^{-4}
Copper	1.1×10^{-2}	4.4×10^{-3}
Lead	2.6×10^{-2}	1.0×10^{-2}
Nickel	1.1×10^{-2}	4.4×10^{-3}
Zinc	1.1×10^{-2}	4.4×10^{-3}
pH	6 to 9 Units	6 to 9 Units

CONTROL AND TREATMENT OF WASTES

Air Emissions

37. Airborne emissions can be kept within required air quality limitations through the use of cyclones, scrubbers, strippers, and other methods. In many instances, the gases may be recovered and reused or marketed as saleable products.

Liquid Effluents

38. Management and housekeeping practices should receive first consideration in establishing measures for reducing or eliminating wastewater discharges, and these could include control of water usage, recovery of useful or saleable by-products, and process modifications.

39. The brine treatment and cell room areas should be equipped with fiberglass gratings to collect all spills and leaks. Mercury bearing wastes should receive sulfide precipitation, followed by pressure filtration. This will also remove the other heavy metals which may be present in the stream. The precipitated mercury waste may be stored in a lined pond, transferred to a secure landfill, or processed for recovery of the mercury. The filtrate from the sulfide filtration is recycled back to the process. Where further treatment is needed the filtered effluent can be passed through granular activated carbon beds for removal of residual metal sulfides and metallic mercury.

40. At diaphragm cell plants, the prevailing practice is either to control asbestos wastes by settling or filtering cell wash wastewaters or to neutralize and settle effluents before discharge. Recycling of treated streams is common, although not always the case. Plants using graphite anodes treat lead-bearing wastes by chemical precipitation and settling or filtration before discharge.

41. The control of toxic organic compounds varies greatly between plants. For example, in a plant where the end use of the chlorine is the manufacture of a chlorinated product, the bulk of the chlorinated organic impurities are not removed.

42. Where a more purified chlorine product is required, the organics are accumulated in the reboiler of the chlorine scrubber. The residues are batch-treated for separation and recovery of the organic phase materials, which are then sold as feedstock for the manufacture of related products. The aqueous phase may be stripped for removal of additional organics and chlorine, and then recycled or discharged.

43. The use of metal rather than graphite anodes increases cell power efficiency and greatly reduces the pollutant loading of lead and toxic organics.

44. By changing from contact to noncontact cooling of the vapors from caustic soda concentration, or by recirculating barometric condenser water, the amount of wastewater generated can be considerably reduced.

45. Raw diaphragm materials are being developed, which can appreciably reduce power consumption and minimize or eliminate asbestos discharges. The modified diaphragms include polymer modified asbestos membranes, polymer membranes and ion exchange membranes.

46. The use of high pressure and refrigeration for chlorine recovery will reduce the chlorine content of tail gases. Before venting of the tail gas to the atmosphere, the common practice is to scrub it with caustic soda and produce a hypochlorite solution. The hypochlorite can be sold, used on site, or discharged.

Solid Wastes

47. The solids contained in the brine muds, as well as those resulting from other parts of the plant operations, should first be examined for possible by-product recovery, either on site or elsewhere. When on site disposal is required, these residues may be transferred to ponds, drying beds, or dumped in land fills. Since such residues may contain mercury or other toxic substances, extreme care should be taken to avoid runoff or drainage into surface waters or seepage into ground waters. Disposal grounds may need to be sealed and provided with surrounding walls to prevent both seepage and surface runoff.

ENERGY CONSIDERATIONS

48. In the electrolytic chlor-alkali production process the energy requirements will be very large. The process requires an average of 21.6 giga-joules of energy per metric ton of chlorine produced (1 giga-joule equals 1 billion joules).

49. This energy will be in the form of electric power, which may either be brought in from outside sources or generated on-site. Where power is brought in from outside sources via a grid system, the available

energy varies from 30 to 45 percent of the energy content of the fuels used to generate the electricity. If the power is generated at the chemical plant site the available energy can be increased to a range of 60 to 80 percent by, for example, the use of pass-out steam for other factory operations such as distillation or drying.

50. The above energy requirements do not include the energy required by the equipment used for treatment and disposal of plant wastes. These requirements will vary according to the treatment and disposal techniques adopted, and must therefore be determined on a case-by-case basis.

BIBLIOGRAPHY

1. UN Economic and Social Council. "Air Pollution Problems of the Inorganic Chemicals Industry". Proceedings of Seminar held in Geneva, Switzerland, 1-6 November 1976. Doc. ENV/SEM. 7/3, CHEM/SEM. 5/3. (22 July 1977).
2. Economic Commission for Europe "Annual Review of the Chemical Industry 1979". Doc. ECE/CHEM/34. United Nations. New York (1980)
3. Jarrault, P. "Limitations des Emissions de Polluants et Qualite de L'Air. Valeurs Reglementaires dans les Principaux Pays Industrialises". Institut Francais de L'Energie. Paris (1978).
4. U.S. Environmental Protection Agency. "Compilation of Air Pollutant Emission Factors". Second Edition. Doc. AP-42. Washington (March 1975).
5. U.S. Environmental Protection Agency "Development Document for Effluent Limitations Guidelines and Standards for the Inorganic Chemicals Manufacturing Point Source Category" (Proposed). Document EPA 440/1-79/007. Washington (June 1980).
6. U.S. Environmental Protection Agency. "Treatability Studies for the Inorganic Chemicals Manufacturing Point Source Category". Document EPA 440/1-80/103. Washington (July 1980).
7. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater". 15th Edition. American Public Health Association. New-York (1980).
8. Shreve, R.N. "Selected Process Industries". McGraw-Hill Book Co. New York (1950).
9. The Chemical Society. "Conservation of Resources". A Symposium held at the University of Glasgow, 5th-9th, April, 1976. Special Publication No. 27. London (1976).

THE WORLD BANK

FEBRUARY 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

GUIDELINES

DAIRY PRODUCTS INDUSTRY

1. The dairy products industrial operations are difficult to treat because of wide variations between individual plants in raw material inputs, processes used, varieties of products manufactured, volumes of wastes generated as affected primarily by internal plant practice and other factors. These guidelines will present general information on typical plant operations, which may then be applied and/or adapted to specific projects.

INDUSTRIAL PROCESSES

2. Dairy products plants may be categorized by specific product output. Categories and products generally included in each category are shown in Table 1.

3. Plants may perform a combination of these product operations, although there are plants which have only one or two process categories. Typical manufacturing processes for these products can be found in the suggested references cited below.

4. For example, processing of fluid milk includes clarifying, cream separation, pasteurizing, homogenizing and possibly deodorizing. For butter production, a culture of bacteria is added to cream, the mixture is "ripened" and agitated under controlled temperatures until butter and buttermilk are separated.

5. Cheese is produced through addition of a "starter" to whole milk or skim milk under controlled temperature conditions. An acid or enzyme is added to this mixture to form lactic acid which, in turn, results in curd formation. Curd is separated, washed, and subjected to various additional processes, depending upon the type of cheese being made.

SOURCES OF WASTES

6. Dairy industry effluents are primarily all liquid. Main sources of wastes result from:

- a) Washing and cleaning of tank trucks, cans, piping and other equipment.
- b) Spills from leaks, overflows, equipment malfunctions, careless handling and other similar causes.

Table 1 - General Categories and Products for Dairy Processing Plant Operations

Category	Products
Receiving Station	Raw Milk
Fluid Products	Market milk (ranging from 3.5% to fat-free), flavored milk (chocolate and other) and cream (of various fat concentrations, plain and whipped).
Cultured Products	Cultured skim milk ("cultured buttermilk") yoghurt, sour cream and dips of various types.
Butter	Churned and continuous-process butter.
Natural and Processed Cheese	All types of cheese foods except cottage cheese and cultured cream cheese.
Cottage Cheese	Cottage cheese and cultured cream cheese.
Ice Cream, Frozen Desserts, Novelties and other Dairy Desserts	Ice cream, ice milk, sherbert, water ices, stick confections, frozen novelty products, frozen mello-creme, puddings, other dairy-based desserts.
Ice Cream Mix	Fluid mix for ice cream and other frozen products.
Condensed Milk	Condensed whole milk, condensed skim milk, sweetened condensed milk and condensed buttermilk.
Dry Milk	Dry whole milk, dry skim milk, and dry buttermilk.
Condensed Whey	Condensed sweet whey and condensed acid whey.
Dry Whey	Dry sweet whey and dry acid whey.

Note: While some plants carry out operations in only one of these categories (single-product plants) most plants produce a combination of two or more of the above categories.

- c) Processing losses such as evaporator entrainment bottle and case washer discharges, container breakage and product change-over in filling machines.
- d) Wastage of spoiled products, returned products, or by-products such as whey.
- e) Detergents and other compounds used in working and sanitizing solutions that are discharged as wastes.
- f) Entrainment of lubricants from conveyors, stackers and other equipment.
- g) Routine operation of toilets, washrooms and eating facilities.
- h) Waste materials that may be contained in incoming raw water which ultimately goes to waste.

7. The greatest amount of waste originates from the first five sources listed above and is directly related to various dairy products handled at the plant. Typical contributions of waste materials to the total final waste load, as estimated for a fluid milk plant in terms of 5-day biochemical oxygen demand (BOD_5), are shown in Table 2.

Table 2 - Estimated Waste Contribution, as BOD_5 , By Source - Fluid Milk Plant.

Waste Source (as BOD_5)	Percent
Milk, milk products and other edible products	94
Cleaning products	3
Sanitizers	Very Small
Lubricants	Very Small
Sanitary and domestic wastes (employees)	3
Total	100

CHARACTERISTIC OF WASTES

8. Several water quality parameters may be used to assess the pollution potential of wastes from processing of dairy products. Three parameters are considered most significant: 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and hydrogen ion concentrations (pH). Parameters of lesser significance include, chemical oxygen demand (COD), temperature, phosphorous as phosphates, nitrogen as ammonia and nitrates, and chlorides.

9. Wastes are largely organic in nature. The major pollution effect is to decrease dissolved oxygen in receiving waters. The BOD_5 test is most useful as a measure of this potential to decrease dissolved oxygen.

10. Suspended solids will adversely affect turbidity of receiving waters, as well as causing a build-up of bottom deposits. This is particularly objectionable when solids are organic in nature, as is the case for dairy wastes. Bottom deposits of organic sludge may exert a heavy oxygen demand on receiving waters. Anaerobic decomposition may produce hydrogen sulfide or other intermediate products which can cause noxious odor problems and can be toxic to aquatic life.

11. A pH outside the acceptable range may have an adverse direct impact on the receiving waters or may have secondary effects such as increasing the solubility of heavy metals. There may also be increased toxicity to aquatic life, increased corrosiveness of water supplies, increased costs of water treatment, rendering of waters unfit for certain processes such as food and beverage canning or bottling, and other similar effects. Though individual waste streams may exhibit unusually high or low pH values, the combined discharge from a plant generally results in a final effluent within acceptable ranges of this parameter.

EFFLUENT LIMITATIONS

12. Table 3 presents permissible levels of biochemical oxygen demand, total dissolved solids and pH. These levels are to be met by individual discharges from the product category indicated. Loadings apply to single-product plants only. Limitations for the final effluent of a multi-product plant should be determined from these, using a weighted average based on the contribution and reduction to be affected by each of the categories comprising plant operations.

13. Where a plant discharges to a municipal sewage collection and treatment system, effluent limitations are governed by local regulations. Depending upon character and volume of the industrial wastes, some pre-treatment may be required to render them acceptable to the municipal system.

14. In determining plant effluent loadings and applying these standards, it is essential that currently well recognized and accepted laboratory analytical techniques be utilized. Detailed procedures may be found in the literature.

Table 3 - Final Effluent Limitations for Dairy Products Industry - By Individual Product Category^(a)

Individual Product	Effluent Limitation ^(a)		
	BOD ₅ ^(b)	TSS ^(b)	pH
Receiving Station	0.010	0.014	6 to 9
Fluid Products	0.076	0.096	"
Cultured Products	0.076	0.096	"
Butter	0.426	0.534	"
Natural and Processed Cheese	0.970	1.210	"
Cottage Cheese	0.168	0.210	"
Ice Cream Mix	0.068	0.084	"
Ice Cream	0.264	0.330	"
Condensed Milk	0.190	0.236	"
Dry Milk	0.156	0.194	"
Condensed Whey ^(c)	0.060	0.076	"
Dry Whey	0.150	0.190	"

(a) For new sources

(b) As Kg/Mg of Finished Product.*

(c) At 40% solids

* Mg = megagram

1 Mg = 1 metric ton

CONTROL AND TREATMENT OF WASTES

15. Control and reduction of waste discharges can be achieved through (1) in-plant control and management; (2) end-of-pipe treatment; and (3) discharge to municipal systems. In most cases a combination of two of these is utilized.

16. In-plant control and management techniques should always be applied, regardless of final disposal of plant effluents. Final discharges will be reduced in strength and/or volumes, thus reducing loading on treatment systems.

17. Internal measures most commonly used include: (1) a comprehensive waste monitoring system to provide a basis for effective waste management; (2) an equipment maintenance program to minimize product losses; (3) a product and process scheduling system to assure optimum equipment utilization; (4) a product quality control program to prevent loss of products to waste streams; (5) development of uses for waste products; and (6) constant improvement of processes, equipment and systems.

18. The major concern in treatment of dairy wastes is to reduce the concentration of oxygen-demanding materials, and thus make wastes generally amenable to one form or another of biological treatment. More commonly applied techniques include activated sludge, trickling filters, aeration lagoons, stabilization ponds, spray irrigation, ridge and furrow irrigation, and anaerobic digestion. In general practice, wastes are treated by a combination of these techniques, depending upon volumes, strengths, effluent standards, and other conditions.

19. Probably the most difficult problem in disposal of dairy wastes is whey handling. In many cases, whey supply exceeds that which can be marketed for useful purposes. Whey is difficult to treat by usual biological techniques. The most common methods for disposal include (1) livestock feeding; (2) spray irrigation; (3) discharge to municipal systems where feasible; and (4) concentrating and drying.

20. Depending upon the volume and strength of the wastes and capability of the municipal treatment system, dairy wastes may be discharged to public sewers. The dairy waste load may need to be equalized either through individual holding facilities or through incidental storage in municipal sewers, in order to avoid shock loads on the municipal treatment plant. Effective in-plant control measures will reduce the strength and volume of the effluents. Where the dairy waste constitutes a significant portion of the total volume reaching the municipal plant, the whey should be segregated to avoid possibly upsetting the municipal treatment system.

BIBLIOGRAPHY

1. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Dairy Product Processing Point Source Category". U.S. Environmental Protection Agency. Doc. EPA 440/1-74-021-a. Washington. (May 1974).
2. Nemerow, N.L. "Liquid Waste of Industry - Theories, Practices, and Treatment". Addison-Wesley Publishing Company, Inc. Reading, Mass. (1971).
3. Finch, J. "Guidelines for the Control of Industrial Wastes - Dairy Wastes". World Health Organization. Doc. WHO/WD/71.7. Geneva (1971)
4. Jones, H.R. "Pollution Control in the Dairy Industry". Noyes Data Corporation. Park Ridge, N.J. and London, England (1974).

THE WORLD BANK

APRIL 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

DUST EMISSIONS

GENERAL POLLUTION GUIDELINES

Introduction

1. Two series of dust guidelines are presented: one for the workplace and one for the environment beyond the plant fence.

2. Dust concentration levels inside industrial or agroindustrial plants are threshold limit values (TLV) for workers exposed eight hours a day, and forty hours per week. For this reason, a plant should be designed and operated to provide actual dust levels well below the TLV.

3. Concentration levels given for environment (beyond plant boundaries) could probably be exceeded a few times per year without experiencing permanent adverse affects.

4. The Office of Environmental Affairs (OEA) will revise these guidelines when additional knowledge from inside or outside the Bank Group warrants changes.

Definition and Properties of Dust

5. Dust or particulate matter consists of finely divided solids, so small in size as to be capable of remaining suspended by the atmosphere for long periods of time. The lower size limit for particulates is the transition size to larger gas molecules (about $0.1 \mu\text{m}$ or less), whereas the upper particulate size limit is about $500 \mu\text{m}$. When the upper size limit is exceeded, gravity will remove a particle from the air so rapidly, that it cannot constitute a breathing hazard. Industrial, agroindustrial, transportation and domestic activities all can release particulates into the air. This dust may or may not be mixed with other gaseous or liquid contaminants.

6. The five main factors which influence the interaction between dust and the human body are:

- (a) Physical characteristics (size, shape, hardness)
- (b) Chemical composition
- (c) Concentration in the atmosphere
- (d) Duration of exposure
- (e) Individual susceptibility

7. Size of dust particle: Dust retention by human lungs varies with particle size as shown by the following table (from the US Bureau of Mines):

<u>Particle Diameter (micrometers, μm)</u>	<u>Approximate Retention in human lungs (percent)</u>
Between 6 - 10	20%
5	25%
4	42%
3	50%
2	70%
1	70%
0.5	50%

Lung retention drops rapidly below $0.2 \mu\text{m}$, because dust particles of this size tend to act as gas molecules and will be exhaled as readily as they are inhaled. This is a general rule that will vary with particle shape and specific gravity.

8. Chemical composition: Dust deposited in the lungs may cause pneumoconiosis (pneumo = lung; koni = dust; osis = disease) which can be disabling or non-disabling depending on whether or not the dust is physiologically active. Most forms of disabling pneumoconiosis are caused by crystalline silica or quartz (SiO_2). Amorphous silica and silicates (except asbestos) do not cause disabling diseases.

9. Concentration and exposure time: Dosage is the product of dust concentration and exposure time. The TLV table presented below for mineral dusts in industrial plants, represents in fact dosages for an 8-hour workday. This means that if a particular dust has a 5 mg/m^3 concentration for an 8-hour workday (Dosage = 5×8 or 40) with a 10 mg/m^3 concentration, a worker could only stay in the facility for a 4-hour workday to receive the same dosage (Dosage = 10×4 or 40).

10. The bottom portion of the Table lists a series of factors to determine allowable dust concentration levels for workdays differing from 8-hours. Thus in the example used above, if one established in the upper table a 5 mg/m^3 TLV for an 8-hour workday and was interested in the allowable concentration for a 4-hour workday, he would use the lower table to determine the appropriate correction factor of 2. Then, multiply the upper table values by the correction factor in order to establish the allowable 4-hour workday concentration. ($5 \text{ mg/m}^3 \times 2 = 10 \text{ mg/m}^3$ for a 4-hour workday).

11. Individual susceptibility: Genetic factors not yet fully understood make some individuals more resistant than others. Environmental factors can change this resistance. Heavy smokers or workers exposed to chemical irritants will likely develop pneumoconiosis at an earlier stage.

Sampling and Measuring Dust

12. Accurately determining dust concentrations in the air remains a problem. One must remember that total dust is much less important than respirable dust. The sampling instrument should thus duplicate insofar as possible, retention characteristics of the human lung. A number of such instruments have been developed. The best known are the British MRE (Mines Research Establishment) and the American personal sampler. Their retention characteristics are compared with the human lung in Table 1. There is a good correlation between these two instruments. The MRE sampler collects 1.88 times more than the personal sampler. As these instruments will collect only a few milligrams of dust over an eight hour period an accurate and sensitive balance is necessary to weigh the collected particles. The preceding discussion shows why it is imperative to provide the sampling instrument name and its retention characteristics with any analytical results.

Occupational Guidelines

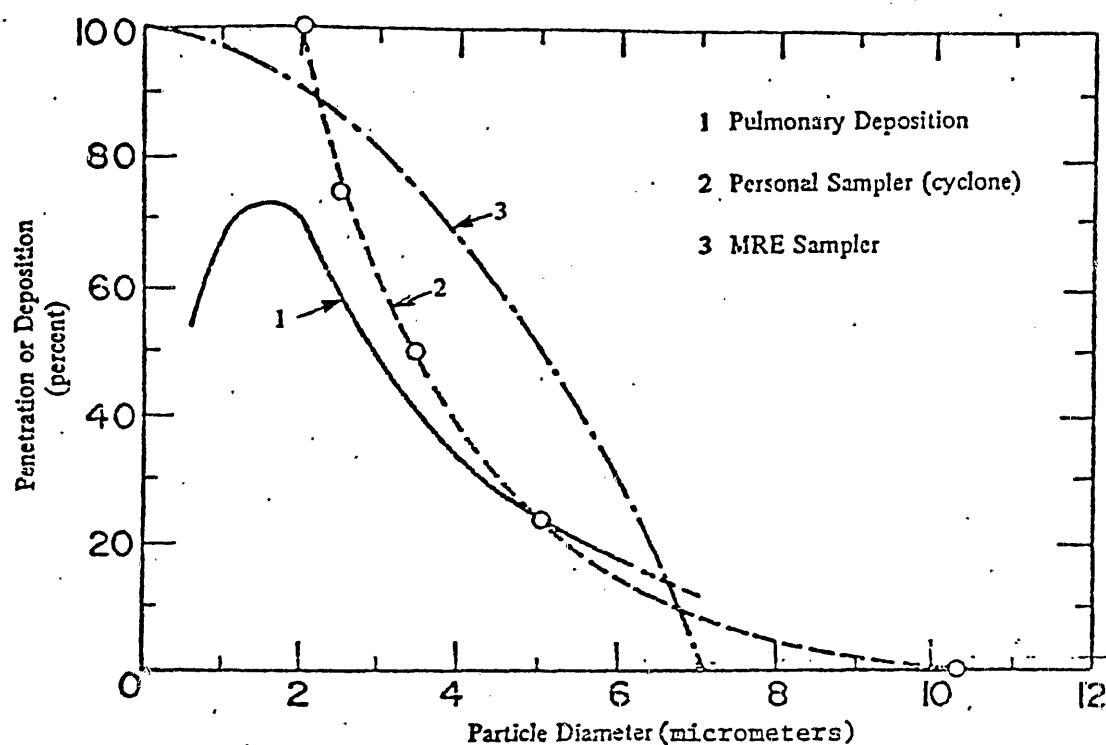
13. Occupational guidelines given in the following table are extracted from Occupational Safety and Health Administration (US Department of Labor) and from the booklet "TLV" published by the American Conference on Governmental Industrial Hygienists (1977). As discussed earlier, entries in this table are TLV values for 8-hours exposure. Actually, any facility should be designed and operated to give levels well below these values (no more than one-half the TLV is recommended).

14. When figures are presented in millions of particles per cubic foot (mppcf) they were determined by measurements on impinger samples counted by light field techniques.

Vegetable Dust

15. If these dusts contain less than 1% SiO₂ the inert dust TLV value applies. If they contain more than 1% SiO₂ the quartz TLV applies. Many of these dusts produce allergic reactions either from their own antigen content or from mold or fungi dusts that grow during storage. Vegetable dusts can create three kinds of hazards: respiratory effects, skin and eye effects and fires and explosions.

Table 1.



Source: U.S. Bureau of Mines. Sampling and Evaluating Respirable Coal Mine Dust: A Training Manual. U.S. Bureau of Mines, Information Circular No. 8503, February 1971, p. 3. Adapted from Figure 1.

<u>TLV FOR DUSTS</u>		
<u>Based on 8-Hour Workday</u>		
Substance	mppcf	mg/m ³
<u>Silica (SiO₂)</u>		
Crystalline Quartz Respirable *1,4	$\frac{300}{\% \text{SiO}_2 + 10}$	$\frac{10}{\% \text{SiO}_2 + 2}$
Total Dust		$\frac{30}{\% \text{SiO}_2 + 2}$
Cristobalite Thidymite	Use one half of the values calculated for total dust	
Tripoli (Respirable) *4		$\frac{10}{\% \text{SiO}_2 + 2}$
Fused Silica	Use quartz formula	
Amorphous Respirable *4 (including diatomaceous earth)		1 (< 5 μm)
Total		3 (all sizes)
<u>Silicates (< 1% quartz)</u>		
Asbestos (all forms) *3	2 fibers (> 5μm)/cc	
Graphite (natural)	15	--
Mica	20	--
Mineral Wool Fiber	--	10
Perlite	30	--
Portland Cement	30	--
Soapstone	20	--
Talc (Non-Asbestiform)	20	--
Talc (Fibrous)	Use asbestos value	
Tremolite	Use asbestos value	
<u>Coal Dusts</u>		
Bituminous		
Respirable fraction <5% SiO ₂ *4		2.4
Respirable fraction >5% SiO ₂ *4		$\frac{10}{\% \text{SiO}_2 + 2}$
<u>Inert or Nuisance Dusts (2)</u>		
Respirable *4	15	5
Total	50	15

TLV CORRECTION FACTORS
FOR
WORKDAYS DIFFERING FROM 8 HOURS

<u>Workday Hours</u>	<u>TLV Correction Factor</u>
1	8.0
2	4.0
4	2.0
8 (Base Case)	1.0
10	0.8
15	0.53
20	0.4

Notes: (1) Both concentration and % SiO₂ to be determined from dust fraction passing a size selector with the following characteristics.

<u>Aerodynamic Diameter (μm) (unit density sphere)</u>	<u>% Dust Passing Through the Selector</u>
< 2	90
2.5	75
3.5	50
5.0	25
10.0	0

- (2) Should contain less than 1.0% quartz; if quartz content is greater use quartz formula.
- (3) As determined by the membrane filter method, at 400-450 X magnification (4 mm objective) with phase contrast illumination.
- (4) Respirable dust as defined by the British Medical Research Council criteria, and as sampled by a device producing equivalent results (MRE sampler).

Environmental Guidelines

16. The U.S. Department of Health, Education and Welfare estimates adverse human health effects begin when ambient levels of dust exceed 80 $\mu\text{g}/\text{m}^3$, whereas adverse effects on materials and vegetation can begin with dust levels as low as 60 $\mu\text{g}/\text{m}^3$. These estimates formed the basis of the following EPA dust guidelines (issued in July 1974).

- (a) 75 $\mu\text{g}/\text{m}^3$ -- annual geometric mean
- (b) 260 $\mu\text{g}/\text{m}^3$ -- maximum 24 hour concentration,
no more than once a year.

To make these guidelines easier to use, EPA (at the same time) also provided a guideline for stack discharges: 50 mg/m^3 (dry). As a comparison, the USSR guideline is 150 $\mu\text{g}/\text{m}^3$ (maximum 24 hour concentration). The preceding figures are applicable to total inert dust (< 1% SiO_2) containing no carcinogenic compounds. Large variations from one project to another exist in terms of requirements for dust control.

These variations are due to the physical and chemical characteristics of dusts between projects, climate (dry or rainy, calm or windy), and other factors of location. Therefore it is difficult to offer universal guidelines for dust control. As a rule, the following levels should not be exceeded:

Stack Emissions:

When background levels of dust are high, dust emissions from the stack should not be greater than 100 mg/m^3

Ambient Levels:

Annual geometric mean	100 $\mu\text{g}/\text{m}^3$
Maximum 24-hour concentration	500 $\mu\text{g}/\text{m}^3$

If the dust under consideration is affecting vegetation, the annual mean and 24-hour concentration figures should be adjusted downwards.

Sampling and Analysis

17. Only analytical results which give both sampling method and method of analysis are meaningful. The most reliable sample is "respirable dust". If it is not possible to collect a "respirable dust" sample, the total dust sample should be evaluated. Whatever sample type is selected, the name of the sampling instrument and its retention characteristic should be given. Weighing a sample (if possible) is the most accurate method of analysis. Precautions should be taken to weigh only dry dust from which all moisture (humidity) has been removed. Particle counting is less accurate than weighing, but nonetheless is acceptable for any silicate except asbestos. If particle counting is the only available means for asbestos, it should only be done for fibers longer than 5 μm .

Control

18. The appraisal mission should receive assurances that the project will meet the guidelines and that necessary equipment and trained personnel will be available to sample, analyze, and take any necessary corrective measures. Follow-up missions should check analysis results in comparison to the guidelines. If results are higher than guideline values, mission members should ask for reasons and discuss possible corrective measures.

Legislation

19. If existing legislation in the project country incorporates dust standards or guidelines stricter than IBRD's guidelines, country standards prevail.

20. If, on the other hand, existing legislation in the project country is less restrictive than IBRD guidelines, the appraisal mission should present reasons why it is expected that plant personnel and the neighboring exposed population and its environment will be as well protected as if the guidelines were followed.

THE WORLD BANK

OCTOBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

GENERAL GUIDELINES

DISPOSAL OF INDUSTRIAL EFFLUENTS

1. These guidelines are intended for general application to disposal of effluents and pollutants for most industrial sources. Although general in nature, they should be applied to the total environment whether the effluents are in the gaseous, liquid or solid state. These guidelines may be applied where particular data is not otherwise available, or as a supplement for those specific industries where guidelines have been developed by the Bank.

2. Pollution may be defined as the addition, from either natural or man-made sources, of any foreign substances to the air, water or land in such quantities as to render such medium unsuitable for specific or established uses. An industry may frequently produce wastes that affect more than one of these media. Thus, the Appraisal or Supervision Mission must consider the total range of disposal operations in order to properly evaluate effluent treatment and control measures. Toxic properties are of prime concern in evaluating effects of industrial pollution. Table 1 presents a summary of waste toxicity from a number of industries.

3. Pollution may also result from noise and heat, which are measurable in terms of intensity and effect but have no physical, chemical or biological composition.

4. This guide is concerned primarily with the effects of pollution on the environment. However, consideration should also be given to the effects of specific contaminants on personnel at the industrial work place.

SOURCES AND CHARACTER OF WASTES

5. Effluents are frequently complex, heterogeneous mixtures of several substances or materials. Gaseous effluents may include particulates (solids) or aerosols (liquids); liquid effluents may include dissolved solids or gases, as well as suspended solids; and solid wastes often contain one or several liquids.

Gaseous Effluents

6. Airborne pollutants originating at stationary sources whether or not diluted with air, are generally exhausted through a stack. From the stack they will disperse into the atmosphere and eventually return to ground level. Ground level concentrations may be estimated on the basis of the stack height and diameter at stack mouth, gas velocity or flow, and temperature. For new installations some of this information will need to be derived from performance at existing installations.

TABLE 1 - Some Hazardous Wastes Produced by Industry^(a)

Industry	Toxic Waste Produced				
	Solvents	Metals	Gases	Org.	Inorg.
Mining		X	X		X
Textiles		X		X	
Paper Prod. Etc.			X		X
Alkalai & Chlorine					X
Cyclic Intermediates	X	X	X	X	X
Organic Chemicals	X	X	X	X	X
Inorg. Chemicals		X	X	X	X
Plastics	X		X	X	
Drugs			X	X	X
Soaps & Cleaners				X	
Paints, etc.	X			X	X
Agri. Chemicals	X			X	X
Explosives				X	X
Petr. & Coal Products	X	X	X	X	X
Leather Tanning		X		X	X
Asbestos Products			X		X
Blast Furn. & Steel		X	X	X	X
Non-Ferrous Metals			X		X

(a) From "A Study of Hazardous Waste Materials, Hazardous Effects and Disposal Methods", Vol. 1, Report PB 221-465. Booz-Allen Applied Research, Inc. Available from National Technical Information Service, Inc., Springfield, Va. (1973).

7. Gaseous effluents most frequently result from combustion processes. They may also be either by-products of chemical reactions or suspended particulates resulting from mechanical operations such as grinding. Principal impurities of combustion gases generally include sulfur dioxide (SO_2) particulates (flying ash or carbon), nitrogen oxides (NO_x), carbon dioxide (CO), and mercury compounds from combustion of certain coals.

8. Chemical products released to the atmosphere are too numerous to mention, and depend upon the particular industry considered. As examples, hydrofluoric acid and fluoride compounds evolve from production of both aluminum and phosphoric acid; arsine a particularly lethal arsenic compound, (AsH_3) can result from the burning of pyrites or blends in a reducing atmosphere.

9. Quarrying and mining operations can discharge dust or particulate matter into the atmosphere, as can plants producing steel, cement, and fertilizers. While dusts may create environmental problems, it is important to note that they may also create serious occupational hazards if the work place has been poorly designed or is not properly operated. The human health problem is of primary importance in these situations.

Liquid Effluents

10. Apart from normal human wastes discharges, other liquid effluents from industrial plants consist principally of cooling water and waste by-products dissolved or suspended in water originating from the process or other sources. In many cases the gaseous effluents are stripped of particulate matter by wet scrubbers which, in turn, discharge to plant sewers.

11. Cooling water, as the nomenclature implies, is used to cool process materials. It is generally uncontaminated in flowing through the plant, except for an increase in temperature and for containing chromates used to protect surfaces from corrosion. When cooling water is combined with other waste streams, the total effluent will contain these other contaminants.

12. Liquid effluents will generally be at temperatures higher than those in receiving waters. Therefore, care must be exercised to keep the temperature differences as small as possible to avoid harmful effects on aquatic plant and animal species living in the receiving waters.

13. As a general guideline for Bank projects, effluent temperatures should not be more than 3° C higher than that of the receiving waters. Where the receiving water temperatures are at 28° C or less, the effluent temperature may be a maximum of 5° C above that of the receiving waters. In cases where maintaining these differentials causes excessive increases in project costs or undue harm to fisheries or other aquatic life, the maximum allowable temperature may be determined from the following equation:

$$T_{\max} = OT + \frac{URLT - OT}{3}$$

Where: T_{max} = Maximum allowable stream temperature after mixing

OT = Optimum temperature for species affected

URLT = Ultimate recipient lethal temperature for species affected.

14. An important but frequently overlooked source of liquid pollution is the accidental or deliberate discharge of hazardous materials. Toxic materials have been known to reach adjacent waterways during plant start-up periods because of accidents or inadequate preparation. Village wells and surface supplies have been contaminated from careless disposal of ion-exchange unit backwash discharges. Where toxic materials are used or produced in the industrial operations, measures for prevention of accidental spills should be established and fully described by appraisal and supervision missions.

Solid Wastes

15. Land may become polluted or rendered otherwise unsuitable for specific uses through addition of waste materials. Among the more common substances are (1) paper, cartons, plastics, and other packing materials; (2) rubble from demolition and other discarded building materials; (3) stripped soil, exposed erodible soil and tailings from mining operations; (4) slag heaps from smelting operations; (5) pulp, pits, culs, vines and other organic residuals from canning operations; and (6) organic sludges from pulp and paper mills, textile plants and other industrial operations.

16. Land disposal may include spray irrigation, land farming, sanitary landfill, deep well disposal and "secure" burial.

17. Proper location and operation of disposal sites are principal factors in handling solid wastes. A general unsightliness, noxious odor caused by decomposing organic residues, and breeding of disease carriers, can result from improperly operated areas.

18. Dust may also create a problem at dump sites that are completely dry. These sites should be kept to a minimum or eliminated, depending upon their composition and the environment surrounding the disposal site.

MANAGEMENT OF WASTES

19. Measurement of effluents, both as to quantity and quality is basic to a waste management program. Acceptable and recognized techniques are readily available for this purpose. The management program will involve sampling and analysis of effluents, flow measurements, application of established standards, and control of discharges through treatment or other means. Standardized laboratory techniques should be utilized to assure data acceptability.

Sampling and Analytical Procedures

20. Monitoring of air contaminants may be accomplished through emission source testing or atmospheric monitoring. Industrial processes may involve frequent cyclic changes. Therefore source monitoring must be carefully timed so that measurements are made when the process is operating in typical fashion. Fluctuations of peak loadings must be determined. All waste source variables should be defined so that samples will represent typical process conditions.

21. Atmospheric monitoring requires establishment of an air monitoring network. Location of the sampling stations should be based on the use to be made of the data, such as (1) source-oriented monitoring for enforcement purposes; (2) zones of highest projected pollution concentrations; (3) background data needs prior to industrial development; (4) high population density areas; and (5) background data needs where industrial development is not imminent.

22. Analytical methods for air contaminants are described in the literature. Methods are generally classified as chemical or physical, and cover dustfall, suspended particulate matter, gaseous substances and organic pollutants.

23. Wastewater sampling points should be such that flow conditions in the discharge stream will have achieved a homogeneous mixture. The effluent discharge velocity at the sampling point should be high enough to assure collection of a well-mixed representative sample.

24. Flow measurements are an integral part of any wastewater monitoring program. Selection of a method will depend upon the facilities available, the degree of precision required, and the conditions under which the wastes are discharged (batch operations, operating periods, etc.). The weight of contaminants discharged to a receiving stream can be calculated from both the flow rate and the measured concentration of contaminants derived from the analytical data.

25. Techniques for the qualitative analysis of wastewaters fall into four categories; chemical, physical, biological and biochemical. Specific analyses will depend upon the nature of the industrial operation and other factors determined on a case-by-case basis.

26. All significant waste streams, including single or combined flows, which are present or planned, should be described in terms of flow rate (volumetric) and their chemical, physical, and biological characteristics. If partial or full treatment of the waste stream is being or will be provided, a full description should be furnished by the missions.

27. Solid wastes from industry often pose special problems such as non-degradability (plastics) and toxicity (chemical residues). In establishing disposal methods, solid wastes should be classified and rated as to their effects such as (1) human toxicity; (2) groundwater contamination; (3) biodegradability; and (4) mobility. Chemical, physical, and biological methods, as described above, are normally used to analyze air and water effluents from solid waste disposal areas.

28. Quantities of solid wastes are measured in terms of both volume and weight. Leachates are measured by collecting all drainage from the disposal area, and passing it through a device for flow measurement and sample collection.

Units of Measurement

29. In order to permit comparison of data between projects it is essential that, insofar as possible, the same units be used in reporting environmental data. With the rapid movement towards universal use of metric units throughout the scientific and technical communities, Bank missions should confine themselves to that system.

30. More commonly-used metric units are as follows:

<u>Gaseous Effluents:</u>	Micrograms per Normal cubic meter	$\mu\text{g}/\text{m}^3$	(normal)*
	Milligrams per Normal cubic meter	$\mu\text{g}/\text{m}^3$	(normal)
	Grams per Normal cubic meter	g/m^3	(normal)

Liquid Effluents:

Milligrams per liter	mg/L
Micrograms per liter	$\mu\text{g}/\text{L}$

Solid Effluents:

Milligrams per kilogram of solid waste (dry basis)	mg/kg
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Flows:

Liters per second	L/s
Cubic meters per hour	m^3/h

Pressure:

Kilograms per square centimeter	kg/cm^2
Newton's per square centimeter	N/cm^2

Temperature:

Degrees Centigrade	$^{\circ}\text{C}$
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* Normal Conditions: 0° C , 101.3 kPa (760 mm Hg)
kPa - kilo Pascals

Application of Standards

31. "Standards" are to be defined as levels at which specific materials may be safely discharged to the environment. "Standards", "regulation", and "norm" are terms frequently applied very loosely in appraising a plant's performance. A strict definition may differ between countries, or even between regions in the same country. Therefore, appraisal and supervision missions should clearly define standards used in rating effluent disposal performance. Data for both standards used and a plant's performance should be expressed in units of contaminant per unit of production of raw material input.

Effluent Controls

32. Reduction of waste effluents to meet applicable discharge standards can be accomplished by in-plant measures (process changes, good house-keeping, etc.), treatment systems, or some combination.

33. Measures for reducing gaseous effluent contaminants include (1) operational improvements; (2) increasing stack height; (3) removal of gases by adsorption, absorption, catalytic conversion, or other methods; and (4) particulate removal systems such as filters, sedimentation, centrifugal separators, electrostatic precipitators, wet scrubbers or other equipment.

34. Techniques applicable for liquid effluent disposal include in-plant measures and process changes, discharge to municipal treatment systems, or on-site treatment facilities designed to reduce specific contaminants. When releasing liquid effluents, precautions must be taken to avoid contamination of adjacent aquifers, particularly in the case of deep-well injection. Thorough tests, using tracer dyes or other methods, should be conducted at each specific location where it is planned to use this method.

35. Handling and disposal of solid wastes must give attention to the land at the disposal site, as well as the effect of disposal methods on air and water resources. Sites should be designed and operated to prevent, or minimize or properly channel runoff. Runoff collection and settling have been effective for this purpose. Latex films covering waste piles have also been effective. Unprotected waste piles are subject to leaching which may result in acidic or alkaline effluents percolating to streams or aquifers used for water supply.

36. Appraisal missions should make certain that engineering designs for the project have incorporated necessary treatment equipment and controls to achieve predetermined acceptable levels of effluent quality. The mission should also make certain that equipment cost is included in project funding, and is properly scheduled for procurement and delivery. Plans should also be developed for the training or employment of personnel to efficiently use the equipment. The sampling and analysis program should be critically reviewed to assure complete coverage of industrial operations, including night shifts and weekends.

37. Supervision missions should ascertain that pollution control equipment has been installed, that it is being efficiently operated, and that adequate monitoring is being provided to assure continuing conformance with control requirements.

38. In all cases, proposed or actual handling of waste materials and final effluents should be completely described. This is particularly important with large projects involving several contractors. Where treatment elements are being planned and designed by different organizations or agencies, it must be ascertained that these elements are compatible with each other and will result in an overall system that reduces plant discharges to acceptable levels.

ENERGY CONSIDERATIONS

39. Energy needs for the individual plant must be considered. The fuel requirements for optimum operation of a plant have been determined for a number of industries. Fuel consumption for new plants should readily meet the established levels or ranges. Failure to meet these limitations should be fully explained by the Bank's missions.

BIBLIOGRAPHY

1. "Environmental Considerations for the Industrial Development Sector". The World Bank, Washington. (August 1978).
2. "Treatment of Industrial Effluents". Ed. by A.G. Callely, C.F. Forster, and D.A. Stafford. John Wiley & Sons, New York. (1976).
3. Powers, P.W. "How to Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation. Park Ridge, N.J. and London. (1976).
4. "Land Application of Residual Materials". Selected Papers-Engineering Foundation Conference, September 26 - October 1, 1976. Pub. by American Society of Civil Engineers, New York. (1978).
5. "Manual on Urban Air Quality Management". European Series No. 1. World Health Organization, Regional Office for Europe, Copenhagen. (1976)
6. Nemerow, N.L. "Liquid Wastes of Industry - Theories, Practices, and Treatment". Addison-Wesley Publishing Co., Reading, Massachusetts. (1971)
7. "Air Quality Control - National Issues, Standards and Goals". National Association of Manufacturers, Washington. (1975)
8. "Analysis of Raw, Potable and Waste Water". U.K. Department of the Environment, HMSO, London. (1972)

9. "Standard Methods for the Examination of Water and Wastewater" 14th Edition. American Public Health Association, New York. (1975)
10. "Standard Methods for the Water Quality Examination for the Member Countries of the Council for Mutual Economic Assistance". Ministry of Forestry and Water Management, in cooperation with the Hydraulic Research Institute, Prague. (1976)
11. Martin, W. & Stern, A.C. "The Collection, Tabulation, Codification, and Analysis of the World's Air Quality Management Standards". Vol. I. ESE Publication No. 380. University North Carolina, Chapel Hill. (October 1974)
12. "Water Quality Criteria - 1972". U.S. Environmental Protection Agency, Washington. (March 1973)
13. "Quality Criteria for Water". U.S. Environmental Protection Agency, Washington. (July 1976)

THE WORLD BANK

AUGUST 1979

OFFICE OF ENVIRONMENTAL AFFAIRS

INDUSTRIAL LIQUID EFFLUENT

LAND DISPOSAL AND LAND TREATMENT

1. When land is available and concentrations of toxicants are low enough, land disposal is the simplest technical and the most economical way to dispose of liquid effluents.

2. If the effluent is suitable, it can be used for land treatment including irrigation and soil desalination.

Land Disposal

3. In this technique, the effluent is spread on a piece of land for a few hours, then on a second piece for the same amount of time, and so on until it is possible to come back to the first when the water has been absorbed and the biological oxidation completed.

4. It is difficult to give figures in a general guideline. The area required depends on the type of soil, its thickness and on the characteristics of the industrial wastes. It is advisable to err on the conservative side when estimating the land necessary and this estimation should be left to specialists.

5. All agro industries liquid effluents (i.e. slaughter houses, dairies, sugar plants etc.) can probably be disposed of on land as most of the impurities can be subjected to biological oxidation.

6. The US EPA estimates that land disposal is 20% more economical than the usual techniques. When the effluent contains nitrogen and/or phosphorus, land disposal is an easy way to prevent eutrophication of a lake or a river.

Land Treatment

7. Certain industrial effluents can be beneficial if used on the land. A few industries produce water as a by-product (i.e. urea). When this water is pure or, as in the case of urea, only slightly contaminated with beneficial products like ammonia and urea, it can be used in irrigation. Because of the continuous supply ^{1/}, crops can increase from one per year to two or three.

1/ The yearly plant turn around can be done during monsoon time and/or crop harvesting.

8. Cooling water used in process industries can also be used for irrigation if chromates are replaced by phosphates as corrosion inhibitors and if the free chlorine is kept to a low value.

9. This raises the question of considering the industrial effluents one by one instead of mixing them in a pond or lagoon and then deciding on the treatment. Some effluents can be used without treatment, others with some very slight treatment and these two could then be disposed of on the land or even used in irrigation, the rest must be treated and discharged in a waterway or in the sea.

10. The advantages of land treatment affects not only the economics of the project but also of the agriculture in the region. For this reason land treatment should be considered as the first option in any industrial project.

BIBLIOGRAPHY

1. A History of Land Application as a Treatment Alternative.
United States Environmental Protection Agency, April 1979- 430/9- 79-012,
Washington D.C. 20460.
2. EPA Design Manual for Land Treatment (in preparation).

THE WORLD BANK

JANUARY 1981

OFFICE OF ENVIRONMENTAL AFFAIRS

ELECTROSTATIC PRECIPITATORS (ESP's)

GUIDELINES

1. Electrostatic Precipitators (ESP's) are one of the best ways to collect dust from gaseous effluents. Several industries use them extensively; among them, cement, mining, steel and non-ferrous metals. They act by ionizing the dust particles in the gas stream. The particle is then pulled towards an electrode by the electrostatic field then removed from the electrode and collected.

ESP Design

2. The design takes into account the following factors:

gas flow and composition
dust concentration in raw gas
dust concentration exit ESP

All other conditions being equal, the dust amount in the gas exit ESP will determine the characteristics of the precipitators (electrode total surface).

3. If, instead of a 100 mg/m^3 concentration we want 50 mg/m^3 exit ESP, we will have to practically double the electrode total surface and, at the same time, the equipment price.

4. From the preceding, it is easy to see that the most important technical guarantee is the dust concentration exit ESP. Defining ESP performance by the ratio of dust removed over total dust should be avoided as this depends on the dust concentration inlet equipment.

5. The US and West German standard is now 50 mg/Nm^3 in the stack.

World Bank Guidelines

6. The World Bank guideline will be 100 mg/m^3 in the stack. The concentration 150 mg/m^3 can be accepted if the plant is in a rural area, and if dust concentration at ground level is within World Bank guidelines inside the plant fence and $260 \mu\text{g}$ (microgram)/ m^3 maximum outside the plant fence.

7. Up to 1980 the ESP for LDCs were designed usually for 300 mg/m^3 . This has created problems particularly in conjunction with low level stacks. The decrease to 100 mg/m^3 will also have the added benefit of decreasing the shut down time and the maintenance cost on the extracting fan. At 300 mg/m^3 in a power station using normal coal (10% ash), the fan has to be shut down every 3 to 4 months to rebalance or replace some blades.

THE WORLD BANK

APRIL 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

ETHANOL PRODUCTION

ENVIRONMENTAL GUIDELINES

1. Ethanol, an organic chemical, is commonly used as an industrial solvent, in medicine, and in the manufacture of alcoholic beverages. It can be used as a fuel, but is costlier than hydrocarbon fuels.
2. Ethanol (ethyl alcohol) can be produced by fermentation from any of three main types of biomass raw stocks: (a) sugar bearing materials (such as sugarcane, molasses, and sweet sorghum); (b) starches (such as cassava, corn, babassu mesocarp, and potatoes); and (c) celluloses (such as wood and agricultural residues).
3. Production of ethanol from these materials first requires conversion of the carbohydrate into soluble sugars (except when sugar bearing materials are used), then fermentation of the sugars into ethanol, and finally separation of ethanol from water and other fermentation by-products by distillation.

RAW MATERIALS

4. Sugarcane is considered to be the most suitable raw material. It not only requires the simplest conversion method but its processing also generates a waste product called bagasse. Bagasse is generally dried and used as a fuel for generating steam and power needed for crushing, fermentation, and distillation operations. One ton of sugarcane having an average sugar content of 12.5 percent produces about 70 liters of ethanol by direct fermentation of the juice. Sugarcane gives one of the highest ethanol yields per hectare of crop land, and is currently the most commonly used raw material worldwide.
5. Cane molasses, a by-product resulting from the extraction of sugar from cane and known as blackstrap molasses, has been the most widely used raw material. Production of one ton of sugar yields 190 liters of molasses, containing 50 to 55 percent fermentable sugar. A ton of molasses (consisting mainly of sucrose, glucose, and fructose) will yield about 280 liters of ethanol. Sugar production from beets will also yield molasses which could be used as a source for ethanol.
6. Main starch materials of interest as ethanol sources are cassava (also called mandioca) and corn. Cassava is a root widely grown as a subsistence crop in a number of developing countries. Under proper conditions, cassava yields can reach 20 tons per hectare. One ton of cassava yields about 180 liters of ethanol. Use of cassava produces no suitable residual energy source.

7. Historically, corn has been used principally for fermentation in whiskey production, and as a minor source of industrial alcohol. Considerable work is currently underway to produce ethanol for use as a gasoline blend. Corn yields average 6 tons per hectare, and a ton of corn yields about 368 liters of ethanol. Corn-based ethanol plants do not produce any residual fuel suitable as an energy source.

8. Wood and agricultural crop residues are the principal cellulosic materials used. Ethanol production from this source is more complex and larger in scale than that from sugar and starches. No commercial scale processes, suitable for use in developing countries, are currently available. Considerable development work is presently being carried out in many countries, and this may become an important biomass source at some future time. Since this source is not commercially proven, it will not be discussed further in this document.

MANUFACTURING PROCESSES

9. In a plant using sugarcane as the raw material, cane is washed, crushed, and then filtered to separate cellulose (or bagasse) from the sugar juice. The juice is concentrated and sterilized. This is followed by yeast fermentation of the juice in a batch system. Yeast is removed by centrifuging, treated (to grow additional yeast), and recycled to the fermentation system. Bagasse is dried and burned to generate steam and power to meet in-plant requirements.

10. Conventional ethanol technology uses batch fermentation with common strains of yeast to produce a solution containing 8 to 10 percent alcohol after 24 to 72 hours fermenting. A concentration of 8 to 10 percent ethanol is the maximum achievable in batch systems.

11. Fermented mash (called "beer") is sent to a stripping column. Here, two separate streams are made, the ethanol product stream (with a trace of water) and a waste stream, called stillage. The stillage contains most of the water and the fermentation solids. It must be properly discarded to avoid environmental pollution.

12. The stream containing the ethanol is distilled in a multistage column to a concentration of about 94 percent ethanol. Anhydrous ethanol, having 99.8 percent purity, is produced in a third distillation column, by adding benzene and further distilling. Benzene is separated from the alcohol and recycled.

13. If the end product is to be hydrous or straight alcohol, containing 94 percent ethanol, the third distillation step is not used, thus reducing steam requirements and eliminating the need for benzene.

14. The basic process for other sugar materials is the same as described above. The size of fermentation and distillation units might be different, depending upon raw materials used and resulting materials balance. For these sugar materials, fermentation takes 4 to 5 times longer than in the case of sugarcane.

15. Operations in a starch based ethanol plant are also similar, except that mash preparation is required prior to fermentation. Cassava roots, (containing 25 to 30 percent starch) are frequently used. First, they are washed, peeled, and liquified in a cooker. Liquified starch is broken down into fermentable sugar by adding two enzymes: amylase and gluco amylase. Once fermentable sugar is formed, processing is identical to that for sugarcane, beginning at the fermentation step.

16. Cassava roots contain essentially no cellulose. No bagasse is formed and energy requirements must be supplied from external sources.

17. Other starch bearing materials use practically the same processing procedures as cassava, although preparation facilities must be designed for the particular crop being used.

18. A process flow diagram for sugarcane and starch-based plants is presented in Figure 1.

19. Technology for production of ethanol from biomass has not changed greatly in recent years. However, with the increasing interest in the use of alcohol as a fuel, several efforts are underway.

20. Continuous fermentation, though not yet commercially developed, can yield liquor with up to 12 percent alcohol content. Additional microbiological research is in progress to improve yeast strains to yield higher alcohol concentrations during fermentation. This technology is expected to reduce energy requirements for distillation and simultaneously reduce stillage volume as well.

21. Use of agricultural wastes for feedstock or fuel purposes and the development of new or improved crops as raw materials are also receiving some attention. A major constraint in utilizing cassava and corn is the need for external fuel sources. Certain agricultural waste products could be made suitable for fuel purposes by modifying current boiler designs.

WASTE SOURCES AND CHARACTERISTICS

22. Ethanol production produces a number of waste products having an impact on the environment. No extremely toxic waste streams are associated with the biomass conversion technologies. Occasionally some heavy metals may be found, but this is rare.

23. Sources of air emissions for a particular ethanol facility will depend upon the feedstock used. The utilization of grains rather than sugar feedstocks will generate particulate emissions during unloading, loading, conveying, rough grinding, screening, cleaning, and fine milling the stock.

24. Generally, air emissions originate from fermenter vents as well as the condenser vents on distillation columns. Fugitive volatile organic compound emissions also occur at valves, pumps, flanges, open-ended lines, and storage tanks, throughout the plant.

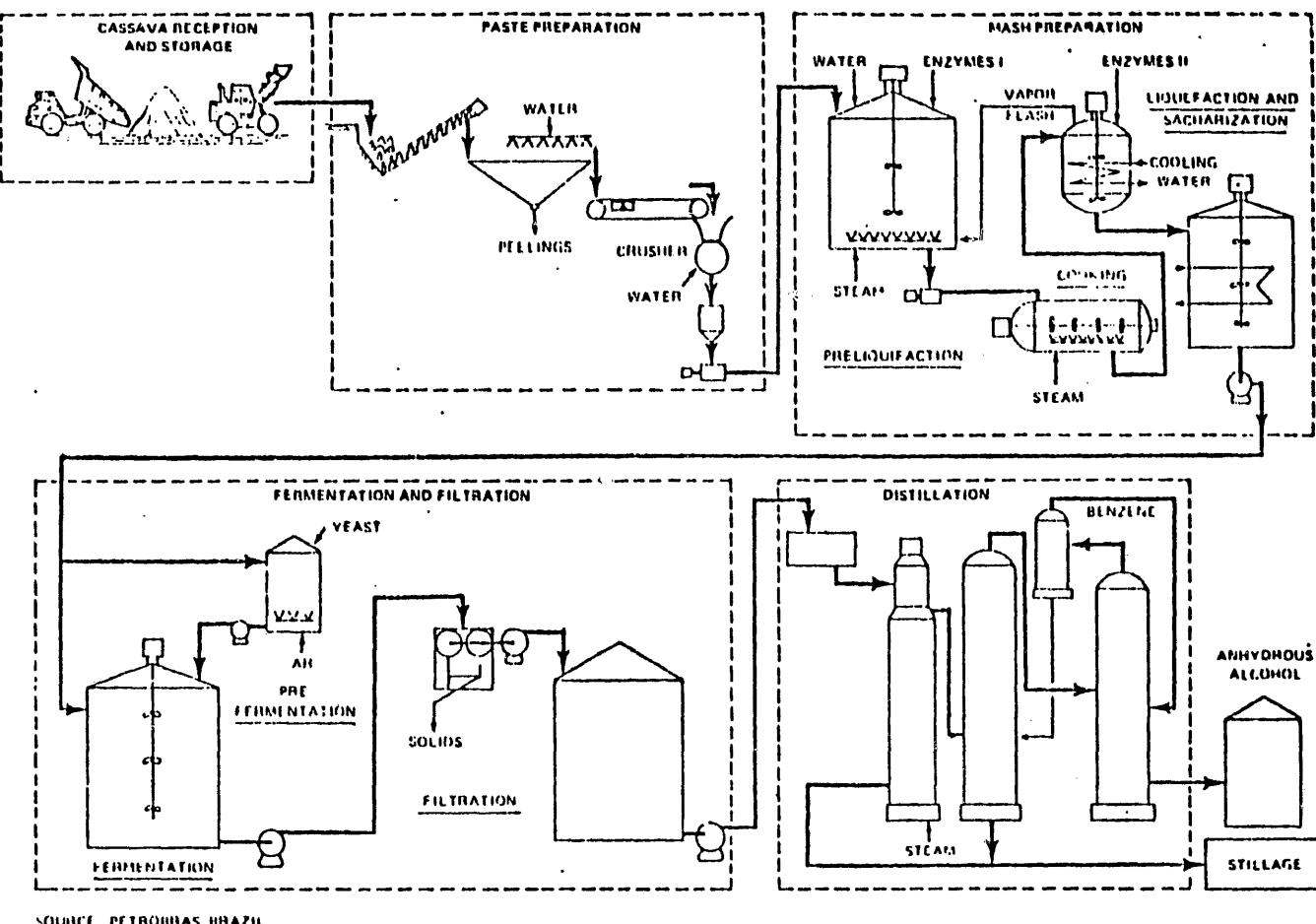


Figure 1. Process Flow Diagram Sugarcane and Starch Based Plants.

25. Carbon dioxide is produced during fermentation. Due to high recovery costs, the gas is usually vented to the atmosphere. Trace amounts of ethanol may occasionally escape with the carbon dioxide. Trace amounts of benzene may also escape from the dehydration/benzene recovery process, in both the gaseous and liquid wastes. Benzene discharges are not considered harmful so long as they are limited to trace amounts. Such discharges should be regularly monitored since benzene is a known carcinogen and is highly explosive. Regular equipment maintenance and proper housekeeping procedures will generally provide adequate control.

26. Fusel oils produced as one of the fractions in the distillation column, consist mainly of amyl or isoamyl alcohols and glycerol. About 5 kilograms of fusel oils are produced per 1000 liters of ethanol. This valuable by-product is either sold to outside markets or blended with the ethanol as a fuel denaturant. (A denaturant is an additive which, once combined, is very difficult to separate and makes the mixture unfit for human consumption). Molasses fermentation yields about 1.1 liters of fusel oil per 1000 kilograms of feedstock. With corn the yield amounts to about 3 percent of the alcohol produced.

27. Stillage consists of non-fermentable material, and can be removed at various points in the production process. The most commonly used method, resulting in minimum ethanol loss, is to withdraw it from the bottom of the still during or after distillation (thus the term stillage). This waste can have a biochemical oxygen demand (BOD_5) as high as 40,000 mg/liter and contain about 10 percent of solid material. Stillage contains some fertilizer nutrients made up of about 1 percent nitrogen, 0.2 percent phosphate, and 1.5 percent potash.

28. Yeast grows rapidly in the fermentation step, and the excess is generally recovered, purified, and recirculated into the system. Yeast recovery will amount to about 72 grams per liter of ethanol produced.

29. If steam and power for conventional sugarcane base operations are generated from burning bagasse, particulate emissions may result. Where sugarcane is not the biomass source, fossil fuels are generally used and, dependent upon the choice of fuel, emissions of sulfur oxides, nitrogen oxides and particulates may result.

30. Cooling tower blowdowns are another waste source. This stream (having high concentrations of dissolved inorganic material) will be high in solids but low in BOD_5 . Feedstock plant and equipment washes constitute another significant waste stream, and can account for up to 20 percent of the total BOD_5 loading.

31. Fly ash, coal dust, and grain dust are the primary solid wastes resulting from fermentation process using coal as a source of fuel.

EFFLUENT LIMITATIONS

32. Many of the waste materials resulting from ethanol production yield valuable by-products, or are suitable for other uses. For other pollutants, as discussed below, treatment methods are available for eliminating or reducing their discharges to the environment.

33. Where disposal to the environment is unavoidable, effluent discharge levels are to be reduced to the following:

Air Emissions

Sulfur Dioxide (as SO ₂):	Ann. Arith. Mean	100 µg/m ³
	Max. 24-hr. Peak	1000 µg/m ³
Nitrogen Oxides (as NO ₂):	Ann. Arith. Mean	100 µg/m ³
Particulates:	Ann. Geom. Mean	75 µg/m ³
	Max. 24-hr. (once per year)	260 µg/m ³
Benzene		1 ppm

Liquid Wastes

5-Day BOD	: 30 to 60 mg/L
Suspended Solids	: 30 to 60 mg/L
pH	: 6 to 9 Units

WASTE CONTROL TECHNOLOGY

34. Emissions from the various steps in the process can be reduced to acceptable levels by use of conventional mechanical collectors or wet scrubbers. This will remove or drastically reduce both the particulates and gases. A liquid waste, containing the particulates as suspended solids, will be produced and will require disposal.

35. Carbon dioxide is recoverable, and it may be economical to do so if a market is readily available. It can be used in the manufacture of carbonated beverages, fire extinguishers, dry-ice production, food processing, and the chemical industry. Some 70 to 80 percent of the carbon dioxide is recoverable. The gas contains a few impurities (such as aldehydes and alcohols) and these do cause odors. They can be readily removed by absorption or adsorption.

36. Fusel oil is a combination of higher alcohols, its composition depending upon the crop used to supply the sugar base. It can be used as a feedstock in chemical production and as a solvent. It may also be burned as a fuel. In large scale fermentation it is removable in an extra column, fractioned, and marketed as a by-product. Removal is not practical in a small scale plant.

37. Stillage constitutes by far the major liquid waste requiring disposal. It is high in both BOD and suspended solids (in the range of 30,000 to 40,000 mg/liter), and volumes will be in the range of 10 to 15 times the volume of the ethanol produced. The waste has found wide usage in many countries as animal feed, fertilizer, and for crop irrigation.

38. Starch crop fermentation stillage contains non-fermentable solids in suspension and in solution. The waste can be applied directly to the land as a fertilizer, but the amounts must be carefully monitored, because of their acidity and odor. The coarser solids can be separated, dried, and blended with the dried soluble material. These are normally referred to as distillers dark grains (DDG) or, when combined with the dried soluble material, as distillers dried grains with solids (DDGS). The nutritional value of these products for animals will vary according to the feedstock and production process used.

39. Stillage products from beverage distilleries are generally all used for animal feed. The bourbon whiskey industry is the main source, with corn being the principal feedstock. Wheat and rye stillages are also used for this purpose. In addition to supplying protein and energy, such feeds also act to stimulate digestive processes in ruminants. Distillers feeds have been found to be of benefit to chickens, turkeys, beef and dairy cattle, calves, sheep, swine, and warm-water fish.

40. Residue from molasses fermentation is also used as an animal feed, but mainly for dairy cattle. It is also used as an antidusting agent in feed mixing and handling. The residue contains potash salts, nitrogen compounds, and phosphates and hence can be used as a fertilizer. As a fertilizer, it can be applied directly to the soil as a liquid, but costs and logistics tend to limit its use to areas close to the fermentation facilities. Excessive use can create a number of problems, such as proliferation of insect pests.

41. Under normal operations the stillage, after removal, is separated into solids and liquids (thin stillage). After initial screening and processing through a dewatering press the solids will still contain about 65 percent water, and are known as wet stillage. This may be fed directly to livestock. One head of cattle will consume the stillage produced from production of about 3.8 liters of ethanol. Further drying is necessary if long-distance transportation or long-term storage is required. The dried material must be protected from insects and rodents.

42. The thin stillage of fermented grains also contains valuable proteins and carbohydrates, but it is difficult to dry any further. It is acidic and may be applied directly to the soil through irrigation systems. It may also be anaerobically fermented to produce methane.

43. Where stillage wastes are not used for by-product recovery or other beneficial use, they should not be discharged to surface waters without treatment. If volumes are small in relation to the capacity of an available publicly owned sewage treatment plant, the wastes may be discharged to public sewers.

44. If large volumes are to be handled, then treatment should be provided at the plant site. The nature of this waste is such that treatment methods normally used for domestic sewage may be applied. Secondary treatment, such as activated sludge or trickling filters, may be used after some form of pretreatment to remove the high concentrations of organic materials and solids. The BOD₅ and suspended solids should be reduced to the 300 mg/liter range before secondary treatment. Again depending on volumes, settling ponds or lagoons may also be used, particularly if the operation is seasonal and based on the availability of crops. Care must be taken to avoid damaging ground waters.

45. The liquid waste from the wet scrubbers should receive treatment before discharge to the environment. Since the principal contaminant is in the form of suspended solids, the discharge can go to settling or evaporation ponds.

46. The principal solid wastes will be the sludges resulting from in-plant waste treatment facilities and the settled solids from any ponds operated at the site. Consideration should be given to possible recovery of valuable by-products from the solids which are generated. Otherwise the solids should be removed and dumped on controlled (such as diked) areas in the plant. Means should be provided for preventing rain runoff into nearby surface or ground waters.

47. Ocean disposal of wastes is to be avoided whenever possible. However, when no other options are available and it becomes a method of last resort, expert services should be engaged to design the system. This is a highly specialized field, in which only a few designers have had extensive experience.

48. Initial planning for an ocean outfall should include a comprehensive survey of the proposed ocean discharge area to determine the following, as a minimum:

- (a) Currents - direction, magnitude, frequency, variation with depth, relation to tide, water displacements, etc.;
- (b) Densities - variation with depth, as determined from salinity and temperature data and standard tables;
- (c) Submarine topography, geology, and bottom materials;
- (d) Marine biology; and
- (e) Turbidity, dissolved oxygen, and other physical and chemical characteristics.

49. The data derived from this survey should be the basis for design of the outfall and diffusion system. Wastes discharged into the ocean are subject to three stages of diffusion or mixing:

- (a) Initial jet mixing, which is influenced by jet strength, currents, and density differences;
- (b) Development of a homogeneous diffusion field; and
- (c) Turbulent diffusion of the entire waste field due to natural oceanic turbulence.

50. The factors influencing these stages will include:

- (a) Outlet design. For optimum dilution the jets should discharge horizontally with no initial upward velocity;
- (b) Number of outlets. A multiple outlet diffuser will discharge over a large area and provide more effective dilution and dispersion. All other factors being equal, the single outlet unit will generally require a longer distance and greater depths to the point of discharge;
- (c) Diffuser velocity. The velocity in all parts of the diffuser should be sufficient to prevent deposition of residual particles. For settled wastes a velocity in the range of 0.61 to 1 meter per second is considered a minimum;
- (d) Flow distribution. The outflow between the various diffuser outlets should be fairly uniform. Where this may be difficult, as in the case of a sloping sea bottom, the distribution should be fairly uniform at least for the low and medium flows anticipated; and
- (e) Prevention of seawater intrusion. Seawater entering the pipe becomes stagnant, and will tend to trap grit and other settleable materials, causing reduction of hydraulic capacity.

BIBLIOGRAPHY

1. Paul, J.K. (Ed.) "Ethyl Alcohol Production and Use as a Motor Fuel". Noyes Data Corporation. Park Ridge, New Jersey. (1979).
2. The World Bank. "Alcohol Production from Biomass in the Developing Countries". Washington (November 1980).
3. "Alcohol Fuels from Biomass". In "Energy Technologies and the Environment". U.S. Department of Energy. Doc. DOE/EP-0026. Washington (June 1981).
4. Seltzer, Richard E. "Economic Impact of Effluent Regulations on the Rum Industry (Puerto Rico and U.S. Virgin Islands)". Prepared for U.S. Environmental Protection Agency by Development Planning and Research Associates, Inc. Manhattan, Kansas 66502 (March 1979).

5. Houghton-Alico, Doann "Alcohol Fuels-Policies, Production, and Potential". Westview Press. Boulder, Colorado 80301. (1982).
6. "Study of Rum Distillery Waste Treatment and By-Product Recovery Technologies". SCS Engineers. Long Beach, California 90807. (1979).

THE WORLD BANK

MARCH 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

GUIDELINES

FERTILIZER MANUFACTURING WASTES

1. Fertilizer use has increased sharply in recent years. By 1973, total world consumption of N-P-K (nitrogen-phosphorous-potassium) fertilizers had reached 77 million metric tons, having doubled over the preceding eight years. Largest tonnage increases were in developed countries of Europe and North America, but greatest percentage increases were in lesser developed regions of Asia, Africa and Latin America.

2. While formulation of fertilizers, as well as other manufacturing aspects will vary between plants and countries, there are many common production elements in which affect both discharge of waste effluents and subsequent environmental effects.

MANUFACTURING PROCESSES

3. Fertilizer plants produce two types of product - nonmixed (or straight) and mixed. Nonmixed fertilizers contain only a single major nutrient, while mixed fertilizers contain two or more primary nutrients. For purposes of these guidelines the industry will be further subdivided as follows:

Nonmixed Fertilizers

Nitrogen Based

- Ammonia
- Urea
- Ammonium Nitrate

Phosphate Based

- Phosphoric Acid
- Normal Superphosphate
- Triple Superphosphate

Mixed Fertilizers

Ammonium Phosphate and N-P-K's

4. Nitrogen fertilizer manufacture includes four basic process plants: ammonia, urea, nitrate, and nitric acid.

5. Ammonia is the basic nitrogen fertilizer constituent, and is produced by reaction of hydrogen with nitrogen. Urea, another major nitrogen source, is produced by reaction of ammonia with carbon dioxide to form ammonium carbamate, which in turn is dehydrated to form urea. Urea plants usually share a common site with like-size ammonia plants, so that the latter not only supplies ammonia but also high purity carbon dioxide needed to produce urea.

6. Ammonium nitrate is produced by reaction of ammonia with nitric acid. The resulting product is a solution, which can be sold as a liquid or further processed into a dry product. In some cases the final dry form will be prills (or pellets). In other cases the final product will be crystals.

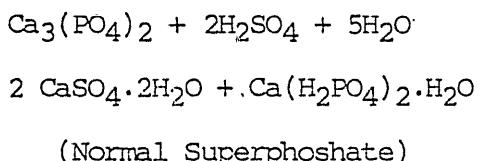
7. Nitric acid is produced in many plants for use in manufacturing nitrogen fertilizers such as ammonium nitrate. Nitric acid is generally made by partial oxidation of ammonia with air, followed by further oxidation and absorption in water to produce a 55 to 65 percent solution.

8. Phosphate fertilizer facilities are usually separated geographically from nitrogen facilities, and therefore are discussed separately in these guidelines. The manufacturing process is comprised of eight separate components: sulfuric acid production, phosphate rock grinding, wet process phosphoric acid production, phosphoric acid concentration, phosphoric acid clarification, and preparation of: normal superphosphate, triple superphosphate, and ammonium phosphate, respectively.

9. The basic components are sulfuric acid production and wet process phosphoric acid production. Sulfuric acid is the essential raw material in producing phosphoric acid and normal superphosphate. It is now usually manufactured by the Contact Process, using elemental sulfur, air, and water.

10. Raw materials used in producing phosphoric acid are ground phosphate rock, sulfuric acid, and water. Other acids, such as nitric and hydrochloric, may also be used. The resulting phosphoric acid solution is concentrated by evaporation, clarified for removal of precipitated solids (consisting mainly of iron and aluminum phosphates, soluble gypsum, and fluorosilicates) and then distributed to markets.

11. Normal superphosphate is produced by mixing 65 to 75 percent sulfuric acid, ground phosphate rock, and water. Following mixing and initial settling of 1 to 4 hours, the mixture is transferred to storage for 3 to 8 weeks to allow complete chemical reaction between the acid and the rock. The basic chemical reaction is as follows:



12. Triple superphosphate (TSP) is produced by combining phosphate rock, phosphoric acid, and water. Two types of TSP are manufactured, using the same raw materials: Run-of-Pile (ROP) and Granular Triple Superphosphate (GTSP).

13. The ROP

phate, except that phosphoric acid is used instead of sulfuric acid. Mixing of the phosphoric acid and phosphate rock is done in a cone mixer. This produces a slurry, which rapidly becomes plastic and solidifies. Solidified material passes through a rotary mechanical cutter, which breaks it up and discharges to storage piles for curing. Following 2 to 4 weeks of curing, the product (triple superphosphate) is taken from storage, sized and shipped to markets. The solidification process may release obnoxious gases which can create air pollution problems.

14. The GTSP process utilizes a lower concentration of phosphoric acid, different proportions of the same ingredients, and other changes from the ROP process. The product is a hard, uniform, pelletized granule made in equipment which permits easy collection and treatment of dusts and noxious fumes.

15. Ammonium phosphate fertilizers are produced in two major formulations: monoammonium phosphate (MAP) and diammonium phosphates (DAP). These vary in the amount of nitrogen and phosphate present. The two primary raw materials, in either case, are ammonia and wet process phosphoric acid. Sulfuric acid is sometimes used in certain MAP formulations. The final granular product is dried, cooled, and shipped. Small sized granules are separated and used as recycle material.

16. During the past several years there has been a trend towards compound fertilizers. While these have always been popular in the United States, their use has grown considerably in Western Europe and Japan. These compounds (sometimes referred to as mixed fertilizers) are produced by mixing inorganic acids, various solutions, double nutrient fertilizers, and certain types of straight fertilizers mixed in accordance with required N-P-K ratios. Another form of compound fertilizers, called blend fertilizers, are produced by simple combination of granular dry straight and mixed fertilizers, again, in accordance with the N-P-K ratio required.

SOURCES AND CHARACTERISTICS OF WASTES

17. Fertilizer industry wastes can affect air, water, and land resources of an environment. Pollution problems arise from low process efficiency, disposal of unwanted by-products, contaminants in flue dusts and gases, contaminants in process condensates, and accidental spills or losses.

18. In production of nitrogen fertilizers, no air pollution results from ammonia and urea manufacture. Overhead vapors from neutralizers in the reaction of ammonia with nitric acid to form crystal ammonium nitrate which may lead to an air pollution problem. However it can frequently be handled by cyclones or baghouses. Concentrator and prill tower exhausts can contain ammonium nitrate particles and may also result in an air pollution problem.

19. Liquid wastes from the nitrogen fertilizer industry can originate from wastewater treatment plant effluents (filtration, clarification, softening, deionization), closed loop cooling tower blowdown, boiler blowdown, compressor blowdown, process condensates, spills or leaks, and nonpoint source discharges. Nonpoint polluted water sources may originate from air-borne ammonia dissolving into falling rain or snow, or prill dusts or other materials lying on the plant grounds, dissolving into rainwater as it runs off various surfaces in the vicinity of the fertilizer plant.

20. Since air pollution problems for a nitrogen fertilizer complex are considered minor in nature, no air pollution parameters are applied. Major wastes are liquid in nature and are measured in terms of ammonia nitrogen, organic nitrogen, nitrate nitrogen, and hydrogen-ion concentration (pH).

21. Phosphate fertilizer plants generate considerable amounts of dust in grinding phosphate rock. Fluorine (as SiF₄) may evolve in the acidulation process (changing phosphates in phosphate rock from an insoluble to a soluble state). Air pollution problems are caused by ROP production. While dust and obnoxious fumes result from GTSP production these are readily collected and treated.

22. Liquid effluents include water treatment plant wastes, cooling tower and boiler blowdowns, make-up water, spills and leaks, surface runoff, and gypsum pond water. Cooling is generally by indirect means, and cooling waters are not contaminated. In the United States the majority of phosphate fertilizer plants impound and recirculate all water which has direct contact with process gas or liquid streams. Uses include barometric condensers, gypsum sluicing, gas scrubbing, and heat exchangers. This contaminated water is normally not discharged from the plant complex.

23. Fluoride emissions are the principal air pollution concern in phosphate fertilizer plants. Hence this is the only air pollutant for which effluent limitations are provided in this guideline. Primary parameters for liquid wastes are phosphorous, fluorides, suspended solids, and pH.

24. For all fertilizer plants, solid materials may be found in storage piles, settled dust, and similar forms. As rain water falls upon these dust sources, dusts may be swept into the rainwater runoff. This will increase both the dissolved and suspended solids levels in these runoff waters.

EFFLUENT LIMITATIONS

25. Effluent limitations are given below for nitrogen, phosphate, and mixed fertilizer plants. The permissible levels are based on best currently available demonstrated control technology.

26. For all plants, where applicable, the ambient air quality levels should not exceed those given in Table 1, to assure public health protection.

Nitrogen Fertilizer Plants

27. Except for ammonia, as given in Table 1, air emissions from nitrogen fertilizer plants are usually of minor importance under proper operating conditions. Therefore, no other limitations are included for gaseous effluents from this type of plant. Limitations for liquid effluents from nitrogen plants, as presented in Table 2. Where applicable, gaseous nitric acid effluent limitations are the same as those for phosphate fertilizer plants, as shown in Table 3.

Table 1 — Ambient Air Quality Limitations ^{a/}

Pollutant	Period	Limitation ug/m ³ . ^{b/}
Particulates	Ann. Geom. Mean	75
	Max. 24-Hours	260
Sulfur Oxides: Inside plant fence	Ann. Arith. Mean	100
	Max. 24-Hour peak	1000
	Ann. Arith. Mean	100
	Max. 24-Hour peak	500
Carbon Monoxide	Max. 8-Hour	10,000
	Max. 1-Hour	40,000
Photochem. Oxidants	Max. 1-Hour	160
Hydrocarbons	Max. 3-Hour	160
Nitrogen Oxides	Ann. Arith. Mean	100
Ammonia	Max. 8-Hour	72,000

a/ From "Expert Group Meeting on Minimizing Pollution From Fertilizer Plants". Helsinki, 26-31 August 1974. UNIDO. Vienna (1974).

b/ ug/m³: Microgram/cubic meter.

Table 2 — Liquid Effluent Limitations for Nitrogen Fertilizer Plants

Type of Plant	Parameter	Limitation - Kg/Mg of Product
		Daily Ratio
Ammonia	Ammonia as N	0.11
Urea	Ammonia as N " Organic N as N "	0.065 0.065 0.24 0.7
Ammonium Nitrate	Ammonia as N " Nitrate as N "	0.05 0.10 0.025 0.05
All Plants	pH (no units)	6 to 9

Phosphate Fertilizer Plants

28. Limits on gaseous emissions from phosphate fertilizer plants are presented in Table 3.

Table 3 -- Gaseous Emission Limits for Phosphate Fertilizer Plants

Process	Parameter	Limitation
Nitric Acid	Nitrogen Oxides (NO_x) Visible Emissions	1.5 kg/Mg Product 10% Opacity ^{a/}
Sulfuric Acid	Sulfur Dioxide (SO_2)	2.0 kg/Mg Product as 100% Acid
	Acid Mist	0.075 kg/Mg Product as 100% Acid
	Visible Emissions	10% Opacity ^{a/}
Wet Process Phosphoric Acid	Fluorides (as F)	10 gm/Mg Equiv. ^{b/} P_2O_5 Feed
Superphosphate	Fluorides (as F)	5 gm/Mg Equiv. P_2O_5 Feed
Triple Superphosphate- ROP and Granular	Fluorides (as F)	5 gm/Mg Equiv. P_2O_5 Feed
	Visible Emissions	20% Opacity ^{a/}
Triple Superphosphate- Gran.	Fluorides (as F)	0.25 gm/hr/M ton Equiv. P_2O_5 Stored
Storage Facility		

a/ "Opacity" is defined as the degree to which emissions reduce the transmission of light and obscure the view of an object in the background.

b/ g = gram
1 megagram = 1 metric ton
1 Mg = 1 metric ton

29. Process waste liquid effluents should not be discharged. Impoundment design should be adequate to hold all waste streams and all runoff expected from the maximum 10-year, 24-hour rainstorm for the area. In any calendar month when precipitation exceeds evaporation, a volume of waste flow equivalent to the difference between the two may be discharged, but subject to the following limitations:

Parameter	Max. Daily
	mg/L <u>a/</u>
Phosphorous - as P	70
Fluorides - as F	30
Total Susp. Non-filterable Solids	50
pH (no units)	6 - 9

a/ milligram/liter

Mixed Fertilizer Plants

30. For a mixed fertilizer plant, fluorides in gaseous emissions (measured as F) are limited to 30 g/Mg of Equivalent P₂O₅ Feed. No liquid effluents are to be discharged.

WASTE CONTROL AND TREATMENT

31. Process control and in-plant procedures can be effective in minimizing pollution effects from fertilizer plants. Careful application of such measures can result in significant economic benefits for plant operators. Specific measures taken for protecting the environment must be based on the raw material, processes, climate conditions, and other factors applicable to individual plants.

32. For nitrogen fertilizer plants, ammonia stripping has been found effective for removing ammonia in process condensates, and boiler and cooling tower blowdowns at ammonia, urea, and ammonium nitrate plants. The stripping medium may be either air or steam, depending upon the use to be made of the overhead vapors, local air pollution regulations, and other factors. At urea plants hydrolysis has been used to convert urea in waste streams back to ammonia and carbon dioxide.

33. Recently a number of investigations have been made into removing nitrate from wastewater by the use of biological action in aerated ponds or basins. Ion exchange units have also been used successfully to remove ammonia and nitrates from waste waters. At ammonium nitrate plants condensates contain ammonia, ammonium nitrate, and some oxides of nitrogen, and these all require treatment before discharge. These condensates have been used as absorber feed in the nitric acid plant. Thus creating an internal use of the waste stream which results in recovery of both ammonia and nitrate. Oils and greases can also present problems in nitrogen fertilizer complexes, but application of available technology can reduce these pollutants to less than 25 mg/liter.

34. For phosphate fertilizer plants, technology exists for reducing contaminants present in waste effluents. Air pollution of SO₂ from sulfuric acid plants can be reduced by use of the "double-contact" process or ammonia scrubbing. Tail gas from nitric acid plants, containing oxides of nitrogen (NO_x), can be handled by extended absorption or catalytic reduction. In general, gaseous emissions as a group can be reduced by the use of absorber towers. They are either collected as dusts or water scrubbed.

35. Although there should be no discharge of liquid effluents from phosphate fertilizer plants, rainfall conditions may be such as to require treatment of discharges on certain occasions. Frequently reductions in pollutant concentrations can be effected on separate process streams. Critical points where measures can be applied include: (1) cooling water blowdown and accidental leakage from sulfuric acid coils; (2) drainage from waste by-product gypsum piles; and (3) seepage from gypsum ponds.

36. Because of differences in production of N-P-K fertilizers, resulting pollution problems will vary widely. Usually cyclones and filter bags will reduce dust emissions in dry-process plants. In other cases scrubbers will be the preferred alternative and these, in turn, will require further pollution control procedures for the resulting liquid effluent.

BIBLIOGRAPHY

1. "Minimizing Pollution from Fertilizer Plants". Report of an Expert Group Meeting, Helsinki, 26-31 August 1974. UN Industrial Development Organization. Vienna (1974).
2. Hignett, T.P., "Recent Developments in Fertilizer Production Technology and Economics, with Special Reference to Ammonia and Compound Fertilizers". ASPAC Food and Fertilizer Technology Center. Taiwan (August 1974).
3. Finneran, J.A. "Guide to Building an Ammonia Fertilizer Complex". UN Industrial Development Organization. Vienna (1969).
4. "World Guide to Pollution Control in the Fertilizer Industry". British Sulphur Corporation. London (1975).
5. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Basic Fertilizer Chemicals Segment of the Fertilizer Manufacturing Point Source Category". U.S. Environmental Protection Agency. Washington. Doc. EPA-440/1-74-011-a (March 1974).
6. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Formulated Fertilizer Segment of the Fertilizer Manufacturing Point Source Category". U.S. Environmental Protection Agency. Washington, Doc. EPA/1-75-042-a (January 1975).
7. "Standards of Performance for New Stationary Sources". U.S. Environmental Protection Agency. Washington (August 1, 1976).

THE WORLD BANK

OCTOBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

GUIDELINES

FISH AND SHELLFISH PROCESSING

1. There is a wide variety of finfish and shellfish which could be processed at projects involving Bank financing. Therefore, it is not possible to prepare a guideline covering all forms that may be encountered. This document will deal only with ocean fish and marine life, and will confine itself to a representative group of species, thereby providing information considered typical of and applicable to processing, canning, and preserving of fish and shellfish.
2. Specific species to which these guidelines may be applied include, but are not limited to, salmon, herring (sometimes as sardines in the immature state), ocean perch, mackerel, halibut, cod, sole, tuna, clams, oysters, scallops, crab and shrimp.

PROCESSING OPERATIONS

3. Harvesting utilizes a wide range of old and new technologies for supplying the basic raw material. Techniques fall into one of four general methods; netting, trapping, dredging, and line fishing. Airplane spotting and other systems are sometimes used for locating the fish. Once harvested and aboard the vessel, the catch is either taken directly to a processing plant or is iced and frozen on board for later delivery.

4. At the receiving point, the catch is unloaded, weighed, and transported by conveyor or suitable containers to the work area. It may be processed immediately or transferred to cold storage. Pre-processing prepares the catch for the later operations. It may consist of washing of dredged crabs, thawing of frozen fish, beheading shrimp at sea, and other operations prior to butchering. Wastes from butchering and evisceration are usually dry-captured or screened from the waste stream and processed as a fishery by-product.

5. Except for those portions intended for the fresh fish and seafood markets, some form of cooking or pre-cooking is usually practiced in order to prepare the commodity for the picking and cleaning operation. Precooking or blanching facilitates removal of skin, bone, shell, gills, and other parts which must be separated before marketing. In some cases steam condensate from this operation is collected and further processed as a by-product. For example, the condensate or stick water from the tuna precook. Stick water is water which has been in close contact with the fish, and contains large amounts of entrained organics.

6. End product is prepared in its final form by picking or cleaning to separate edible from non-edible portions. Non-edible portions resulting from this procedure are usually collected and saved for by-product processing. The cleaning operation may be manual, mechanical, or a combination of the two. With fresh fish or fresh shell-fish, the meat product is packed into suitable containers and held under refrigeration until shipment to consumer outlets. If the final product is to be held for extended periods before consumption, then freezing, canning, pasteurization, refrigeration, or some combination of these is used for preservation to prevent spoilage.

7. Fish and shellfish, and their waste products, are frequently used for production of such industrial commodities as fish meal, concentrated protein solubles, oils, liquid fertilizers, fish food pellets, kelp products, shell novelties and pearl essence. Some species are used primarily for industrial purposes. For example, menhaden and anchovy are utilized extensively for preparation of fish meal, and added as a protein supplement in animal feeds; oils are used in shortening, margarine, lubricants, and cosmetics; and fish solubles are used as liquid fertilizers.

SOURCES AND CHARACTERISTICS OF WASTES

8. Edible product yield is highly variable. In general, yields for shellfish are in the 15 to 20 percent range while that for fish such as tuna or salmon yield reach the range of 60 or more percent. Extensive beneficial uses made of non-edible fish portions greatly reduces waste discharge.

9. Wastewater parameters of major importance in the canned and preserved seafood processing industry are the 5-day, 20° C, biochemical oxygen demand (BOD_5), total suspended solids (TSS), combined oils and greases, and pH. Normally, these wastewaters contain no hazardous or toxic materials (heavy metals, pesticides, etc.). Occasionally highly concentrated sodium chloride ($NaCl$) solutions may be discharged. These can interfere with biological treatment systems unless pretreatment, such as dilution or flow equalization, is provided prior to disposal.

Salmon

10. Wastewater flow rates in a salmon processing plant will depend on whether the butchering operation is carried out by machine or by hand. Machine operations will result in higher flow rates, (BOD_5 , and TSS). Many plants will employ both machine and hand butchering, depending on the species, quantity of catch to be processed and other factors.

11. In both fresh and frozen salmon processing, the principal source of wastewater is the wash tank operation. Here eviscerated fish are cleaned to remove adhering blood, tissues lining the body cavity (mesentaries), sea lice, and visceral particles. A preliminary rinse of the fish, as caught, is sometimes used to reduce the amount of slime adhering to the carcass and to facilitate handling. Wash tank and pre-rinse contribute about 90% of all wastewater flow. The remainder comes from wash down of butchering tables and other work areas.

12. Wastewater flows from salmon canning operations are much higher than preparing fresh or frozen salmon products, particularly where butchering is done mechanically. Hand butchering and canning operation is essentially the same as the fresh/frozen operation except for wastes from fish cutting and can filling, which will also increase the amount of wastes into the water.

13. Typical loadings to be anticipated from these two types of operations are presented in Table 1.

Table 1 — Typical Effluent Loadings from Salmon Processing

Parameter	Fresh/ Frozen ^{a/}	Canned	
		Mech. Butchered ^{a/}	Hand Butchered ^{a/}
Flow	3,750 L/Mg	19,800 L/Mg	5400 L/Mg
BOD ₅	2.0 kg/Mg	45.5 kg/Mg	3.4 kg/Mg
TSS	0.8 kg/Mg	24.5 kg/Mg	2.0 kg/Mg
Oils/Greases	0.18 kg/Mg	5.2 kg/Mg	7.8 kg/Mg
pH	6.6	6.5	7.0

^{a/} All loadings except pH, expressed as per megagram of product.
1 Mg = 1 megagram = 1 metric ton; L = liter.

Tuna

14. Processing tuna requires several unit operations including receiving, thawing, butchering, precooking, cleaning, canning, retorting, labeling and casing. Process and waste sources are shown schematically in Figure 1. This operation requires large volumes of both fresh water, (usually from municipal sources) and salt water pumped directly from the ocean or saline wells. Both municipal and saline waters normally come into contact with the tuna only in those stages preceding the precooking operation.

15. Typical waste flows and loadings discharged from a tuna processing plant are given in Table 2.

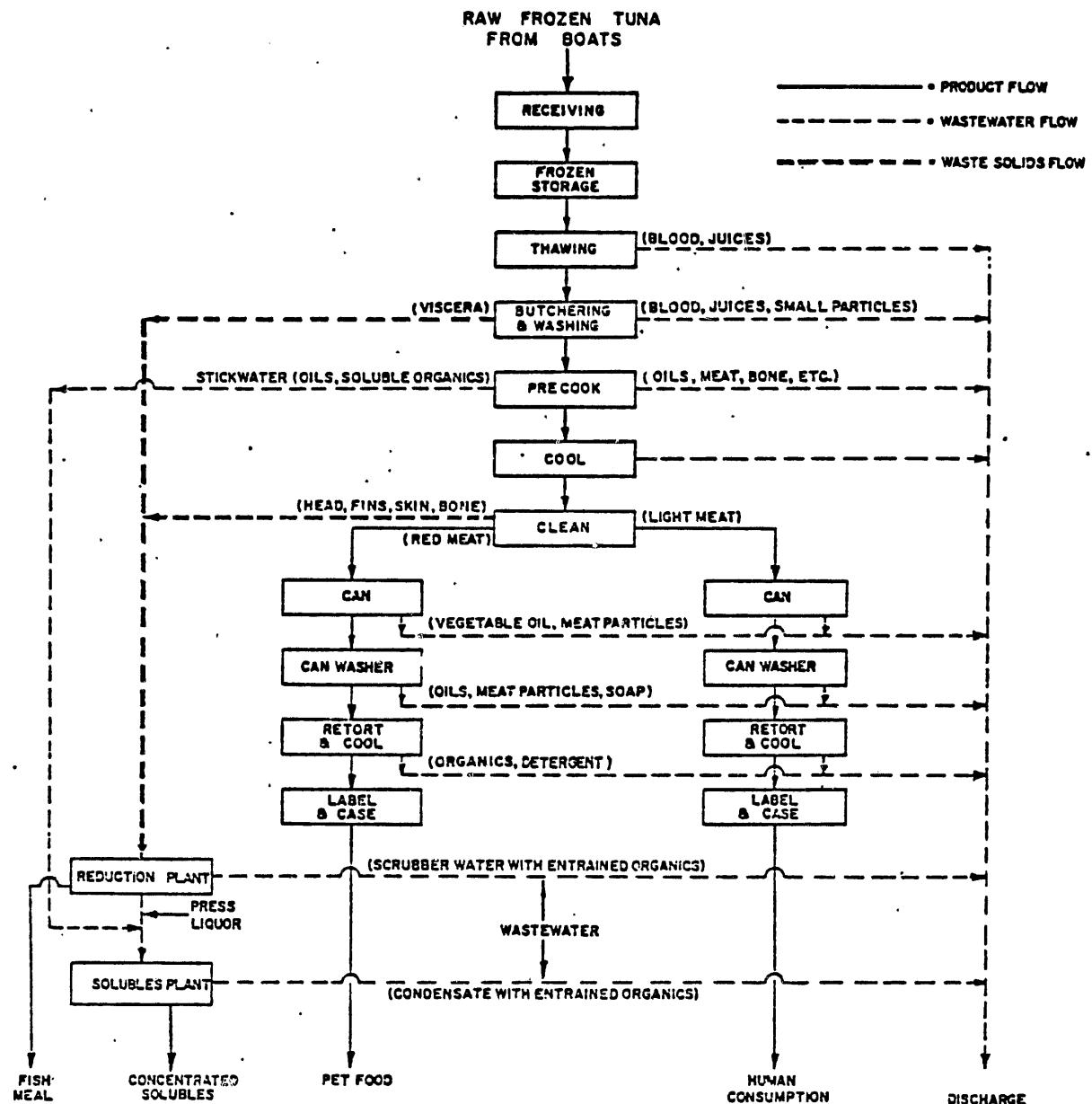


Figure 1. Typical Tuna Processing, Waste Flows, and By-Product Usage.

Table 2 -- Typical Effluent Loadings from Tuna Processing

Parameter	Loadings ^{a/}
Flow - L/Mg	22,300
BOD ₅ - kg/Mg	15
TSS - kg/Mg	11
Oils/Greases - kg/Mg	5.6
pH	6.8

a/ All loadings, except pH, expressed as per megagram of whole tuna processed.

On the average, 45 percent of the raw tuna intake results in food product, 54 percent (viscera, head skin, fins, bone, red meat) in by-products, and the remaining 1 percent goes to waste.

Shrimp

16. Commercial shrimp collection is done by netting at distances of some 100 km from shore. The harvest is taken directly to a processing plant or a "mother" ship. If taken to a ship, the catch must be immediately iced and reiced every 12 hours. Following peeling and preparation, shrimp are processed and marketed as frozen, or as canned or breaded products.

17. Up to the late 1950's shrimp were hand peeled for retail marketing or further processing. Currently, peeling machines are used, thus increasing plant capacities some 30 to 40 fold. Peeling machines are the largest water users and also contribute to the largest waste load. Some 45 to 55 percent of the water entering a plant is used for this purpose.

18. Typical waste flows and pollutant loadings from shrimp processing operations are given in Table 3.

Table 3 -- Typical Effluent Loadings from Shrimp Processing

Parameter ^{a/}	Frozen	Canned	Breaded
Flow m ³ /Mg	73.4	60.0	116
BOD ₅ kg/Mg	130.	120.	84
TSS kg/Mg	210.	54.	93
Oils/ Greases kg/Mg	17.	42.	—
pH	7.7	7.4	7.8

a/ All loadings, except pH, expressed as per megagram of raw shrimp input to plant.

EFFLUENT LIMITATIONS

19. Limitations for liquid effluents from fish processing plants are given in Table 4. Under normal operations no gaseous effluents of any consequence are discharged. Solid wastes, generally removed by screening, are either processed into saleable by-products or transferred to landfills or other facilities for final disposal.

20. Application of these limitations should be based on conditions at each individual plant. These are average values only, based on currently available technology considered to be achievable under present day operating conditions at existing plants.

21. Factors which will influence limitations applicable to any individual plant, are (a) nature of the end product; (b) mechanical versus hand butchering or peeling; (c) extent of processing performed on board ship, prior to transfer to the plant; (d) water quality requirements for receiving waters; and (e) remoteness of plant location.

Table 4 -- Liquid Effluent Limitations for Fish Processing Plants ^{a/}

Category	Max. Daily kg/Mg Live Weight Processed		
	BOD ₅	TSS	O+G ^{b/}
Tuna	2.2	2.2	0.27
Salmon	11.	2.8	2.8
Other Finfish	4.7	4.0	0.85
Crab	3.6	3.3	1.1
Shrimp	52.	22.	4.6
Other Shellfish	41.	41.	0.62

a/ In all cases pH should be 6 to 9.
b/ O + G = Oils and Greases.

CONTROL AND TREATMENT

22. Waste components of greatest concern are solids, oils and greases. The current treatment trends are toward the use of screening and air flotation, combined with effective in-plant measures, as the principal means of reducing overall waste loadings.

23. In addition to in-plant control measures, wastes from all fisheries production operations under proper conditions are amenable to biological treatment or discharge to municipal systems. With adequate operational controls, no materials harmful to municipal waste treatment processes need to be discharged.

24. Application of in-plant control techniques should be the first step in handling of wastes. Basic techniques available are minimizing water use, recovery of dissolved proteins in effluent solutions and recovery of solid portions for use as edible products.

25. Water-saving can be accomplished through reducing the use of flumes for in-plant transport of products. Dry handling of product or use of pneumatic ducts requires a small fraction of the water used by flumes. Spring-loaded nozzles, which automatically shut off when released by the user, should be utilized on butchering lines. Steam and water valves must be properly maintained to avoid leaks and prevent losses.

26. Fish, along with meat and fowl, are frequently categorized as "animal proteins" because they contain the high levels of amino acid required for good nutrition. Protein content will vary from 8 to 10 percent for oysters to over 25 percent for tuna. Several techniques are available for reclaiming protein from those portions not classified as "food products". Proteins can be recovered in wet form and made into high quality frozen products. Whole fish or waste fish parts can be converted to fish meal or flour for animal feed. Protein wastes can also be converted into a high grade flour for human consumption. Concentration and utilization of fish proteins as food additives is finding increasing use in developing countries. Salmon eggs, representing up to 5 percent of by weight of the fish and formerly discarded are now being recovered for caviar in a number of locations.

27. Seafood plants have previously been located near or over receiving waters considered to have had adequate waste assimilation capacity. Therefore, there was little or no application of waste treatment technology to this industry. Despite the fact that these wastes are generally biodegradable, they do not contain unacceptable levels of toxic substances, and are amenable to biological treatment in municipal systems under controlled conditions.

28. Screening is extensively employed, in various forms and degrees, for solids recovery. Solids so recovered have market value and, in addition, recovery eliminates their discharge into receiving waters and municipal sewers. Solids may also be removed by sedimentation basins.

29. If by-product recovery is not practical, proper disposal of solids must be considered. Where permitted and where land is available, private landfill may be a practical solution. Land application of unstabilized, putrescible solids as a nutrient source may be impractical because of nuisance conditions which could be created.

30. Another alternative is deep sea disposal. Such a method does not subject the marine environment to the potential hazards of toxic substances and pathogens normally associated with the dumping of human sewage sludges, municipal refuse, and industrial wastes. To minimize any detrimental effect on the marine environment, waste solids should be ground before disposal, should be discharged only to waters subject to strong tidal flushing action, and at depths of not less than 13 to 15 meters.

31. Wastewaters from which the solids have been separated may be subjected to either physical-chemical or biological treatment to further reduce organic levels in the water prior to final disposal.

32. The most promising physical-chemical techniques currently being investigated are chemical coagulation and air flotation. Economic considerations seriously limit current application of chemical oxidation, since the high cost of supplying chlorine and ozone, the two most promising oxidants, is a deterrent.

33. Air flotation, with addition of appropriate chemicals, is capable of removing high concentrations of solids, grease, oil and dissolved organics. Vacuum flotation, dispersed air flotation, and dissolved air flotation are systems most commonly applied at present. In using these methods it is important to add sufficient quantities of chemical coagulants to completely absorb the oils and greases present.

34. Most wastewaters have sufficient nutrients present to make them amenable to biological treatment. Activated sludge, high-rate trickling filters, ponds, lagoons, and land disposal may all be applied under proper conditions.

35. Selection of a treatment system requires analysis of total plant operation and application of techniques specific for wastes to be treated.

BIBLIOGRAPHY

1. U.S. Environmental Protection Agency "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Catfish, Crab, Shrimp, and Tuna Segment of the Canned and Preserved Seafood Processing Point Source Category". Doc. EPA-440/1-74-020-a. Washington (June 1974).
2. U.S. Environmental Protection Agency "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Fish Meal, Salmon, Bottom Fish, Clam, Oyster, Sardine, Scallop, Herring, and Abalone Segment of the Canned and Preserved Fish and Seafood Processing Industry Point Source Category". Doc. EPA-440/1-75/041-a, Group I, Phase II. Washington (September 1975).
3. "Best Conventional Pollutant Control Technology-Reasonableness of Existing Effluent Limitations Guidelines". Federal Register, Vol. 43, No. 164, pp. 37570-37607, and Vol. 43, No. 170, pp. 39062-39067. Washington (August 23 and August 31, 1978).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

FRUIT AND VEGETABLE PROCESSING

INDUSTRIAL WASTE DISPOSAL

1. Because of the wide variety of fruits and vegetables that are harvested and processed, in varying degrees, discussions of industrial operations covering each of the varieties for which effluent limitations are given below is beyond the scope of this document. Therefore, the discussions are limited to the processing of apples, citrus, potatoes and their various by-products. However, effluent limitations are included for many other fruits and vegetables normally processed in these plants.

INDUSTRIAL PROCESSES

2. Industrial operations covering apples, citrus fruits, and potatoes involve many of the procedures used in fruit and vegetable processing in general. The series of steps outlined below for each of these groups may not all occur at each plant. Therefore, it is necessary to have complete information on the final product to be prepared in order to assure proper application of the effluent limitations.

3. In addition to apples marketed directly for consumption, the fruit is used mainly for preparation of sauce, juice and frozen or canned slices. Other products, but in a lesser volume, include dehydrated apple pieces, special apple rings, spiced whole apples, and baked apples. Apple processing usually involves storage, washing and sorting, peeling and coring, slicing, chopping, extracting juice, dehydration, deaerating, and cooking.

4. Control of the temperatures and relative humidity of storage areas is critical for maintaining quality. Apples received from the field or storage must be washed to remove dirt and other residues, and then sorted to remove undersized, spoiled, or otherwise inferior fruit. Mechanical peeling is most commonly used, particularly where a sliced product is to be produced. The peal and core particles (along with inferior fruit) are used to make juice or vinegar stock. Steam and caustic peeling are also utilized. After slicing, the slices are deaerated in a brine solution, under vacuum. The final step is freezing and packaging or cooking and canning.

5. Oranges, grapefruit, lemons, tangerines (madrarins) and limes are the citrus fruits most frequently grown and harvested. The steps in the processing include: receiving, storage and washing (to remove foreign materials, pesticides, etc.); extraction of raw juice; finishing (to separate pips and membrane segments); and juice concentration. When segments are to be produced the fruit is mechanically peeled, subjected to caustic treatment to remove adhering membrane particles, and manually or mechanically segmented to produce sections. In many cases the peelings are further processed for recovery of citrus oil.

6. The principal forms manufactured by the potato processing industry are frozen products; chips; dehydrated potatoes; and canned, hash, stew, and soup products. The quality of the raw potatoes and the types of manufacturing process are the two principal factors in determining the quantity and characteristics of the waste generated. Ideally, the most suitable potatoes should have a high solids content, low content of reducing sugars, thin peels, and uniform size and shape.

7. The bulk of the potato intake is placed in storage by the processor in order to provide adequate quantities of raw material for year-round operation. Storage facilities require high humidity levels to prevent shrinkage. From storage, the potatoes go to rotary drums or cylindrical washers to remove soil particles and other foreign materials. Next, these vegetables are peeled (using abrasion or rubber studded rolls, or other means). As part of the peeling process the potatoes are electronically inspected for eyes, blemishes, and remaining peel. These undesirable elements are then removed and the potatoes sliced or diced. Considerable starch may be released in the slicing and subsequent washing operation. The crude starch is recovered and shipped elsewhere for further refining.

8. After slicing or dicing, the pieces are blanched (using steam or hot water) prior to preparation of the final product.

SOURCES AND CHARACTERISTICS OF WASTES

9. Effluents from the fruit and vegetable processing industry can be both solid and liquid in nature, and the process waste streams are generally a mixture of the two. Gaseous effluents are minor or non-existent, and hence, will not be covered in this discussion. Odors related to anaerobic ponds, which are sometimes used for waste treatment, may be significant in individual situations.

10. The waste water parameters of major significance are the five-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and hydrogen-ion concentration (pH). Fecal coliforms may be of concern, although not generally found in wastewaters from this industry. To avoid problems in this regard, all sanitary wastes should be handled separately and should in no way come in contact with process wastewaters. This separation can be particularly critical in situations where in-plant reuse of process waters is practiced.

Table 1: Characteristics of Typical Waste Effluents -
Fruit and Vegetable Processing a/

Crop	Flow 1,000 gal/ton raw product b/			BOD lb/ton raw product c/			TSS lb/ton raw product c/		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
Apples	0.2	2.4	13	3.9	18	44	0.4	4.5	21
Apricots	2.5	5.6	14	18	40	80	5	9.9	19
Asparagus	1.9	8.5	29	0.9	4.9	22	4.3	7.5	13
Dry beans	2.5	8.8	33	15	60	182	2.6	43	99
Lima beans	2.4	7.7	22	9.3	48	175	4.6	39	231
Snap beans	1.3	4.2	11.2	1.6	15	81	0.8	6.1	46
Beets	0.3	2.7	6.7	28	53	127	7.3	22	64
Broccoli	4.1	9.2	21	5.8	20	61	4.8	17	61
Brussels sprouts	5.7	8.2	12	4.2	7.5	14	2.9	15	79
Berries	1.8	3.5	9.1	11	19	40	1.4	7.1	22
Carrots	1.2	3.3	7.1	17	30	53	4.5	17	53
Cauliflower	12	17	24	5.5	16	36	2.8	7.8	22
Cherries	1.2	3.9	14	21	38	78	1.0	2.0	3.8
Citrus	0.3	3.0	9.3	0.9	9.6	26	0.7	3.7	14
Corn	0.4	1.8	7.6	12	27	64	3.6	10	27
Grapes	0.6	1.5	5.1	6.4	9.0	13	1.5	1.7	2.0
Mushrooms	1.8	7.8	28	7.7	15	28	5.1	7.3	12
Olives	—	8.1	—	—	27	—	—	27	—
Onions	2.5	5.5	10	57	57	58	5.3	17	55
Peaches	1.4	3.0	6.3	17	35	70	3.4	8.6	21
Pears	1.6	3.6	7.7	19	50	126	3.6	12	33
Peas	1.9	5.4	14	16	38	87	3.8	11	38
Peppers	0.9	4.6	16	5	32	50	1	58	170
Pickles	1.4	3.5	11	26	42	75	3.0	8.2	23
Pimentos	5.8	6.9	8.2	39	55	76	4.1	5.8	8.1
Pineapples	2.6	2.7	3.8	13	25	45	5.2	9.1	17
Plums	0.6	2.3	8.7	6.5	10	14	0.6	2.1	4.3
Potato chips	1.2	1.6	2.2	17	25	38	22	32	48
Potatoes, sweet	0.4	2.2	9.7	39	93	217	40	57	117
Potatoes, white	1.9	3.6	6.6	42	84	167	39	128	423
Pumpkin	0.4	2.9	11	9.2	32	87	2	67	12
Sauerkraut	0.5	0.9	3.0	4.6	5.6	15	—	1.0	2.6
Spinach	3.2	8.8	23	5.7	14	31	1.8	6.1	21
Squash	1.1	6.0	22	—	20	—	—	14	—
Tomatoes, peeled	1.3	2.2	3.7	6.3	9.3	14	5.8	12	26
Tomatoes, product	1.1	1.6	2.4	2.2	4.7	9.7	5.6	10	19
Turnips	2.4	7.3	18	—	—	—	—	—	—

a/ From suggested Reference No. 5

b/ Multiply by 4.17 to convert to liters/megagram

c/ Multiply by 0.500 to convert to kg/megagram

1 Mg = 1 megagram = 1 metric ton

11. Water is extensively used in all phases of industry, principally as (b) a cleaning agent to remove dirt and other foreign material; (a) a heat transfer medium for heating and cooling; (c) a solvent for removal of undesirable ingredients from the product; (d) a carrier for the incorporation of additives into the product; and (e) a method of transporting and handling the product.

12. Wastewaters from the processing of individual products are common to the industry as a whole, and are made up mainly of biodegradable organic matter. Although the procedures used in processing the various commodities have many aspects in common, there are variations which affect the quantity and strength of the effluents produced.

13. Wastewater characteristics will be affected by: (a) the condition of the raw fruit or vegetable (such as freshly picked versus stored); (b) the peeling method (caustic peeling produces higher BOD₅ and TSS than does mechanical peeling, for example; (c) water usage, including the extent of water transport; (d) age and efficiency of equipment; (e) the processing operations for the commodity being produced; and (f) in-plant measures and housekeeping practices.

14. Average flows and characteristics of waste effluents are presented in Table 1. The data covers both screened and unscreened effluents, which accounts for the wide variations between minimum and maximum values.

EFFLUENT LIMITATIONS

15. Effluent limitations for wastes originating from the fruit and vegetable processing industry are presented in Tables 2, 3, and 4, below.

Table 2. Liquid Effluent Limitations - Specialties a/.

Commodity	BOD ₅	TSS
	Kg/Mg Raw Product	
Baby Foods	0.84	1.15
Chips - Corn	1.14	2.12
Chips - Potato	1.68	3.03
Chips - Tortilla	1.66	3.02
Ethnic Foods	1.59	2.83
Jams/Jellies	0.19	0.34
Mayonnaise/Dress.	0.21	0.39
Soups	2.77 b/	4.93 b/
Tomato/Starch/Cheese	0.98	1.74
Vegetables - Dehy.	1.78	3.18

a/ For plants processing approximately 1000 to 5000 megagrams per Year.

b/ Represents Kg per megagrams raw ingredients.

Table 3. Liquid Effluent Limitations - Vegetable Processing a/.

Commodity	BOD ₅	TSS
	---	Kg/Mg Raw Product
Asparagus	0.28	0.50
Beans - Dry	1.40	2.51
Beans - Lima	1.75	3.12
Beans - Snap	1.05	1.86
Beets	0.68	1.24
Broccoli	1.89	3.34
Carrots	0.97	1.76
Cauliflower	2.36	4.17
Corn - Canned	0.45	0.84
Corn - Frozen	0.99	1.83
Mushrooms	1.19	2.12
Onions - Canned	1.72	3.14
Onions/Garlic - Dehyd	1.16	2.07
Peas	1.00	1.97
Pickles-Fresh Pack	0.64	1.14
Pickles - Process Pack	0.65	1.21
Pickles - Salt Stations	0.08	0.16
Pimentos	2.00	3.84
Potatoes - Sweet/White	0.52	1.09
Sauerkraut - Canned	0.26	0.47
Sauerkraut - Cutting	0.05	0.09
Spinach	1.18	2.08
Squash	0.30	0.53
Tomatoes	0.98	1.74

a/ For plants processing approximately 1000 to 5000 megagram per Year.

Table 4. Liquid Effluent Limitations - Fruit Products a/.

Commodity	BOD ₅	TSS
	Kg/ Mg Raw Product	
Apple Juice	0.20	0.20
Apple Products	0.20	0.20
Apricots	1.26	2.28
Caneberries	0.18	0.33
Cherries - Sweet	0.45	0.81
Cherries - Sour	1.10	2.01
Cherries - Brined	0.76	1.44
Citrus Products	0.14	0.20
Cranberries	0.62	1.12
Dried Fruit	0.72	1.34
Grape Juice - Canned	0.76	1.39
Grape Juice - Pressed	0.11	0.20
Olives	2.28	3.93
Peaches	0.75	1.40
Pears	0.86	1.58
Pineapples	1.48	2.60
Plums	0.28	0.50
Raisins	0.20	0.38
Strawberries	0.62	1.10

a/ For plants processing approximately 1000 to 5000 megram per Year.

16. In addition to the limitations given above, all effluents should maintain the MPN fecal coliform count below 400 per 100 mL and the pH at 6.0 to 9.5.

CONTROL AND TREATMENT

17. The wastes resulting from this industry are principally organic in nature. They are therefore amenable to biological treatment, either at the point of discharge or, with pretreatment, in a municipal sewage treatment system. In-plant procedures and housekeeping practices can be effective in reducing the waste load to be treated or discharged to municipal plants.

18. A fruit or vegetable processing plant is completely dependent upon a supply of good quality water. The increasing use of pesticides and other contaminants requires more effective washing following the harvesting process. The use of mechanical harvesting techniques results in increased quantities of soil and dirt pickup and consequently requires more extensive washing. It has been demonstrated that when washing is done at a site removed from the processing facility (such as adjacent to the harvesting area) total plant water usage can be reduced by as much as 8 to 10 percent.

19. Where peeling is necessary, mechanical means are usually employed, using either caustic or steam. Water sprays or rubber abrading are the two principal methods of removing the peel. The use of the rubber abrading technique can reduce the total waste flow, BOD₅, and TSS by as much as 50 percent.

20. Water used in the sorting, trimming, and grading operation can be recirculated for a given period of time. Since it comes into contact with the interior of the fruit or vegetable there is a tendency to build up the concentration of soluble and suspended solids. When these solids reach the point where the water must be replaced, the contaminated water can be further concentrated by evaporation and used as vinegar stock.

21. Wastewater volumes can be reduced by substituting other methods (screw conveyors, air propulsion, pump transport, etc.) in place of fluming to convey the products through the operation. The system substituted for fluming must be adapted to the product and the processing on an individual basis. Other operations which should be carefully examined for economies in water use include the blanching, container cooling, and clean-up. Water recirculation, using cooling towers where necessary, can also be effective in reducing effluent volumes. Flow equalization through the use of storage tanks to reduce large fluctuations in volumes will reduce overall treatment needs.

22. It is currently the general practice in this industry to separate the solid waste from the liquid waste streams. This is usually done by physical means such as screening (stationary, rotary, or vibrating), plain sedimentation, hydroclones, or flotation. For operations producing significant volumes of french fried products, traps may be necessary to reduce oil and grease discharges.

23. Waste effluents are readily treatable by biological methods, after the major volume of the suspended solids have been removed by screening, sedimentation, or other primary treatment. Once this separation has been accomplished most of the biodegradable material is in the soluble form, and may be treated by such systems as activated sludge, trickling filters, lagoons (anaerobic or aerated), rotating biological contactors, and others.

24. Land application of these effluents has been successfully utilized. Its operation depends upon a number of factors, including: (a) infiltrative and percolative capacity of the soil; (b) clogging; (c) quality changes in the soil; (d) travel of the sprayed effluent to springs and streams or, through faults, to ground water supplies; (e) evaporation; and (f) transpiration through cover plant growth.

25. In evaluating the application of this method it is necessary to consider: (a) available land area; (b) soil characteristics; (c) available slope, to minimize ponding of water; (d) intervals required to rest the soil between applications; (e) nature and density of the cover crop; (f) and the characteristics of the wastes in terms of the components which may affect the soil mantle.

BIBLIOGRAPHY

1. Jones, H.R. "Waste Disposal Control in the Fruit and Vegetable Industry". Noyes Data Corporation, Park Ridge, N.J. and London. (1973).
2. Powers, P.W. "How To Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation, Park Ridge, N.J. and London (1976).
3. "Treatment of Industrial Effluents". Ed. by A.G. Callely, C.F. Forster, and D. A. Stafford. Halstead Press (John Wiley & Sons), New York (1976). pp.245-257.
4. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Apple, Citrus, and Potato Processing Segment of the Canned and Preserved Fruits and Vegetables Point Source Category". Doc. EPA-440/1-74-027-a. Washington (March 1974).
5. U.S. Environmental Protection Agency. "Pollution Abatement in the Fruit and Vegetable Industry" Doc. EPA-625/3-77-0007 (3 Volumes). Washington (July 1977).

THE WORLD BANK

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OFFICE OF ENVIRONMENTAL AFFAIRS

GEOOTHERMAL DEVELOPMENT

GUIDELINES

1. The environmental impact of geothermal development can be important and should be part of any World Bank study in this field.

2. The main points to consider are as follows:

- Direct physical effects on habitat
- Erosion
- Surface water effects
- Ground water effects
- Air pollution
- Noise
- Human presence

3. The project should take into consideration the survival and well being of the wildlife species including fish. This should be done from the exploration phase through the well-field development, the plant construction, the plant operation and finally, the field abandonment.

4. Erosion of the land can be caused by water, by wind or by stream channels. Pronounced erosion can result from minor disturbances of the land surface and/or the vegetation. Good planning, reasonable grading, and good construction regulations will prevent significant erosion.

5. Geothermal development will reduce some stream flows (construction period) or increase others. The quality of the surface water will probably be changed. Significant alterations of the hydrology or drainage routes should be avoided.

6. Changes in ground water level, quality and temperature will occur. These should be forecast to avoid any drastic impact. Reinjection should be considered especially if the effluent is highly polluted.

7. Although the air pollution should not be a major problem it should be considered in each phase especially if emission of radioactive vapors or vapor borne salts is possible.

8. Noise will be generated by several activities or pieces of equipment and could interfere with normal behavior of animals; breeding, rest, hibernation and migration patterns could be disrupted.

9. Human presence should not interfere to a great extent with wildlife. Precautions should be taken to keep vegetation growing and not to restrict wildlife movements.

BIBLIOGRAPHY

1. Impact Prediction Manual for Geothermal Development (FWS/OBS - 78/77) prepared for EPA and the U.S. Fish and Wildlife Service by Woodward-Clyde Consultants, Three Embarcadero Center, Suite 700, San Francisco, California 94111.
2. Geothermal Handbook, U.S. Fish and Wildlife Service 1976) (FWS/OBS - 76/36).
3. Site Specific Analysis of Geothermal Development. U.S. Department of Energy 1978 (ECP/T 4014-01/3).

THE WORLD BANK

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OFFICE OF ENVIRONMENTAL AFFAIRS

GLASS MANUFACTURING

EFFLUENT GUIDELINES

1. The glass manufacturing industry may be divided into a number of segments descriptive of the products from specific processes. However, based on the types of plants most frequently encountered in World Bank projects, this document will confine itself to those plants producing flat glass, pressed and blown glass (bottles).

MANUFACTURING PROCESSES

Flat Glass

2. Flat glass is produced by melting sand together with other inorganic ingredients and then forming the molten material into a flat sheet. The techniques most frequently used are the float, plate, sheet, and rolled processes. Although the raw materials and melting operations are basically the same, each process uses a different method for forming flat sheets from the molten glass.

3. In the float process the glass is drawn across a molten tin bath. In the plate process the rollers used to form the sheets will also control the initial thickness, with the final thickness being achieved by grinding and polishing. The glass is formed by a vertical drawing procedure in the sheet process. Texturizing rolls serve to impart surface textures in the rolled process. The primary glass sheets may be further fabricated into related products such as mirrors, coated products, automotive and architectural glass, windshields, and others.

4. The most common type of flat glass produced utilizes the soda-lime method. Generally, about one-half of each batch consists of sand (silica). Other major ingredients include soda ash ($Na_2 CO_3$), limestone ($Ca CO_3$), dolomite ($Mg CO_3$), and cullet. The cullet consists of the broken glass generated in the manufacturing or fabricating processes. This is recycled with the raw materials to improve the melting qualities of the batch.

5. The manufacturing steps include (a) batching — mixing of raw materials; (b) melting; (c) forming — to effect dimensional control and surface texture, based on applying sheet, plate, rolled or float processes; (d) annealing — to remove internal stresses; (e) grinding and polishing — to achieve flat and parallel surfaces; (f) washing; and (g) cooling.

Pressed and Blown Glass

6. The pressed and blown glassware category covers the manufacture of glass containers, machine pressed and blown glass, glass tubing, television picture tubes, envelopes, incandescent lamp envelopes, and hand pressed and blown glass products.

7. The soda-lime process is most commonly used for pressed and blown glass production, but the composition differs from that used in the flat glass category. Sand comprises about 70 percent of the batch. Soda or soda ash comprise 13 to 16 percent, with the remainder made up of cullet. Soda and, sometimes, small quantities of potassium oxide are added as fluxing agents. Calcium oxide (lime) and small amounts of aluminum and magnesium oxides are added to improve chemical durability. Iron and other materials may be added as coloring agents.

8. The manufacturing consists of (a) raw material storage and mixing; (b) melting; (c) forming -- including blowing, pressing, drawing, and casting; (d) cullet quenching; (e) annealing; and (f) finishing. The steps will vary from plant to plant, depending upon the final product.

SOURCES AND CHARACTERISTICS OF WASTES

9. Process wastewaters are considered to be those which have come into direct contact with the glass, mainly including such sources as washing, quenching, grinding, and polishing. No process wastes are produced in the manufacture of sheet and rolled glass. Water is added to the raw materials for dust suppression, but the water is evaporated and discharged as a vapor.

Air Emissions

10. Although there are numerous unit operations used in glass manufacturing, most of the key processing steps responsible for generating the bulk of atmospheric emissions are common throughout the industry.

11. Emissions from raw material handling and storage are generally due to solid particles becoming airborne when materials are moved to storage, upon receipt at the plant or when they are moved from storage to the process. In the glass melting operation pollutants arise from two sources: combustion of fuel and vaporization of raw materials. Pollutants frequently encountered include NO_x, SO_x, CO, and hydrocarbons, depending upon the fuel utilized. It has been estimated, for example, that a fuel oil containing 1 percent sulfur by weight will yield approximately 600 mg/L of SO₂ in the flue gas.

12. The second source of air pollutants from the melting process results from the vaporization of raw materials in the glass melt. This consists mainly of particulates which are vaporized from the molten glass surface and condense at lower temperatures in the furnace checkerworks or in the stack. The chemical composition of the particulates will depend upon the particular formulation used. Emission levels for uncontrolled glass melting furnaces are given in Table 1.

13. Based on current information, gaseous emissions from the final steps of glassmaking, normally referred to as "forming and finishing" operations, are generally not significant enough to be of concern.

TABLE I - Typical Gaseous Emission Levels from Uncontrolled Glass Melting Furnaces a/

Emission	Plant Type	Flat Glass	Con-tainer Glass	Pressed & Blown	
				Soda - Lime	Non-Soda-Lime
Gms/Kg Glass pulled from furnace					
Nitrogen Oxides	4.0	2.3	4.2	—	—
Particulates	1.5	1.2	1.2	5	—
Sulfur Oxides	1.5	1.4	2.7	3.0	—
Carbon Monoxide	0.02	0.08	0.10	—	—
Hydrocarbons	0.04	0.07	0.15	—	—
Fluorides	—	—	—	10	—
Selenium	—	0.002	—	—	—

a/ From Reference (6).

Liquid Effluents

14. Pretreatment of water supplies is required in some cases, depending upon raw water quality and intended water use. However, information on effluent characteristics of these auxiliary wastes is not readily available. Because practices vary considerably each case should receive separate study and consideration to determine the impact on overall waste discharges.

15. For the plate glass category significant pollution results from the production of plate glass, solid tempered automotive glass, and windshield fabrication. The major parameters of pollutional significance include suspended solids, oil, hydrogen-ion concentration, pH, 5-day biochemical oxygen demand (BOD_5), total phosphorous, and temperature. Typical increases in concentrations of these parameters over process influent water levels are presented in Table 2.

TABLE 2 - Increase in Concentrations Over Levels in Process Influent Waters for Flat Glass Plants (a)

Parameter	Plate Glass	Float Glass	Solid Temp Auto	Wind-Shield Fabric (b)
Flow (c)	45,900 (d)	138 (d)	49 (e)	175 (e)
Susp. Solids -mg/L	15,000	15	100	25
Oil -mg/L	Trace	5	13	1,700
COD -mg/L	100	15	25	1,700
BOD ₅ -mg/L	—	2	15	33
Total Phosph -mg/L	0	0	0	5
Dis: Solids -mg/L	175	100	100	Low
pH (f)	9	8	7	7 - 8
Temperature -°C	2.8	(g)	8	19

- (a) No significant process wastewater discharges from rolled and sheet glass operations.
- (b) Typical process waters from fabrication of windshields using oil autoclaves.
- (c) Process water only, exclusive of cooling water.
- (d) Liters per Metric Ton of production.
- (e) Liters per square meter of area on one side.
- (f) Represent absolute values.
- (g) Moderate increase.

16. In glass container manufacturing the process water is used for cullet quenching and non-contact cooling of batch feeders, melting furnaces, forming machines and other auxiliary equipment. Wastewater characteristics which should receive attention include flow, biochemical oxygen demand (BOD), total chemical oxygen demand (COD), total suspended solids (TSS), and oil. Typical increases in these parameters over and above the levels found in the incoming process water, are given in Table 3.

TABLE 3 - Increase in Concentrations Over Levels in Process
Influent Waters for Glass Container and Machine Pressed
Glass Plants.

Parameter	Glass Containers	Machine Pressed & Blown
Flow-Liters/Met. Ton ^(a)	1540	2920
Temperature - °C.	6	8
pH ^(b)	7.5	7.8
BOD - mg/L (5-day, 20°C)	5	5
COD - mg/L	50	50
Susp. Solids - mg/L	24	25
Oil - mg/L	10	10

(a) Process water only, exclusive of cooling water.

(b) Represent absolute values.

17. In machine pressed and blown glass manufacturing the raw materials are first melted and then formed (by use of presses, or other techniques) into tableware, lenses, reflectors, headlamp parts, and other similar items. Water is used principally for non-contact cooling and gullet quenching. Wastewater characteristics which may be of significance include flow, temperature, hydrogen-ion concentration (pH), 5-day biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), total suspended solids (TSS), and oil. The loadings of these pollutants added to the incoming process waters during the production process are also presented in Table 3.

18. Wastewaters in the hand pressed and blown glass industry originate almost entirely in the finishing steps. The finishing steps which require water and hence will produce wastewater discharges include (a) crackoff and

polishing; (b) grinding and polishing; (c) machine cutting; (d) alkali washing; (e) acid polishing; and (f) acid etching. Some plants may utilize only one or two of these steps while other plants may employ several or all of the processes. Some handmade glass plants also use machine forming presses.

19. Waste water parameters which should be considered include flows, total suspended solids (TSS), fluorides (F), lead (Pb), hydrogen-ion concentration (pH), and temperature. The increases in these parameters in the incoming process waters are shown in Table 4.

TABLE 4 - Increase in Concentrations Over Levels in Process Influent Waters for Hand Blown and Pressed Glass Plants.

Process Parameter	Flow L/MT (a)	Temp °C.	pH (b)	TSS	F	Pb
				Mg/Liter		
Crackoff/Polish.	9,920	2.8	3.2	36	194	0.96
Grinding/Polish.	3,460	2.8	—	4350	—	0.43
Machine Cutting	10,880	1.6	10.0	2580	—	100. —
Alkali Washing	4,795	57	11.2	17	—	—
Acid Polishing	5,380	46	2.2	220	1980	31
Acid Etching	36,530	33	4.0	8	462	7.9

(a) Process water only, exclusive of cooling waters.

(b) Represent absolute values.

Solid Wastes

20. There are no significant solid waste disposal problems associated with the basic glass production process. The waste or broken glass, called cullet, is normally segregated and added to the raw material batches, as already discussed above. Some sludges and other solids will result from systems treating glass industry wastes.

EFFLUENT LIMITATIONS

21. Ambient air quality at ground levels in the vicinity of glass manufacturing plants should be maintained at or below the concentrations given in Table 5. These concentrations should be considered as World Bank guidelines.

TABLE 5 - Allowable Ambient Air Quality Concentrations at Ground Level.

Pollutant	Averaging Time	Allowable Concentrations
Nitrogen Dioxide	Ann. Arith.	100 $\mu\text{g}/\text{m}^3$
Particulates	Ann. Geom.	75 $\mu\text{g}/\text{m}^3$
Sulfur Oxides	(a)	(a)
Sulfur Oxides	(a)	(a)
Carbon Monoxide	8-Hour	10 mg/m^3
Carbon Monoxide	1-Hour	40 mg/m^3
Hydrocarbons	3-Hour	160 $\mu\text{g}/\text{m}^3$

(a) Inside plant fence
Ann. Arith. mean: 100 $\mu\text{g}/\text{m}^3$
Max. 24-hr. peak: 1000 $\mu\text{g}/\text{m}^3$

Outside plant fence
Ann. Arith mean: 100 $\mu\text{g}/\text{m}^3$
Max. 24-hr. peak 500 $\mu\text{g}/\text{m}^3$

22. Effluent limitations for glass plants, based on the application of currently available technology are shown in Tables 6 and 7. These Tables should be considered as World Bank guidelines.

TABLE 6 - Effluent Limitations for Wastewater Discharges from Flat Glass Plants (a)

Parameter	Plate Glass (b)	Float Glass (c)	Solid Temp. Autom. (d)	Wind-Shield Fabric. (d)
pH	6 - 9	6 - 9	6 - 9	6 - 9
Total Susp. Solids	2.76	2.0	1.95	4.4
Oil	—	0.7	0.64	1.76
COD	0.90	2.0	—	4.9
BOD (5-day, 20°C)	—	—	0.73	—
Total Phosph.	—	0.05	—	0.98

(a) No wastewater discharges from sheet and rolled glass plants.

(b) Kg/Metric Ton.

(c) gm/Metric Ton.

(d) gm/Square meter of area on one side.

TABLE 7 - Effluent Limitations for Wastewater Discharges from Container and Blown/Pressed Glass Plants.

Parameter Process	Oil (a)	Susp. Solids (a)	pH	Fluo- ride (b)	Lead (b)
Glass Containers	30	70	6 - 9	—	—
Mach. Blown/Press	—	—	—	—	—
Hand Blown/Press (c)	—	—	—	—	—
-Leaded & HF Ac Fin.	—	10	6 - 9	13	0.1
-Non Lead. HF Ac Fin.	—	10	6 - 9	13	—
-Non HF Ac. Fin	—	10	6 - 9	—	—

(a) Average daily values for 30 consecutive days as g/Metric Ton Furnace pull.

(b) Average of daily values for 30 consecutive days as mg/Liter.

(c) For plants which melt raw materials, discharge over 190 liters per day and produce type of glassware shown.

WASTE CONTROL AND TREATMENT

Gaseous Emissions

23. For control of particulates from raw materials handling operations, it is the general practice to enclose the unloading and conveying areas and to vent through fabric filters. The chemical composition of the fugitive dusts will be the same as the raw materials, since no chemical reactions occur during storage and handling.
24. Control of gaseous emissions arising from fuel sources can be controlled by changing to fuels having a lower content of certain pollutants, such as sulfur. Electric "boosting" also has been effective for this purpose. In this technique electric current is dissipated through the molten glass, supplying part of the required heat and reducing the amount of fossil fuels needed to maintain proper melting temperatures. Boosting is most commonly used in container glass plants. All-electric melters, which have been developed primarily to improve melting efficiency and product control, have resulted in lowering gaseous emissions from the melting operation. Construction is less expensive for all-electric melters as compared to that for fossil fuel furnaces.
25. Several process modifications can be used to lower emissions. These include (a) reducing the amounts of materials in the fuel, which vaporize at furnace temperatures; (b) increasing the fraction of recycled glass in the furnace fuels; (c) installing sensing and control equipment on the furnace; (d) modifying the burner design and firing patterns; and (e) utilizing electric boosting, as discussed above.
26. Particulates in the glass melting furnace exhaust can be collected by discharging through fabric filters. Fabric filter systems have the advantage of high collection efficiency, low pressure drop across the system and low energy requirements. Venturi (wet) scrubbers and electrostatic precipitators are also used for removal of particulates.
27. Sulfur oxides are the gases of principal concern in melting furnace exhausts. It has been demonstrated that wet scrubbers provide good control for both sulfur oxides and particulates. Electrostatic precipitators will remove varying amounts of these pollutants. It has been reported that treating the exhaust streams with an alkaline spray converts gaseous sulfur oxides to solids which can then be collected as particulates. Fluorides, where present, are reduced by electric boosting. Electrostatic precipitators have proven effective in capturing arsenic in the particulate form.

Liquid Wastes

28. The major constituents requiring treatment in wastewaters from primary flat glass and automotive glass fabrication are suspended solids and oil. In all cases, in-plant modifications should receive first consideration. No process wastewaters are produced by the sheet and rolled glass subcategories, since these are essentially dry operations and water is used only for dust

control in each batch.

29. For plate glass manufacturing plants, lagoon treatment with the addition of polyelectrolyte to the incoming wastewater, has resulted in very high suspended solids removals. System efficiency can be improved in various ways such as by using a two-stage lagoon arrangement, applying sand filtration to the lagoon effluent, recycling of effluents for other plant uses, and other similar techniques.

30. Phosphorous is the pollutant of principal concern in float glass manufacturing, when detergents are used. Wastewater phosphorous loadings can be eliminated by discontinuing the detergent wash. All effluent discharges can be eliminated by recycling the washwater to the batch and cooling tower. Dissolved solids removal may be required if the water is recycled for washing.

31. Suspended solids and oils are most commonly removed by coagulation-sedimentation and filtration at plants producing solid tempered automobile window glass. A solids contact coagulation-sedimentation system, with sludge dewatering by centrifuge, is employed. A further decrease in suspended solids and oil can be accomplished by filtering the settled effluent through a diatomaceous earth filter containing a medium especially treated for oil removal. These measures will also effect a reduction in BOD and COD levels.

32. Oil is the major contaminant which must be removed from windshield lamination wastewaters. Most of the oil can be removed by centrifuging, plain flotation using an American Petroleum Institute (API) separator, or by dissolved air flotation. Suspended solids and residual oil can be removed by filtration through oil absorptive media.

33. The pollutants of principals concern in the pressed and blown glass industry are oil, fluoride, ammonia, lead and suspended solids. In current practice oil is reduced by using gravity separators such as belt skimmers and API separators. Treatment for removal of fluoride and lead is accomplished by the addition of lime, rapid mixing, flocculation, and sedimentation of the remelting reaction products. Treatment for ammonia removal is presently not practiced in this industry. Ammonia removal by stream stripping can be used for control of high ammonia discharges. It has been reported that several plants are able to recycle non-contact and cullet quench waters.

Solid Wastes

34. Control systems for air pollution control will generate solids. These presently have little or no economic value and are not considered to be an attractive source of chemicals. Generally, these solids are best disposed of by recycling back into the glass melting process or through landfilling.

35. Treatment of liquid wastes results in the production of various solids, such as sludges and spent diatomaceous earth. These should be dewatered to the degree feasible and then disposed of to landfill. The lagoons used for suspended solids removal can also serve as solids disposal sites in some cases.

BIBLIOGRAPHY

1. "Information Sources on the Glass Industry". UNIDO Guides to Information Sources-No. 16. United Nations. New York (1975).
2. United Nations Industrial Development Organization. "Glass and Glass Making". United Nations. New York (1977).
3. The World Bank "Environmental Considerations for the Industrial Development Sector". Washington (August 1978).
4. U.S. Environmental Protection Agency. "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Flat Glass Segment of the Glass Manufacturing Point Source Category". Doc. EPA 440/1-73/001-a. Washington (October 1973).
5. U.S. Environmental Protection Agency. "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Pressed and Blown Glass Segment of the Glass Manufacturing Point Source Category". Doc. EPA 440/1-75/034-a, Group I, Phase II. Washington (January 1975).
6. U.S. Environmental Protection Agency. "Glass Manufacturing Plants. Background Information: Proposed Standards of Performance". Doc. EPA 450/3-79-005-a. Washington (June 1979).

THE WORLD BANK

MARCH 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

EFFLUENT GUIDELINES

IRON AND STEEL INDUSTRY

GENERAL CONSIDERATIONS

1. Iron and steel production utilizes a highly complex system, in which raw materials consisting of iron ore, coke, and limestone are converted through a series of processes into steel of various compositions, sizes, and shapes as required by market demands.
2. Basically the conversion process may be broken down into five major segments: (a) ore preparation, sintering, and pelletizing; (b) coke production; (c) blast furnace operations (pig iron production); (d) steel production; and (e) rolling and finishing operations.
3. For each of these segments a document has been prepared to cover the manufacturing process, waste sources and characteristics, effluent limitations based on the best practicable treatment technology currently available, and control and treatment of wastes.
4. This document presents a broad simplified summary of the processes carried out in an integrated iron and steel plant, as well as a discussion of noise considerations, sampling and analytical aspects. These are applicable to all segments of the industry, and hence are included in this general section. Figure 1 presents a process flow diagram for the iron and steel industry.

THE INDUSTRY

5. Iron-bearing materials consisting primarily of iron oxides, to which coke and limestone have been added, are reduced to molten iron (pig iron) in a blast furnace. The iron absorbs carbon from the coke in this step and results in cast iron, containing 3 to 4 percent carbon. Since modern steel contains less than 1 percent of carbon, the excess carbon must be removed to convert the cast iron into steel.
6. This removal is accomplished through controlled oxidation of mixtures of molten pig iron, melted iron, and steel scrap in steelmaking furnaces to produce carbon steels. Various elements (such as chromium, manganese, and molybdenum, alone or in combination) may be added to the molten steel to produce alloy steels.

7. The molten steel, after reaching the desired composition, is poured into molds where it solidifies to form ingots. After removal from the molds the ingots are reheated to a uniform temperature and rolled into shapes known as blooms, billets, and slabs. These shapes are referred to as semifinished steel.

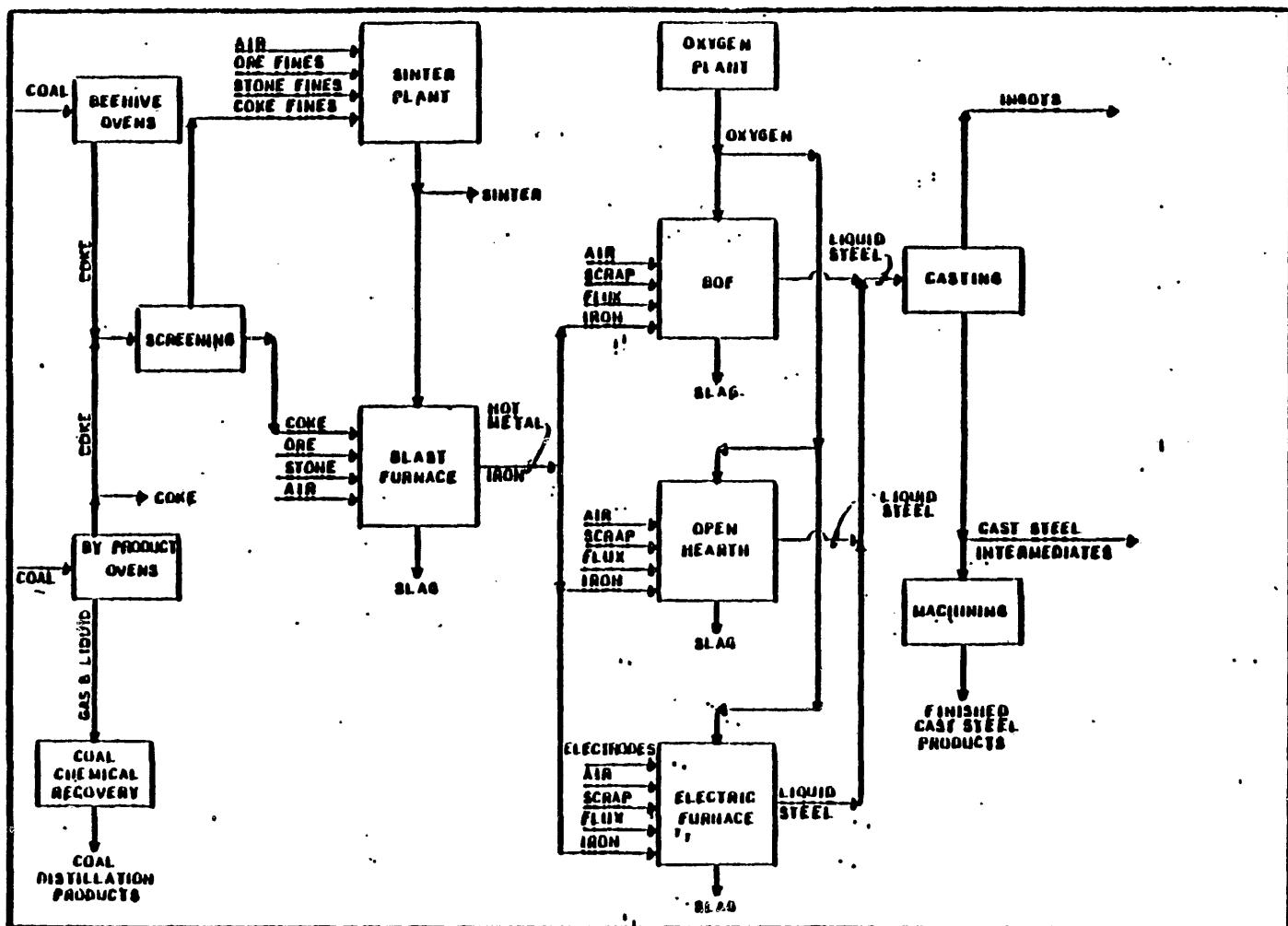


Fig. 1 -- Process Flow Diagram - Iron and Steel Industry (From U.S. EPA Doc. 440/1-79/024a, Vol. I, Oct. 1979)

8. The semifinished steel is then further processed in one or more of several ways such as hot rolling, cold rolling, forging, extruding, drawing, or other means to produce the finished products needed to fill market demands. Bars, plates, structural shapes, rails, wire, tubular shapes, and coated products are among the forms most frequently produced.

NOISE

9. In a typical integrated iron and steel works, noise results from (a) production and processing operations; (b) handling and transport of raw materials, semi-finished and finished products; and (c) aerodynamic and hydrodynamic sources. Efforts to limit noise in steelworks should be aimed at lowering exposure to noise in the working environment to an acceptable level and removing noise problems in nearby residential areas. These two are frequently complementary with the solution to the in-works problem often providing a suitable answer to the community situation. As a general rule, the problem should be resolved as close to the source as possible in order to assure best results.

10. Typical peak noise levels are as follows:

Production and Processing Operations

Ore crushing, 5 meter distance	98 dBA (continuous)
Loading scrap pans, 25 meter distance	105 dBA (intermittent)
Electric arc furnace (melt down period) 6 meter distance	109 dBA (semi-continuous)

Handling and Transport of Raw Materials, Semi-finished and Finished Products

Conveyor discharge point, 5 meter distance	85 dBA (continuous)
Slab mill roller tables, 5 meter distance	95 dBA (intermittent)

Aerodynamic and Hydrodynamic Sources:

Valves and dampers, blast furnace cold blast, 1 meter distance	96 dBA (continuous)
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Blast furnace hot stove operation, 10 meter distance	91 dBA (continuous)
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11. A number of measures may be taken to reduce noise levels, in addition to maximum possible reduction at the source. Quieter machines can be substituted, and where this is not possible the noise area should be isolated and acoustically sealed. To protect neighborhoods it may be necessary to acoustically treat entire buildings. Noise controls should be incorporated in the design of new plants or units.

12. Conveyor belts and systems, in place of road or railway haulings, will greatly reduce noise emissions. Emissions in the handling and transfer of semi-finished or finished products can be offensive. Rolling mill finishing departments, for example, represent a major source. For light products the handling equipment can be modified for control purposes, but this is not always possible for the larger and heavier products. The shape, weight, speed of transport, and similar aspects should receive consideration.

13. As production units increase in size, the quantities of process and by-product gases and liquid which must be transported will also increase. Aerodynamic and hydrodynamic noises originate in the integrated collection and distribution systems used to handle these materials. Noises are caused by turbulence (due to high velocities) and pressure fluctuations. Levels can be decreased by careful piping design, covering pipes with layers of insulation, isolating and correcting vibration sources, using low noise valves and ventilators, and other similar measures. Noise barriers, screens, and earth mounds are also effective in reducing noise in many cases.

14. To avoid possible hearing damage weighted sound levels per 24-hour period should be kept below 70 dBA with a maximum of 90 dBA. (See "Noise" Guideline, Office of Environmental Affairs, The World Bank, January 1979).

SAMPLING AND ANALYTICAL PROCEDURES

15. A major element of any program for management of the environment is the basic information on the source, nature, levels, and the concentrations resulting in the medium to which discharged, following mixing and adsorption.

Air Pollution

16. There are two general applications in monitoring air contaminants-emission source testing and atmospheric monitoring. In both cases the location of monitoring devices, the type of equipment, the duration of sampling, and pollutant discrimination are of paramount importance in quantitatively appraising air quality. Furthermore, these considerations require an intimate knowledge of the emission source(s), background pollution, meteorology and topography of the area under study, and other pertinent factors.

17. Source testing requires a relatively elaborate set of measurements to establish a starting or final contaminant condition. Because industrial processes involve frequent cyclic changes, the timing of source testing or monitoring must be planned accordingly. Process operations should be carefully reviewed so that individual polluting substances and classes of pollutants can be identified. Fluctuations of peak loadings must be determined and thus predictions of process peculiarities, such as equipment-caused effluent and temperature variations, are possible. All the variables of source testing must be accounted for so that the final pollutant analysis will be representative of the entire source process. A review of the various combinations of devices and techniques and their inherent limitations in current literature is required. This will assure the application of the optimum sampling method for a general range of factors, such as greatest reliability, minimum cost, minimization of

required personnel skills, ease of access and duration of sampling for each specific sampling situation.

18. Monitoring of the atmosphere requires the establishment of an air monitoring network to supply the aerometric data necessary to support air pollution prevention, control and abatement activities. At the same time, it should consume the minimum amount of financial and manpower resources. The first step in establishing an air monitoring network is to determine the use of the aerometric data, collection devices available, the limitations of the sampling procedures and equipment, what pollutants must be monitored, location of pollutant monitors, and the duration of monitoring. The very nature of the air pollution problem varies widely from area to area, depending upon the peculiarities of meteorology, topography, source characteristics, and legal and administrative situations.

19. The decision as to which pollutants must be monitored depends on the data needs as defined by the source inventory. In most cases, it is necessary to set priorities because of resource limitations. Pollutants to be monitored should be selected on the basis of their (a) representing a definite hazard; (b) possibility of becoming hazardous to the public health and welfare at some time in the near future; and (c) being controlled by existing or proposed standards.

20. Generally, the methods of analysis for sootfall, dustfall, suspended particulate matter, gaseous pollutants and organic pollutants fall within the chemical, physical or biological category. Among the physical methods are spectrophotometry, thermal conductivity, chromatographic analysis, mass spectrometry, and gravimetric methods. Biological methods are applied in the preparation of bacterial cultures of organic contaminants and monitoring of respiration rate to correlate with quantities of organic pollutants. There are many variations to these methods. The most recent literature should be carefully reviewed and evaluated for application to the problem at hand.

Water Pollution

21. The composition of industrial wastewaters varies widely, and no truly satisfactory classification system has yet been devised. Hence, the importance of industrial wastewater monitoring cannot be overstressed. Flows are measured to determine the quantity of wastewater being discharged. The combination of flow rate data with analytical data obtained from laboratory analysis permits the calculation of weight of contaminants being discharged into the receiving stream. The next logical step after the amount of contaminants is known is to determine what effect these contaminants have on the receiving body of water and then finally establish some acceptable level of contaminant discharge. Monitoring of wastewater also facilitates locating major sources of wastes.

22. The location of a sampling station should be selected such that the flow conditions will have achieved, as closely as possible, a homogenous mixture. The velocity of flow at the sampling point should, at all times, be sufficient to prevent the deposition of solids, thus assuring the collection of a well mixed representative sample. Homogenous flow conditions normally exist after channeling all flow at a weir, Parshall flume or hydraulic pump. A free-falling discharge from a pipe is also an excellent sampling location. A sampling point

of approximately one-third the wastewater depth from the bottom and as near to the center of flow as possible is recommended for monitoring flows in sewers and channels. Types of equipment for the monitoring of industrial wastewater contaminants vary from manual to automatic type devices. The selection of the appropriate sampling equipment is dependent mainly upon the type of sample desired, either "grab" or "composite".

23. The quantity of sample to be collected varies with the extent of laboratory analysis to be performed. A sample volume between two and three liters is normally sufficient for a fairly complete analysis. The total number of samples will depend upon the objectives of the monitoring program. The use of a few strategic locations and enough samples to define the results in terms of statistical significance is usually much more reliable than using many stations with only a few samples from each.

24. Techniques and methods for the qualitative analysis of wastewater contaminants may be divided into four basic categories: chemical, physical, biological and biochemical. Detailed procedures are found in the literature, and should be carefully reviewed for application to the problem at hand.

Solid Wastes

25. The production and composition of solid waste has changed substantially in recent years because of changing patterns of living, population shifts, and other reasons. Where once solid wastes were mostly domestic, they are now produced in substantial quantities by industry as well. Solid wastes from industry may pose special problems such as nondegradability (plastics) and toxicity (chemical residues). Because of the increased importance of solid wastes from the industrial sector, monitoring and analytical methods have been developed for control purposes.

26. The environmental and other impacts on the land disposal site and its environs should be monitored and complete records maintained at all times. Data to be kept for each disposal site should include:

- Quantitative measurements of the solid wastes handled;
- Description of solid waste materials received, identified by source of material;
- Major operational problems, complaints or difficulties;
- Vector (a carrier that is capable of transmitting a pathogen from one organism to another) control efforts;
- Dust and litter control efforts; and
- Quantitative and qualitative evaluation of the environmental impact of the land disposal site with regard to the effectiveness of gas and leachate control, including data from leachate sampling and analyses, gas sampling and analyses, ground and surface water quality sampling and analyses upstream and downstream of the site.

27. Upon complete filling of the site, a detailed description (including a plan) should be recorded with the area's land recording authority. The description should include general types and location of wastes, depth of fill, and other information of interest to potential future users or owners of the land.

28. Special attention should be given to the disposal of hazardous materials to landfill areas. Because it is sometimes difficult to classify wastes as hazardous or non-hazardous a rough classification may be made by evaluating each one in terms of (a) human toxicity, (b) groundwater contamination potential, (c) disease transmission potential, and (d) biodegradability.

BIBLIOGRAPHY

1. "Environmental Control in the Iron and Steel Industry," International Iron and Steel Institute, Brussels (1978).
2. "The Making, Shaping and Treating of Steel," Ed. by H.E. McGannou. Ninth Edition. United States Steel Corporation, Pittsburgh (1971).
3. Russel, C.S. and Vaughn, W.J. "Steel Production: Processes, Products and Residuals." Resources for the Future. The Johns Hopkins University Press, Baltimore and London (1976).
4. United Nations Development Organization, Development and Transfer of Technology Series No. 11 "Technological Profiles of the Iron and Steel Industry." United Nations, New York (1978).
5. U.S. Environmental Protection Agency "Draft Development Documents for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Industry." Doc. EPA 440/1-79/024a. Washington. (October 1979), as follows:

- Vol. I - General
- Vol. II - By-product Coke Making and Beehive Coke Making Subcategories
- Vol. III - Sintering and Blast Furnace Subcategories
- Vol. IV - Basic Oxygen Furnace and Open Hearth Furnace Subcategories.
- Vol. V - Electric Arc Furnace, Degassing, and Continuous Casting Subcategories.
- Vol. VII - Pipe and Tube and Cold Rolling Subcategories.
- Vol. VIII - Sulfuric Acid Pickling, Hydrochloric Acid Pickling, and Combination Acid Pickling Subcategory.

6. U.S. Environmental Protection Agency. "Water Quality Criteria." Doc. EPA-R3-73-033, Washington (March 1973).

7. Jarrault, P. "Limitation des Emissions de Polluants et Qualite de L'Air - Valeurs Reglementaires dans les Principaux Pays Industrialises." Institut Francais de l'Energie. Paris (1978).
8. U. S. Federal Register. "Interim Effluent Limitations and Guidelines, and Proposed Performance and Pretreatment Standards - Electroplating Point Source Category." V.40 No. 80. Washington (April 24, 1975).
9. U. S. Environmental Protection Agency "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulates, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds." Doc. EPA-450/3-79-024, Washington (April 1979).
10. J. M. Campbell, R. R. Willis "Protection Against Noise," J. Iron and Steel Institute, Vol. 211, Pt. 5, p. 346 (May 1973).
11. J. M. Campbell, R. R. Willis "A Practical Approach to Engineering Noise," Proc. Metals. Soc. Conf. on Engineering Aspects of Pollution Control in the Metals Industries, 17-29 Nov. 1974. P. 184.
12. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater." 14th Edition. American Public Health Association. New York (1975).
13. United Kingdom Department of the Environment, "Analysis of Raw, Potable and Waste Waters." H. M. Stationery Office, London (1972).
14. U. S. Environmental Protection Agency. "Industrial Guide for Air Pollution Control." Doc. EPA-625/6-78/004. Washington (June 1978)
15. U. S. Environmental Protection Agency. "Handbook for Monitoring Industrial Wastewaters." Washington (August 1973).
16. "Environmental Considerations for the Industrial Development Sector". The World Bank. Washington (August 1978).

THE WORLD BANK

MARCH 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

EFFLUENT GUIDELINES

IRON AND STEEL INDUSTRY

BLAST FURNACE AND DIRECT REDUCTION PROCESSES

1. Iron and steel production utilizes a highly complex system, in which iron ore and other raw materials are subjected to a series of processes to convert them into finished steel products.
2. The series of conversion processes may be divided into five major segments: (a) ore preparation, sintering and pelletizing; (b) by-product coke production; (c) pig iron production; (d) steel production; and (e) rolling and finishing operations.
3. This document is one of a series which has been prepared on the individual segments. Each one presents information as needed for assessing the environmental effects of the gaseous, liquid, and solid wastes produced by the operation. In each case the document discusses the manufacturing processes, waste sources and character, effluent limitations based on best practicable treatment technology currently available, and applicable waste treatment methods. A bibliography is also included.

BLAST FURNACES

Manufacturing Process

4. Pig iron (containing over 90 percent iron), is the product resulting from reactions of a mixture of iron-bearing materials, coke, and limestone in a blast furnace. These furnaces are large cylindrical structures, some 30 meters in height. Heated air is blown into the lower part of the unit to promote coke combustion. The iron oxide reacts with the hot carbon monoxide from the burning coke, while the limestone reacts with the impurities in the iron-bearing material and coke to form molten iron and slag. Materials are charged into the top of the furnace, where the reactions begin. As these melt and decrease in volume the charge passes to the bottom of the furnace, where molten iron and slag exist. The molten slag floats on top of the iron and is drawn off through an opening in the upper part of the furnace. The molten iron is drawn off through an opening at the bottom of the furnace (below the slag discharge opening), formed into ingots and cooled for subsequent processing.

5. The combustion process produces gases, which are a valuable heat source. They are discharged through the top of the furnace, cleaned to remove large quantities of solids and other pollutants, and then recycled.

Waste Sources and Characteristics

6. Blast furnace operations produce wastes in the gaseous, liquid, and solid states. Air pollutants are produced by three different segments of the operation: blast furnace gas, cast house emissions, and slag handling and processing.

7. Blast furnace gas is a relatively pollution-free fuel when stripped of its dust burden. Large production units are frequently connected to combined power and furnace blowing units. For certain other uses, the calorific value of this gas is increased by mixing it with coke oven gas. The gas must be cleaned of dust to a high degree before being used as a fuel. Cleaning or scrubbing is done by a wet process, producing a liquid waste which may contain toxic substances. Under normal operations, air pollution from blast furnace gas production is not considered significant.

8. Molten metal and slag are discharged from the furnace and cause fume emissions as the result of exposure to air and oxidation. Further emissions arise from vaporization of alkaline oxides from slag, and sometimes from combustion of tars and resins in impregnated refractory clays. Emission of sulfur dioxide from molten slag may also be a problem. Manganese fumes in ferromanganese operations constitute a potential health hazard.

9. Coarse aggregate is prepared by pouring the molten slag into a slag pit in layers, either adjacent to or at a distance from the furnace. Water spraying is frequently used to accelerate the cooling process, and this can result in a hydrogen sulfide odor. A condensation chimney is often used to scrub noxious vapors. Materials from slag pits are further processed to produce aggregate of specific size ranges. Effective dust control measures can reduce this source to insignificant levels.

10. Blast furnace wastewaters originate primarily from top gas cleaning. Water is also used for cooling the furnace, but this is a non-contact operation and therefore of little or no significance from the pollution standpoint. The wastewaters contain large quantities of particulate matter and quantities of cyanide, phenol, and ammonia. Other pollutants include heavy metals and certain organics originating in the raw materials or formed during the combustion process.

11. Wastewater flows and characteristics will vary, according to the raw materials, the iron making process used, and the gas scrubbing process applied. Ranges of flows and concentrations that are typically found are presented in Table 1.

12. Solid wastes include blast furnace slag, dry dust and moist filter cake, cast house fumes, refractory wastes, and ladle skull (the metal shell which solidifies on the sides and bottoms of the ladle). The slag is processed and used as a building material, raw material for blast furnace cement, and other similar purposes.

Cast house dusts are collected on filter extraction systems and fed to the sinter plant. Used refractory material and ladle skulls are generally dumped on site.

Table 1. - Wastewater Flows and Characteristics for a Typical Blast Furnace Operation

Parameter*	Concentrations
Flow - L/Mg (a)	4600 - 12,900
Ammonia N - mg/L (b)	10 - 17
Cyanide mg/L (b)	1 - 54
Phenols mg/L (b)	0.05 - 2.9
Fluoride mg/L (b)	1.4 - 6.5
Sulfide mg/L (b)	2.0 - 54
Suspended Solids mg/L	354 - 7040
pH - Units	6.4 - 10.2

(a) L/Mg = Liters per megagram of iron produced.
(b) mg/L = milligrams per liter of effluent

Effluent Limitations

13. Gas cleaning and recovery will normally reduce atmospheric discharges to concentrations well below acceptable levels. In all cases, ambient air quality should be maintained below the following levels outside the plant fence:

Sulfur Dioxide

Inside plant fence	Annual Arith. mean:	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr peak	1000 $\mu\text{g}/\text{m}^3$
Outside plant fence	Annual Arith. mean:	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr peak	500 $\mu\text{g}/\text{m}^3$

* 1 Mg = 1 megagram = 1 metric ton
L = Liter

Hydrogen Sulfide

Average 24-hour

8 $\mu\text{g}/\text{m}^3$

Particulate Matter

Annual Geo. Mean

75 $\mu\text{g}/\text{m}^3$

Max. 24-hour, not over once a year

260 $\mu\text{g}/\text{m}^3$

(a) $\mu\text{g}/\text{m}^3$ = Micrograms per cubic meter of air sampled

14. Limitations for blast furnace wastewater effluents, based on best practicable treatment technology currently available, are presented in Table 2.

Table 2. - Effluent Limitations for Blast Furnace (Pig Iron) Wastewater Discharges.

Parameter	Limitation (per Mg Product) (a)
Flow (b)	520 Liters
Susp. Solids	26 Grams
Sulfide	3.1 Grams
Fluoride	21 Grams
Phenols	2.1 Grams
Cyanide	7.8 Grams
Ammonia - N	65 Grams
pH	6.0 - 9.0 Units

(a) Per megagram of iron produced.
(b) Excluding all non-contact cooling water

Control and Treatment of Wastes

15. Because blast furnace gas is recycled and reused, it undergoes a very high degree of cleaning. The cleaning process frequently involves up to three stages — dry collection in a "dust catcher", high energy scrubbing and wet electrostatic precipitation. Excessive emissions from the cast house operations can be avoided by maintaining sufficient ventilation. In the slag handling procedure, the mixing of molten slag with water is in itself effective in controlling much of the air pollution discharged. A condensation chimney is effective for removing any residual gases and materials.

16. Treatment of blast furnace wastewaters is concerned mainly with the removal of suspended solids. Other constituents, such as cyanides, phenols, oils and greases, metals, and others are also of concern. These wastes originate mostly from the cleaning of gases resulting from combustion of the raw materials in the furnace. They are removed through the top of the furnace (and frequently referred to as "top" gases) for subsequent cleaning and use elsewhere in the plant.

17. Treatment in most cases consists of thickener/clarifiers for removing the suspended solids. Sludge is removed continuously from the bottom of the thickener and pumped to vacuum filters, for dewatering. The filtrate is returned to the thickener influent. Various flocculating agents such as polymers, are often used to enhance solids removal. The clarified effluent can be used for cooling purposes. Solids removal, by itself, has only a minor effect on the chemical composition of the wastewater. Chlorination can be useful as a means of destroying cyanides and phenols. Bio-oxidation systems have also been successful in destroying cyanides.

18. Both organic and inorganic toxic pollutants have been found in blast furnace effluents, and hence should receive attention. Depending upon the individual or combination of pollutants involved, varying degrees of removal can be achieved by the application of filtration (as part of the suspended solids removal procedure), activated carbon, and carbon adsorption.

19. Disposal of solids, filter cake, sludges, and other similar materials which cannot be recycled is to controlled landfill. Slurries from the gas scrubbers frequently contain significant amounts of lead, zinc, and alkalis and hence cannot be recycled without receiving additional treatment.

DIRECT REDUCTION PROCESS

20. In recent years, particularly in countries having adequate supplies of both high grade iron ore and energy resources, a number of methods for the direct reduction of ore have been developed. This has been particularly true in countries seeking to establish a local iron and steel industry. The process permits development of smaller production units, with capacities in the order of 1,000 tons of sponge iron per day.

21. Basically the process utilizes the reaction between either a gaseous reducing agent or a solid fuel and the ore. The lump ore and/or pellets are charged to a vertical shaft or fluidized bed to produce metallized products containing a minimum of 90 percent iron. This sponge iron can be readily melted in an electric arc furnace. The main advantages of the process relate solely to the size and flexibility of the operation. The direct reduction/electric furnace steelmaking procedure is much more energy-intensive than the more conventional blast furnace/basic oxygen furnace procedure.

22. Dusts contained in the off-gases from these plants are usually removed by wet scrubbing. Cleaned gases are either used to provide heat for gas reforming or, in some instances, to preheat the feed material. The resulting slurry is filtered, pressed, and recycled. The clarified effluent can be used for cooling. Where pelletizing is used, the fines resulting from the screening of the pellets are fed back to the process.

23. Effluent limitations for gaseous and liquid effluents are the same as those given in paragraph 13 and 14, above.

BIBLIOGRAPHY

1. "Environmental Control in the Iron and Steel Industry", International Iron and Steel Institute, Brussels (1978).
2. United Nations Development Organization, Development and Transfer of Technology Series No. 11 "Technological Profiles of the Iron and Steel Industry". United Nations, New York (1978).
3. U.S. Environmental Protection Agency "Draft Development Documents for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Industry." Doc. EPA 440/1-79/024a. Washington. (October 1979): Vol. III-Sintering and Blast Furnace Sub-categories.
4. Jarrault, P. "Limitation des Emissions de Polluants et Qualite de L'Air - Valeurs Reglementaires dans les Principaux Pays Industrialises." Institut Francais de l'Energie. Paris (1978).
5. U. S. Environmental Protection Agency "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds." Doc. EPA-450/3-79-024. Washington (April 1979).
6. U.S. Environmental Protection Agency. "Industrial Guide for Air Pollution Control." Doc. EPA-625/6-78/004. Washington (June 1978).
7. U.S. Environmental Protection Agency. "Water Quality Criteria." Doc. EPA-R3-73-033. Washington (March 1973)
8. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater." 14th Edition. American Public Health Association. New York (1975).
9. U.S. Environmental Protection Agency. "Handbook for Monitoring Industrial Wastewaters." Washington (August 1973).

THE WORLD BANK

MARCH 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

IRON AND STEEL INDUSTRY

BYPRODUCT COKE OVENS

EFFLUENT GUIDELINES

1. Iron and steel production utilizes a highly complex system, in which iron ore and other raw materials are subjected to a series of processes to convert them into finished steel products.
2. The series of conversion processes may be divided into five major segments: (a) ore preparation, sintering and pelletizing; (b) byproduct coke production; (c) pig iron production; (d) steel production; and (e) rolling and finishing operations.
3. This document is one of a series which has been prepared on the individual segments. Each one presents information needed for assessing the environmental effects of the gaseous, liquid, and solid wastes produced by the operation. In each case the document discusses the manufacturing processes, waste sources and character, effluent limitations based on best practicable treatment technology currently available, and applicable waste treatment methods. A bibliography is also included.

MANUFACTURING PROCESS

4. Two types of ovens have been traditionally used to produce metallurgical coke: beehive and byproduct recovery. The byproduct recovery types, discussed in this document, are the most extensively used at this time. In the United States, for example, less than 1% of the metallurgical coke produced in 1977 came from beehive ovens.
5. The byproduct recovery process not only results in a suitable high-quality coke, but also makes possible the recovery of valuable byproducts from the distillation reaction. Crude coal tars, crude light oils, ammonium sulfate, and naphthalenes are the principal by-products recovered. Other products, such as creosote oils, phosphates, cresols and elemental sulfur, are also recovered in some cases.

6. A byproduct recovery coke plant consists of batteries of ovens in which blends of high, medium, and low volatile bituminous grades of selected coals are heated. The heating occurs out of contact with air in order to drive off volatile components without burning them. The volatiles are drawn off and recovered, while the residue remaining after 12 to 24 hours of heating constitutes the coke product.

7. When ready, the coke is pushed from the oven and quenched (or cooled) before going to storage or use. Two methods are in use — dry quenching and wet quenching. Dry quenching is used in some plants in Russia, England, France, and Switzerland. Wet quenching, the most widely used method, is accomplished by discharging the hot coke from the ovens to the quenching car. The car is then moved to the quenching station by locomotive, and water sprayed on the mass while still in the car, to cool it. The coke is then transferred elsewhere for storage or use.

WASTE SOURCES AND CHARACTERISTICS

8. As previously stated, the byproduct process yields a variety of useful materials, which are either reused in the mill operation or profitably marketed elsewhere. Utilization of these byproducts keeps them out of the waste streams and hence significantly reduces the waste load which might otherwise be discharged from a coke plant. There are, however, several other potential sources of gaseous, particulate, and aqueous emissions which are not removed as part of the recovery process and can have an adverse effect on the environment.

9. Waste gas can originate in the coal preheater units utilized at many plants. Gravity charging of ovens can result in emissions of toxic and flammable gases, as well as fumes and dusts.

10. Major liquid wastes usually include excess ammonia liquor, final cooler wastewater, light oil recovery wastes from the benzol plant, barometric condenser wastes from the ammonia sulfate crystallizer, desulfurizer wastes, and contaminated waters from air emission scrubbers at charging, gushing, quenching, preheating, or screening stations. The largest volumes of water are from indirect (noncontact) cooling operations. These are normally not contaminated, except from leaks in coils, tubes, or other equipment.

11. Typical wastewater flows from byproduct coke oven operations are presented in Table 1.

TABLE 1 - Typical Wastewater Flows from
Byproduct Coke Oven Operations

Source	Flow L/Mg Coke a/
Waste Ammonia Liquor	162
Final Cooler Blowdown	133
Benzol Plant Wastes	226
Misc. Wastes b/	259
Steam Condensates	40
(Subtotal - Basic Flow)	(820)
Baro. Condenser Blowdown	122
Desulfurizer, wet	100
Air Pollution Control Blowdowns	
Preheaters and Dryers	37
Charging	111
Quenching c/	2100

a/ L/Mg = Liters per magagram = liters per metric ton.

b/ May include varying amounts of non-process cooling water.

c/ Amount applied. Generally one-third evaporates and remaining two-thirds is recirculated.

12. Parameters considered of major significance in coke plant wastewaters include: total suspended solids, oils and greases, ammonia -N, total cyanides, phenolic compounds, sulfides, thiocyanates, and pH. In addition, coking will also produce a large number of both organic and inorganic pollutants, which may need to be eliminated from waste streams if concentrations are too high. Over 50 such pollutants have been identified at existing plants.

13. Available data on raw waste quality in coke plants show wide variations, and hence are not presented here. Each plant will need to be evaluated according to its own individual circumstances and merits.

14. Byproduct coke making also produces a number of toxic pollutants, both organic and inorganic. Some 30 organic substances are considered of major significance, including acrylonitrile, ethylbenzene, naphthalene, phenol, fluorine, pyrene, toluene, and xylene. Of the inorganics, antimony, arsenic, cyanides, selenium, silver, and zinc are considered to be the most significant.

15. The use of lime to raise pH levels prior to ammonia stripping produces a sludge in the form of unreacted calcium hydroxide, along with precipitated calcium carbonates and sulfates. Other sludges include coal or coke fines. Another source of solid wastes may occur where recovered byproducts are not sufficiently pure for further use or for resale or reuse.

EFFLUENT LIMITATIONS

16. Coke making may result in discharge of gaseous ammonia, hydrogen sulfide, and hydrogen cyanide to the atmosphere if collectors, ductwork, and piping are not carefully monitored and controlled. Particulates may also escape to the atmosphere. With effective controls, little or none of these substances should be discharged. Odors can be a problem if not carefully controlled.

17. On the basis of best practicable control technology now available, wastewaters from byproduct coke plants should be maintained at or below the levels given in Table 2.

18. The use of lime to raise pH levels prior to ammonia stripping produces significant quantities of sludge. Disposal of these sludges to landfill sites should be such as to prevent escape to the environment.

TABLE 2 - Effluent Limitations for Byproduct Coke Plant Operations

Parameter	Limitation (Per Mg Coke)
Total Cyanide	22 grams
Phenolic Compounds	1.5 "
Ammonia - NH ₃	91 "
Oil and Grease	11 "
Suspended Solids	37-94 "
pH	6.0-9.0 (units)
Flow ^{a/}	730-940 liters

a/ Excludes non-contact cooling water.

CONTROL AND TREATMENT OF WASTES

19. Because the byproducts from coke making can be profitably recovered and marketed or reused, pollution control is largely achieved through the recovery processes. Gases and dusts which are not otherwise recovered as useful byproducts are effectively removed by dust collecting devices, sprays, or a combination of the two. Disposal is either to recycling or to landfills.

20. Odors can be minimized or eliminated by restricting vapor losses to the atmosphere through leaking vent pipes, storage vessels, and liquor seals. Burning of coke oven gas can produce significant emissions of sulfur gas, unless the sulfur component is removed before burning. Desulfurization is most often accomplished either through absorption/desorption or absorption/oxidation. Removal efficiencies will range from 80 to 99 percent.

21. Following application of various byproduct recovery measures, there still remains a residual discharge of contaminated wastewater

which must be treated before release. The three most frequently applied methods are physical/chemical, biological, and incineration/evaporation technologies. Flow minimization should be a first step in all cases.

22. A physical/chemical system would include a fixed leg on the ammonia still to strip additional ammonia from the wastewater, through addition of lime slurry and additional steam. This step is followed by carbon adsorption to remove the organic components. Prior to carbon adsorption the wastes can be oxidized with such chemicals as chlorine, chlorine dioxide, sodium hypochlorite, ozone, or peroxides to destroy the organics. Where these chemicals are used, the carbon column acts mainly as a final polish.

23. In a biological or bio-oxidation system, the wastewaters from the fixed leg to the ammonia still, which have a high pH, are first neutralized with acid and then flow into a single-stage activated sludge bio-oxidation system or pond. Aeration is provided by mechanical agitation or by use of large blowers. Depending upon the pollutants to be removed one or two additional stages may be required to remove phenols, cyanide and ammonia (oxidized to nitrates) and provide denitrification in a final stage. Effluents from these stages are subjected to sedimentation, step aeration, and pH adjustment before discharge.

24. Incineration/evaporation is not widely used, and is best applied in situations where the impact on air pollution would not be significant. In this method, the total raw waste load is distilled and evaporated in a controlled combustion system. Coke oven gas and crude coal tar are the only byproducts recovered.

25. The use of lime to raise pH levels prior to ammonia stripping produces large quantities of sludge in the form of unreacted hydroxide, along with precipitated calcium carbonates and sulfates. Disposal can be to landfill but care must be taken to prevent the sludges from redisolving and reaching streams as runoff. Lesser amounts of sludge form when caustic soda is used as the alkali, but this will cause an increase in the dissolved solids levels. Other sludges will contain coal or coke fines, and these can be readily recycled back to the process.

26. All sludges should be recycled to the process insofar as possible. Controlled landfill is the disposal method of choice for all solid wastes that cannot be recycled to the system, including those byproducts which are not of suitable quality for marketing purposes.

BIBLIOGRAPHY

1. Russel, C.S. and Vaughn, W.J. "Steel Production: Processes, Products and Residuals." Resources for the Future. The Johns Hopkins University Press, Baltimore and London (1976).
2. United Nations Development Organization. Development and Transfer of Technology Series No. 11 "Technological Profiles of the Iron and Steel Industry." United Nations, New York (1978).
3. U.S. Environmental Protection Agency. "Draft Development Documents for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Industry." Doc. EPA 440/1-79/024a. Washington. (October 1979: Vol. II - Byproduct Coke Making and Beehive Coke Making Sub-categories.
4. Jarraud, P. "Limitation des Emissions de Polluants et Qualite de L'Air - Valeurs Reglementaires dans les Principaux Pays Industrialises." Institut Francais de l'Energie. Paris (1978).
5. U.S. Environmental Protection Agency. "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds." Dec. EPA-450/3-79-024 Washington (April 1979).
6. U.S. Environmental Protection Agency. "Industrial Guide for Air Pollution Control." Doc. EPA-625/6-78/004. Washington (June 1978).
7. U.S. Environmental Protection Agency. "Water Quality Criteria." Doc. EPA-R3-73-033, Washington (March 1973).
8. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater." 14th Edition. American Public Health Association. New York (1975).
9. U.S. Environmental Protection Agency. "Handbook for Monitoring Industrial Wastewaters." Washington (August 1973).

THE WORLD BANK

APRIL 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

IRON AND STEEL INDUSTRY

ORE PREPARATION, SINTERING, AND PELLETIZING

EFFLUENT GUIDELINES

1. Iron and steel production utilizes a highly complex system, in which iron ore and other raw materials are subjected to a series of processes to convert them into finished steel products.
2. The series of conversion processes may be divided into five major segments: (a) ore preparation, sintering and pelletizing; (b) by-product coke production; (c) pig iron production; (d) steel production; and (e) rolling and finishing operations.
3. This document is one of a series which has been prepared on the individual segments. Each one presents information as needed for assessing the environmental effects of the gaseous, liquid, and solid wastes produced by the operation. In each case the document discusses the manufacturing processes, waste sources and character, effluent limitations based on best practicable treatment technology currently available, and applicable waste treatment methods. A bibliography is also included.

ORE PREPARATION

Manufacturing Process

4. Higher grades of ore are becoming rapidly depleted throughout the world, due to selective mining of one type or another. During the mining of high-grade ores the low-grade ores which may be present as overburden and capping will mix with the material of good grade, particularly when large-scale mechanical mining methods are used. To assure an acceptable and consistent ore having the desired composition for iron smelting, the run-of-the-mine ore is given special preparation, often referred to as "beneficiation."
5. Various beneficiation techniques are applied to suit the specific ore, depending upon the mineralogical and petrological characteristics of the material. Techniques used include wet screening, gravity treatment, magnetic separation, froth flotation, reduction roasting, thickening, and drying. The combination of techniques used depends upon the cost economics, the required quality of the end product, and the possibilities of recycling waste products.

Waste Sources and Characteristics

6. Raw materials are delivered by water, rail, or highway, and normally require handling within the mill, as well as stockpiling and blending. Within

the works area, raw materials such as ores are usually transported by conveyor belts. Spray installations are used for reducing dust losses, since a high surface moisture content is necessary to avoid wind-borne losses of fine materials. Where no spray facilities are used, studies have shown losses from wind-borne drift to be in the order of 0.35 grams per ton of material stored. With adequate controls, waste production from this segment of the operation should be relatively minor.

SINTERING AND PELLETIZING

Manufacturing Process

7. The beneficiation process produces large proportions of fines, sometimes up to 50 percent by weight of the ore mined. In the case of magnetite ores, the entire quantity of concentrate is in the form of fines. Whatever the source, the fines require sintering or pelletizing before utilization for making iron.
8. Sintering produces a useful agglomerate from the mined ore and a wide variety of wastes, such as coke breeze, mill scale, flue dust, blue dust, limestone, and dolomite fines. The process has great flexibility in the agglomeration of raw materials having different physical properties and mineralogical composition.
9. Pelletizing, another of the agglomeration processes, is most frequently utilized where the ore particles are in a very fine form either as a beneficiated product or as a naturally-occurring mineral like blue dust. The process is carried out in two steps — balling and induration.
10. The purpose of "balling" is to increase the particle size of the dust. After wet or dry grinding of the ore, dewatering, and partial drying, "green" pellets are formed by the addition of a suitable binder. Bentonite, limestone, or hydrated lime are commonly used for this purpose. In order to produce pellets of suitable quality it is necessary to carefully control the type of grind, the size to which the ore is ground, the schedule of drying and preheating, and preheating, and the cooling cycles.
11. The induration process involves the drying of the green pellets, preheating to proper temperatures, firing at the required temperatures, and soaking for a definite period to create iron oxide or a slag bond formation between grains. This is followed by regulated cooling of the final product.
12. A recent development has been the use of cold induration processes, in which special types of cements (containing no sulfur) are used with the pelletizing feed before balling. The green balls, sometimes coated with iron concentrate fines to prevent cluster formation, are allowed to cure and harden for periods of up to 5 weeks.

Waste Sources and Characteristics

13. Although sintering plants are generally fitted with high chimneys to assure adequate dispersion of waste gases, use of high-sulfur raw materials can cause problems from sulfur dioxide combining with other contributions from nearby sources. Dusts or particulate matter can also be major problems. Other gaseous pollutants, such as hydrogen fluoride and nitrogen oxide do not cause problems in most countries, although Japan is experiencing some problems as a direct result of the potential for photochemical pollution. A typical sinter plant waste gas will contain 0.2 to 1.0 g/m³ (normal)* of SO₂, less than 0.4 g/m³ (normal) of NO_x, and less than 0.01 g/m³ (normal) of F.

14. The firing process employed in pellet plants may produce gaseous emissions of sulfur dioxide and nitrogen oxides. When using ores with high fluorine content, gaseous fluorine compounds may be emitted. Both sulfur dioxide and nitrogen emissions depend upon the types of burner and fuel used, and will normally not constitute a serious problem.

15. Wastewater generated during the sintering and pelletizing operation result mainly from the scrubbing of gases and dusts produced during the process. Wastewaters are also generated from the cooling, crushing, and screening of the final product. Newer plants generally use "dry" dust collection equipment and hence have no flows from this source. The pollutants in the effluent reflect the variety of process fuel materials, such as iron and steelmaking flue dusts, ores, mill scale, coke, limestone, slag fines, and others. Oils and gases are also present, principally carried by the scrap and mill scale used in the operation.

16. The average concentrations found in typical untreated effluents from sintering plants are shown in Table 1.

Effluent Limitations

17. Where effective gas scrubbing is used to remove gases and dusts only minor amounts of air pollutants are discharged. In all situations ambient levels of gaseous effluents, outside the plant fence, should be maintained within the following limits:

Sulfur Dioxide

Inside plant fence	Annual Arith. mean:	100 µg/m ³
	Max. 24-hr peak	1000 µg/m ³
Outside plant fence	Annual Arith. mean:	100 µg/m ³
	Max. 24-hr peak	500 µg/m ³

Nitrogen Dioxide

Annual Arithmetic Mean	100 µg/m ³ (normal)
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Particulate Matter

Annual Geometric Mean	75 µg/m ³ (normal)
Max. 24-hour, not more than once a year	260 µg/

* Normal Conditions: 0°C, 101.3 kPa (760 mm Hg)

TABLE 1. Sintering Plant Wastewater Flows and Characteristics

Parameter	Average
Flow - L/Mg* (a)	6100
Oil and Grease - mg/L (b)	245
Suspended Solids - mg/L	6100
pH	6-12
Fluoride - mg/L	17
Sulfide - mg/L	56

(a) L/Mg = Liters per megagram sinter produced

(b) mg/L = Milligrams per liter of effluent.

18. Effluent limitations, based on best practicable technology currently available, should be maintained as shown in Table 2.

TABLE 2. Effluent Limitations for Wastewaters from Sintering Plants

Parameter	Limitation (Per Mg Product) (a)
Oils and Greases	4.2 grams
Suspended Solid	21 grams
pH	6.0 - 9.0 (units)
Flow (b)	416 liters

(a) Per Metric Ton of sinter produced

(b) Excluding non-contact cooling water

(*) 1 Mg = 1 megagram = 1 metric ton

19. Various toxic pollutants, depending upon the raw materials used, are also generally present. These include cyanides, zinc, copper, nickel, lead, silver and others. Limitations for these substances should be as follows:

Cyanides:	0.01 mg/L ^(a)	Nickel:	1 mg/L
Zinc:	1 mg/L	Lead:	0.1 mg/L
Copper:	1 mg/L	Silver:	0.1 mg/L

(a) mg/L = Milligrams per liter of effluent

20. Solid wastes are produced from the gas and dust scrubbers and other sources. These solids are primarily metallic oxides, mostly iron, and are recycled to the sintering process.

Control and Treatment of Wastes

21. Gas and dusts are effectively removed from exhaust streams by means of wet scrubbers or by dry methods, such as electrostatic precipitation. The removed solids are either recycled to the sintering or pelletizing processes or transferred to a waste recovery operation elsewhere.

22. Wastewaters result mainly from the wet scrubbing and cooling of gases, dusts, and other materials involved in the sintering processes. While treatment facilities are concerned mainly with solids removal, a side effect is to remove other pollutants as well. Thickeners and clarifiers or settling lagoons are used for suspended solids removal. Skimmers are effective for oil and grease removal.

23. While suspended solids removal will remove some of the toxic pollutants, higher degrees of treatment are usually required for this purpose. Advanced treatment technologies known to be effective for both organic and inorganic toxic pollutants include alkaline chlorination, sulfide precipitation, filtration, and activated carbon treatment.

24. Solid wastes generated from the treatment of gaseous and liquid effluents are generally recycled into the systems.

BIBLIOGRAPHY

1. United Nations Development Organization, Development and Transfer of Technology Series No. 11 "Technological Profiles of the Iron and Steel Industry." United Nations, New York (1978).

2. U.S. Environmental Protection Agency "Draft Development Documents for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Industry." Doc. EPA 440/1-79/024a. Washington. (October 1979): Vol. III - Sintering and Blast Furnace Subcategories.
3. Jarrault, P. "Limitation des Emissions de Polluants et Qualite de L'Air - Valeurs Reglementaires dans les Principaux Pays Industrialises." Institut Francais de l'Energie. Paris (1978).
4. U.S. Environmental Protection Agency "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds." Doc. EPA-450/3-79-024 Washington (April 1979).
5. U.S. Environmental Protection Agency. "Industrial Guide for Air Pollution Control." Doc. EPA-625/6-78/004. Washington (June 1978).
6. U.S. Environmental Protection Agency. "Water Quality Criteria." Doc. EPA-R3-73-033, Washington (March 1973).
7. U.S. Environmental Protection Agency. "Handbook for Monitoring Industrial Wastewaters." Washington (August 1973).
8. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater." 14th Edition. American Public Health Association. New York (1975).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

IRON AND STEEL INDUSTRY

ROLLING AND FINISHING OPERATIONS

EFFLUENT GUIDELINES

1. Iron and steel production utilizes a highly complex system, in which iron ore and other raw materials are subjected to a series of processes to convert them into finished steel products.
2. The series of conversion processes may be divided into five major segments: (a) ore preparation, sintering and pelletizing; (b) by-product coke production; (c) pig iron production; (d) steel production; and (e) rolling and finishing operations.
3. This document is one of a series which has been prepared on the individual segments. Each one presents information as needed for assessing the environmental effects of the gaseous, liquid, and solid wastes produced by the operation. In each case the document discusses the manufacturing processes, waste sources and character, effluent limitations based on best practicable treatment technology currently available, and applicable waste treatment methods. A bibliography is also included.

MANUFACTURING PROCESS

3. Steel finishing consists of the processing of the steel from the furnaces into the range of shapes and sizes required to supply specific market needs. Because of the wide variety of possible products, the array of technology and equipment required for any particular product, the different operating practices utilized by individual plants, and other similar factors, this is probably the most complex operation in steel making. Some of the typical operations are discussed below.
4. Conventional casting involves the pouring of ingots, subsequent reheating in soaking pits, followed by rolling of semifinished shapes from the ingots. A considerable amount of the original melt, averaging some 14 percent, is lost during all this handling. Losses result from pouring, unmolding, rolling, trimming, and surface preparation (scarfing). This scrap is generally recycled to the steel furnaces.
5. In continuous casting the molten metal is poured into a trough, and then flows to water-cooled molds to form the desired shape. From the mold, the continuous pieces having the required cross-sections are drawn by rollers, cooled by direct water sprays, and cut into pieces of the desired lengths. Scrap production is far less (under 4 percent) in this process than in conventional casting.

6. Hot-rolling strip mills convert heated slabs into thin steel strips, which are either cut into lengths (sheet) or rolled onto cores (coil). A plate mill converts heated slabs into thicker plates (over 6 mm), and functions essentially the same as a strip mill.

7. While some products are sold as they come from the hot-rolling mill, a large portion of the hot-mill production is subject to further processing in the cold mill. In this process, sheet and strip steel products are reduced in thickness by being passed through various cold rolling configurations. As preparation for cold rolling, the surface of the strip is cleaned of scale formed in the hot mill and during storage. This is usually done by passing the strips through baths of dilute hydrochloric or sulfuric acid to dissolve the scale, a process designated as "pickling". Since cold steel has lower plasticity, as compared with hot steel, rolling speeds are slower to achieve the same thickness. Cold rolling can produce thinner strips and a finer surface quality.

8. During cold rolling the steel becomes quite hard and unsuitable for most uses. Therefore, the strip is subjected to an annealing process to restore its ductility and to effect other changes in the mechanical properties to render the material suitable for specific uses.

9. For certain uses it is necessary to apply coatings to the steel in order to provide corrosion protection, wear resistance, antifriction properties, lubricity, heat and light reflectivity, and other effects. The process involves the application of a thin layer of a metallic or non-metallic element to the surface. Metallic elements most frequently used include tin, zinc, chromium, and aluminum. Non-metallic coatings include oxides, sulfides, phosphates, silicates, simple complex organic compounds (alkyd resins and varnishes), and miscellaneous inorganic coatings (vitreous enamel, etc.). The most important step in the process is the careful preparation of the surface of the steel prior to application of the coating.

10. A number of methods are in common use for applying coatings. These include the hot-dip process, metal spraying, metal cementation, fusion welding, and metal cladding. Most metal coatings are applied by the hot-dip method, except for tin which is now generally applied by an electrolytic process.

11. The electroplating process is one in which a basic ferrous or non-ferrous material is coated by electrodeposition of a metal, such as tin. Three steps are involved: (a) cleaning, to remove oil, grease, and dirt from the surface to be coated; (b) electroplating, in which metal ions in acid, alkaline, or neutral solution are reduced on cathodic surfaces (in this case the surface being plated); and (c) post-treatment, in which additional coatings of another material may be applied for special uses. Continuous electroplating of coil steel represents the largest application of electroplating worldwide, in terms of tonnage produced.

WASTE SOURCES AND CHARACTERISTICS

12. The most likely sources of air pollutants in the rolling and finishing operations are the reheating furnaces, soaking pits, scarfing machines, acid recovery plants, galvanizing lines, and organic coating lines. Current control practices provide sufficient reduction, so that these sources are not considered significant.

13. Oil firing of reheating furnaces and oil pits can produce unacceptable sulfur gases in the immediate environment. Coke oven gas, natural gas, and other alternate fuels are coming into widespread use, thus eliminating this problem. Automatic scarfing produces some iron oxide fumes, but this is controlled by means of irrigated precipitators. Spent pickling acids are generally recovered by heating, but effective gas scrubbing prevents fume acid emissions. Fumes from the salt fluxes used in hot-dip galvanizing lines are controlled by extraction and ventilation. Solvent fumes from organic coating lines can be controlled with properly designed ventilating systems.

14. The primary waste constituents from the hot-rolling processes in a pipe and tube mill are scale, oils and greases. Scale is formed as the hot steel surface oxidizes, and is continuously scaled and chipped away. Scale particles are mainly metallic iron, ferrous oxide, and ferric oxide. Oils and greases originate from oil spills, equipment line leaks and breaks, dripping of lubricants, and equipment washdowns. Copper, chromium, lead, zinc, and other heavy metals may be found in wastewaters when these are used in the rolling process, but levels are usually not significant. Typical wastewater characteristics are presented in Table 1.

15. Wastewaters from a cold-rolling pipe and tube mill generate a fine scale (primarily ferric oxide), as well as both soluble and insoluble oils and greases. Wastewater sources include flushing of the product, welders and rolls, and the cold drawing and pickling waste waters. Levels of toxic pollutants are below those for hot-rolling mills, and hence are considered to be of little or no significance. Typical wastewater characteristics are shown in Table 1.

TABLE 1. Wastewater Characteristics for Hot and Cold Pipe and Tube Mills

Parameter	Hot Tube Mill	Cold Tube Mill
Suspended solids - mg/L	500-700	1000
Oils/Greases - mg/L	50-100	100-200
pH	6.0-9.0	6.0-9.0

16. The rolling process generates heat. Oil solutions are added directly to the product to reduce the heat buildup and to provide lubrication for the product being rolled. Three types of oil application systems are in use today—designated as recirculated, direct application and combination. The recirculated system is most widely used at the present time. Due mainly to the use of the oil solutions, high concentrations of various pollutants are discharged. The most common of these are suspended solids, oils and greases. Toxic metals and organic pollutants are also present and must be removed before discharge of the effluent.

17. The major water use in a cold rolling mill operation is for cooling the rolls and materials being rolled. A water-oil emulsion is sprayed directly on the materials and rolls as the material enters the rolls. A flooded lubrication system supplies both the lubrication and cooling operations. Recycle and recovery systems are commonly used, in order to control pollution and reduce the quantities of fresh oils which must be supplied. Characteristics of typical cold-rolling mill discharges are present in Table 2.

TABLE 2. Characteristics of Typical Effluents from Cold-Rolling Mills

Parameter	Recirculated	Direct Application	Combination
Flow - L/Mg*	165	1772	1359
Suspended Solids mg/L	1235	160	624
Oil/Grease - mg/L	22640	1861	1009
Diss. Iron - mg/L	140	22	7.8
pH	6.9	7.2	6.4

18. Acid pickling is the process of chemically removing oxides and scale from the surface of a metal by means of inorganic acid solutions. The process may be carried out using one acid alone or in combination. Sulfuric acid or hydrochloric acid are now most frequently used, depending upon the type of material to be pickled. The process encompasses three operations; pickling, rinsing, and fume scrubbing. Wastewater can originate from the rinsing and fume scrubbing steps. Spent pickle liquor is a third source, but while this is lowest in volume it is highest in contaminant levels. Typical characteristics of wastewater from combination acid pickling operations are show in Table 3.

* 1 L/Mg = 1 liter per megagram = 1 liter per metric ton

TABLE 3. Characteristics of Typical Effluents from Acid Pickling Operations

Parameter	Sulfuric Acid				Hydrochloric Acid			
	Pickle Rinse		Spent Liquor	Fume Scrubber	Pickle Rinse		Spent Liquor	Fume Scrubber
	Batch	Cont.			Batch	Cont.		
Flow - Liters/Mg	960	1020	83	0 ^a	390	465	300	6
Diss. Iron - mg/L	375	520	41,000	1190	190	1690	52,300	402
Tot. Susp. Sol. mg/L	180	44	1,890	93	0	60	740	490
Oil/Grease mg/L	24	12	14	34	3	30	52	780
pH (Units)	2 - 6	2 - 5	< 1	2 - 3	< 2	1 - 4	< 1	< 1
Arsenic mg/L	0.39	0.01	0.18	0.10	---	0.11	0.01	0.07
Cadmium mg/L	1.1	0.02	0.46	0.20	---	0.003	0.12	< 0.07
Total Chromium mg/L	5.1	< 0.001	30	3.2	---	0.57	13	0.19
Copper mg/L	0.45	0.14	3.0	2.3	---	0.72	11	0.21
Cyanides mg/L	0.01	0.01	0.006	0.002	---	---	< 0.01	< 0.01
Lead mg/L	0.14	0.04	1.6	1.5	---	0.28	310	< 0.26
Nickel mg/L	0.64	0.24	21	1.9	---	0.78	10	0.23
Silver mg/L	0.01	< 0.01	0.29	---	---	---	0.20	< 0.10
Zinc mg/L	16	0.10	2.8	1.2	---	0.49	15	0.15
Antimony mg/L	---	---	---	---	---	0.19	0.86	0.18
Selenium mg/L	---	---	---	---	---	---	0.04	< 0.01
Thallium mg/L	---	---	---	---	---	---	0.18	< 0.05

^a/ All flows returned to rinse tank

19. Wastewaters generated by hot coating processes, now most widely used except for tin coating, fall into three categories: (a) continuously run rinse waters (rinses following cleaning operations, flows from fume scrubbing systems, final rinse flows, etc.); (b) intermittent discharges (spent and flux baths, chemical treatment solutions, etc.); and (c) noncontact cooling waters.

20. Wastewater from plating processes originates in the cleaning, surface preparation, plating and related operations. Constituents include the basic material being finished and applied, as well as the components in the processing solutions. The predominant wastewater constituents are the metal cations (such as copper, nickel, chromium, zinc, lead, tin, etc.) and the anions occurring in the cleaning, pickling, or processing baths (such as phosphates, chlorides, and various metal complexing agents).

21. Steel scrap, millscale, scarfing residues, refractory material, and used oils and greases are the principal solid or semi-solid waste substances from the rolling and milling operations. Most of these are recovered or recycled back into the steel-making process. Scrap metal is used as feedstock, while mill scale (about 90% Fe₂O₃) can be recycled to the sinter plant. Refractory wastes are separated, with re-usable material going back into the plant and the non-useable portions going to a dump. Used oils and greases are either incinerated or mixed with inert materials prior to disposal to special dumps. Spent pickling acids from both sulfuric and hydrochloric processes may be regenerated.

EFFLUENT LIMITATIONS

22. Effluent limitations for specific elements of rolling and finishing operations, except for electroplating, are presented in Table 4. Materials consumed or processed do not provide a basis for applying effluent guidelines, in the case of electroplating processes. For this purpose, limitations are based on the surface area (square meters) of materials plated, for each operation (cleaning, plating, etc.) carried out as part of the plating process. Limiting values are presented in Table 5, for a number of substances found in these wastes, depending upon the process being used.

CONTROL AND TREATMENT OF WASTES

23. Discharges of gases, particulates, and fumes can be reduced or eliminated by use of scrubber and other collecting devices, and these normally do not constitute a problem. When dry collecting devices are used to isolate these materials they may be either recycled into the process, if appropriate, or taken to landfill disposal. When wet methods are used the materials are subject to whatever treatment is provided for the wastewaters.

TABLE 4. Effluent Limitations for Steel Rolling and Finishing Mill Wastewaters

Waste Source	Per Mg Steel Processed				pH
	Flow	Susp. Solids	Oil/ Grease	Diss. Fe	
	Liters	Grams			
<u>Pipe & Tube Mill</u>					
Hot Rolling	6700	67	100	-	6-9
Cold Rolling (Water)		(No wastewater discharges)			
Cold Rolling (Oils)		(No wastewater discharges)			
<u>Cold Rolling Mill</u>					
Recirculated	104	3	0.14	0.10	6-9
Dir. Application	1668	104	42	4	6-9
Combination	1043	26	10	1	6-9
<u>Pickling</u>					
<u>SO₄</u> - Batch ^{a/}		(No wastewater discharges)			
<u>SO₄</u> - Batch ^{b/}	2500	125	25	3	6-9
<u>SO₄</u> - continuous ^{a/}		(No wastewater discharges)			
<u>SO₄</u> - Continuous ^{b/}	1042	52	10	1	6-9
HCl - Batch & Cont. ^{c/}	(d)	200	40	4	6-9
HCl - Batch & Cont. ^{e/}	(f)	18	35	4	6-9
Hot Coatings ^{g/}	5000	250	75	-	6-9

a/ Concentrates + rinses, acid recovery

b/ " + " , acid neutralization.

c/ Liquor regen. + rinse neut. + fume scrubbing.

d/ Flow = 4047 L for batch, 2774 L for continuous.

e/ Neut. liquor & rinses + fume scrubbing.

f/ Flow = 3524 L for batch, 2252 L for continuous

g/ With fume scrubbing.

TABLE 5. Effluent Limitations for Electroplating Plants

Parameter	mg/m ² /Operation <u>a/</u>	
	Non-Water Supply Sources	Water Supply Sources and Fish Life
Copper	80	75
Nickel	80	4
Total Cr	80	15
Hexavalent Cr	8	1.5
Zinc	80	—
Total CN	80	1.5
Fluoride	3200	30
Cadmium	48	2.9
Lead	80	4.4
Iron	160	45
Tin	160	—
Phosphorous	160	—
Total Suspended Solids	3200	—
pH (units)	6.0 - 9.5	—
Flow (liters)	145	—

a/ Maximum of average daily values in any 30-day period.
Maximum daily value not to exceed 2 times 30-day average.

24. Treatment technologies are currently available for meeting the wastewater guidelines given in this document. In many cases the treatment is similar, and therefore consideration should be given to combining the wastewater flows for treatment at a common site, when two or more of the operations are carried out at the same time. Treatment processes which either alone or in combination, depending upon the waste characteristics and ultimate disposal, will achieve the limitations given in Tables 4 and 5 are as follows:

Pipe and Tube Mill
Hot Rolling

- a) Primary sedimentation in a scale pit, equipped with oil skimming devices, followed by flocculation with polymer and additional sedimentation in a high rate thickener.
- b) Solids dewatering with vacuum filtration.
- c) Filtration of entire flow prior to discharge or recycle.
- d) Recycle through a cooling tower.

Pipe and Tube Mill
Cold Rolling (Water)

- a) Primary sedimentation in a scale pit equipped with oil skimming devices.
- b) Flocculation with polymer and additional sedimentation in a high rate thickener.
- c) Solids dewatering by vacuum filtration. Complete recycling following filtration.

Pipe and Tube Mill
Cold Rolling (Oil)

- a) Primary sedimentation in a scale pit equipped with oil skimming devices.
- b) Flat bed filtration, followed by complete recycle of all solutions.
- c) Spent soluble oil solutions and oil skimmings removed to outside reclamation or disposal.

Cold Rolling Mill
Recirculated

- a) Reuse of rolling solutions.
- b) Treatment of minimum blowdown via oil separation, equalization, chemical treatment flocculation, air flotation, surface skimming and extended settling.

Cold Rolling Mill
Direct Application

- a) Treatment of solutions via oil separation, equalization, chemical treatment, flocculation, air flotation, surface skimming, and long-term settling.

Cold Rolling Mill
Combination

- a) Maximum degree of reuse practical.
- b) Treatment of Blowdown from recirculation system and water from direct application stands via oil separation, equalization, chemical treatment, flocculation, air flotation, surface skimming, and extended settling.

Pickling - SO⁴
Batch - Acid Recovery

- a) On-site acid recovery.
- b) Reclaim usable sulfuric acid, and solid ferrous sulfate heptahydrate for outside resale.
- a) Equalize acid and alkaline wastes; blend mix, and aerate.
- b) Lime neutralization, with polymer addition.
- c) Extended settling (one day retention).
- a) On-site acid recovery.
- b) Reclaim usable sulfuric acid, and also solid ferrous sulfate heptahydrate for outside resale.
- a) Equalize acid and alkaline wastes; blend, mix and aerate.
- b) Lime neutralization, with polymer addition.
- c) Extended settling (one day retention).
- a) Spent pickle liquor regeneration.
- b) Recycle of fume scrubber water with minimum blowdown to treatment.
- c) Absorber vent scrubber once-through to treatment with rincewater via neutralization, polymer addition and settling or clarification.
- d) pH neutralization.
- a) Equalize acid and alkaline wastes; blend, mix, and aerate.
- b) Treat with lime or caustic soda, add polymer.
- c) Sedimentation via thickener; vacuum filtration of underflow.
- d) pH neutralization.

Pickling - HCl
Liquor Regen.

Pickling - HCl
Liquor Neut.

Hot Coatings

- a) Separate collection, equalization, blending, and settling.
- b) Lime and polymer addition.
- c) One day settling and continuous oil skimming.

Electroplating

- a) Chemical treatment providing for cyanide destruction.
- b) Reduction of hexavalent chromium to trivalent form.
- c) Neutralization and coprecipitation of heavy metals as hydroxides or hydrated oxides.
- d) Settling and clarification to remove suspended solids.

BIBLIOGRAPHY

1. "Environmental Control in the Iron and Steel Industry," International Iron and Steel Institute, Brussels (1978).
2. "The Making, Shaping and Treating of Steel." Ed. by H. E. McGannon. Ninth Edition. United States Steel Corporation. Pittsburgh (1971).
3. Jarrault, P. "Limitation des Emissions de Polluants et Qualite de L'Air - Valeurs Reglementaires dans les Principaux Pays Industrialises." Institut Francais de l'Energie. Paris (1978).
4. U. S. Environmental Protection Agency "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds." Dec. EPA-450/3-79-024 Washington (April 1979).
5. U. S. Environmental Protection Agency "Draft Development Document for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Industry." Doc. EPA-440/1-79/024a. Washington, (October 1979):
Vol. VIII - Sulfuric Acid Pickling, Hydrochloric Acid Pickling, and Combination Acid Pickling Subcategory.
6. U. S. Federal Register. "Interim Effluent Limitations and Guidelines, and Proposed Performance and Pretreatment Standards - Electroplating Point Source Category." V.40 No. 80. Washington (April 24, 1975).

7. U. S. Environmental Protection Agency. "Development Document for Interim Final Effluent Limitations Guidelines and Standards for the Metal Finishing Segment of the Electroplating Point Source Category." Doc. EPA-440/1-75/040-a. Washington. (April 1975).
8. U. S. Environmental Protection Agency. "Water Quality Criteria." Doc. EPA-R3-73-033, Washington (March 1973).
9. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater." 14th Edition. American Public Health Association. New York (1975).
10. United Kingdom Department of the Environment, "Analysis of Raw, Potable, and Waste Waters." H. M. Stationery Office, London (1972).
11. U. S. Environmental Protection Agency. "Handbook for Monitoring Industrial Wastewaters." Washington (August 1973).

THE WORLD BANK

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OFFICE OF ENVIRONMENTAL AFFAIRS

IRON AND STEEL INDUSTRY

STEELMAKING PROCESSES

EFFLUENT GUIDELINES

1. Iron and steel production utilizes a highly complex system, in which iron ore and other raw materials are subjected to a series of processes to convert them into finished steel products.

2. The series of conversion processes may be divided into five major segments: (a) ore preparation, sintering and pelletizing; (b) by-product coke production; (c) pig iron production; (d) steel production; and (e) rolling and finishing operations.

3. This document is one of a series which has been prepared on the individual segments. Each one presents information needed for assessing the environmental effects of the gaseous, liquid, and solid wastes produced by the operation. In each case the document discusses the manufacturing processes, waste sources and character, effluent limitations based on best practicable treatment technology currently available and applicable waste treatment methods. A bibliography is also included.

4. The basic difference between iron and steel is in the relative amounts of impurities in the two metals. The molten iron is saturated with carbon, and also contains undesirable amounts of silicon, manganese, phosphorous, and sulfur. These are removed in the steel-making process. However, in order to impart certain desirable properties to the steel, other elements are added in controlled proportions as part of the steel-making cycle. These are categorized as "residual alloy elements," and are confined mainly to tin, copper, nickel, chromium, and molybdenum.

5. At the present time steel is produced mainly in three principal furnace types or processes - the open hearth furnace, basic oxygen furnace, and electric arc furnaces.

OPEN HEARTH FURNACE

Manufacturing Process

6. The open hearth furnace consists of a shallow rectangular basin or hearth, enclosed by refractory lined walls and roof, into which the charge is placed. The charge may consist of all liquid iron, liquid iron and liquid steel, solid steel (scrap) and liquid iron, or some other similar combination of iron and scrap steel. The charge is heated by a gas flame located at the ends of each furnace. Fuels commonly used include natural gas, coke oven gas, fuel oil, coal tar, or some combination of these. The choice of fuel will influence the sulfur dioxide generation per ton of steel.

7. There are two principal types of open hearth furnaces -- the acid and the basic. The furnace is termed an "acid" furnace where the basin refractory material consists of silicon sand. Where the basin is lined with dolomite or magnesite the furnace is a "basic" unit. The basic furnace has the ability to remove phosphorous and sulfur from iron and its ores. The acid furnace, on the other hand, requires a minimum amount of these substances to operate and can use only selected raw materials. At the end of the heating period the furnace is tapped, at a temperature of approximately 1650°C, and the molten steel poured into moldings to form ingots, castings, or other shapes for subsequent processing.

Waste Sources and Characteristics

8. Waste products from the open hearth process include slag; oxides of iron emitted as micron dust; waste gases composed of air, carbon dioxide and water vapor; oxide of sulfur and nitrogen, and oxides of zinc (if galvanized steel scrap is used). Fluorides may be emitted, both in the gaseous and particulate states. Most of the particulate emissions consist of iron oxides (predominantly Fe_2O_3) generated at an average rate of 12.5 kg per MT of steel produced.

9. In addition to these primary sources, the secondary sources should also receive attention. These include the hot metal transfer station, the hot metal mixer, the fumes caused by charging of scrap and hot metal, and the fumes emitted during tapping of the vessel. The dusts emitted at these points are largely fine grain iron oxides, and can be recycled to the sinter plant either directly or after some form of treatment.

10. The quantity of particulates will vary according to the gas cleaning systems used. A semi-wet system cools the hot gases before entry

into the dry precipitators, which remove the particulates from the gas stream. However, a small portion of the particulate matter does escape into the wastewater systems. On the other hand, the wet scrubber system is specifically designed to remove the particulates from the gas stream, and thus results in larger concentrations of suspended matter. The gas scrubber systems essentially prevent the discharge of gaseous and particulate materials to the atmosphere.

11. Characteristics of a typical raw wastewater from an open hearth furnace are presented in Table 1. This table also includes certain components considered to be toxic and therefore of significance.

12. Solid wastes originating from the open hearth operation include slag, scrap, slurries, dusts, and refractory materials. The largest quantity of these wastes is slag, the amount of which will depend upon the quality of steel being produced and the ratio of scrap to pig iron in the charged materials. Typically, slag quantities can vary from 70 to 170 kg per Mg of liquid steel.* Slags can be used in blast furnace sinter, in construction, and for fertilizers, and hence do not normally constitute a waste problem.

Effluent Limitations

13. Open hearth furnaces are generally equipped with a cleaning system, which can efficiently cool and scrub the hot gases that are produced. The entrained gases will contain one or more of the following: sulfur dioxide, nitrogen oxides, zinc oxide, ferric oxide, fluorides, and particulates. Where the cleaning system is effective, discharges to the atmosphere would be very minor. Where gaseous effluents are discharged to the environment, ambient air quality at ground level should be maintained at or below the following concentrations:

SO₂:

Inside Plant fence	Annual Arith. mean	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr peak	1000 $\mu\text{g}/\text{m}^3$
Outside plant fence	Annual Arith. mean	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr peak	500 $\mu\text{g}/\text{m}^3$

NO_x

Ann. Arith Mean $100 \mu\text{g}/\text{m}^3$

Fluorides (as HF)

Ann. Arith Mean $10 \mu\text{g}/\text{m}^3$
8-hr Peak $100 \mu\text{g}/\text{m}^3$

Particulates:

Ann. Geom. Mean $75 \mu\text{g}/\text{m}^3$
Max. 24-hr $260 \mu\text{g}/\text{m}^3$

14. Effluent Limitations for open-hearth furnace wastewaters, based on application of best practicable control technology presently available, are given in Table 2. These include only suspended solids and pH. Although other pollutants are of concern, effluent limitations are still under development. Treatment methods discussed below will normally reduce these other substances to acceptable levels.

* 1 kg/Mg = 1 Kilogram per megagram = 1 Kg/metric ton.

TABLE 1.- Typical Raw Wastewater Characteristics - Open Hearth Furnace

Parameter	Semi-wet System	Wet System
Flow - L/Mg (a)		
Applied	4670	8100
Discharge	288	807
Susp. Solids - mg/L (b)	500	1100
Fluoride - "	260	110
Nitrate - "	10	320
Zinc - "	0.60	200
Chromium - "	0.08	-
Copper - "	0.08	2.0
Cyanides - "	0.04	-
Nickel - "	0.05	-
Lead - "	-	0.60
pH - Units	2.0 - 3.0	3.0 - 7.0

(a) L/Mg = Liters per megagram of steel produced

(b) mg/L = Milligrams per liter of discharge

TABLE 2 - Effluent Limitations for Open Hearth Furnace Wastewaters

Parameter	Per Mg Steel Prod.	
	Semi-wet System	Wet System
Suspended Solids - g	15	23
Flow - liters a/	293	460
pH - units	6.0 - 9.0	6.0 - 9.0

a/ Excluding all non-contact cooling water

Control and Treatment of Wastes

15. Three types of gas cleaning systems are in general use for cleaning and scrubbing the hot gases from open hearth furnaces - the dry system, the semi-wet system, and the wet system.
16. By maintaining an exact balance between the water supplied for cooling the gases and the water evaporated no wastewater is produced. This is called the dry system. Cooling of the hot gases takes place in an evaporation chamber, located at the top of the open hearth building.
17. In the semi-wet system, an excess of water is supplied to the cooling chamber (spark box), thus producing an effluent discharge. The particulate matter collected in both the dry and semi-dry systems is collected as a dry dust, but some plants slurry this dust and convey it to thickeners.
18. In the wet gas scrubber system, the hot gases containing the particulates are conveyed to Venturi scrubbers for cooling and cleaning. Particulate matter is removed as a result of the pressure drop across the throat of the scrubber. Water is supplied to the scrubber to entrap particulates and cool the gases. The wastewater resulting from this system is generally discharged to a treatment facility.
19. The basic type of equipment applied to wastewaters from the gas cleaning and fume collection systems are clarifiers or thickeners for primary sedimentation. These systems are the major source of wastewaters. Clarifiers may be used ahead of the thickeners to remove the heavier solids. Because open-hearth effluents are acidic, provisions should be made to neutralize them. Either lime or caustic are effective for the purpose. Lime, polymer, or other chemicals are added to the clarifiers to aid in settlement of solids and removal of toxic metals. Clarifier sludges are dewatered in vacuum filters; the overflow is normally recycled. Where the overflow is discharged to a stream, it should receive further treatment, such as lagoon settling, prior to release.
20. The presence of fluorides, heavy metals, and nitrates will require advance levels of treatment. Lime precipitation has been effective in removing heavy metals and fluorides. Both carbonate and hydroxide are suitable. However, the carbonate is preferable since it results in a more dense precipitate, improves solids separation, and yields lower sludge volumes. Nitrates may be removed by anaerobic biological processes, as employed in conventional sewage treatment plants. Nitrate concentrations can be reduced to 10 mg/ .

21. Slags, which constitute the largest byproduct from steel making, have several possible uses. They can be recycled into the sinter mix and fed into the blast furnaces. Large lump size slags have found use in reinforcement of river and canal banks, road building, or as railway track ballast. Slags containing high levels of P₂O₅ (usually over 15 percent) can be ground and used as fertilizer. Process scrap resulting from steel pouring can be readily recycled.

22. Fume cleaning dusts and slurries, depending upon their composition, are dewatered and fed back to the sinter plant. Metallic components from refractory wastes are separated and reused. The residue is innocuous and conveyed to landfill. Mill scale, if virtually oil-free, can be recycled to the sinter plant. Where the oil content is high, the scale should be dumped and precautions taken to prevent oil pollution due to runoff.

BASIC OXYGEN FURNACE

Manufacturing Process

23. The basic oxygen furnace for steelmaking is a relatively recent development, having been first introduced in the 1950's. The process is now most universally used, both for new installations and for replacements of older facilities.

24. The Basic Oxygen Furnace (BOF) process produces steel in a pear-shaped, refractory-lined open-mouth furnace using a mixture of hot iron (at 1370°C), cold steel scrap, and fluxes. Fluxes such as burnt lime (CaO) are used to produce a slag which floats on the molten steel surface and collects impurities during steel production. Pure oxygen is injected to the surface at supersonic velocities (Mach 2), through a water-cooled copper-tipped lance for approximately 25 minutes. The lance is lowered through the open furnace mouth and positioned about 1.5 meters above the surface of the bath. The high velocity of the oxygen results in violent agitation and intimate mixing with the molten iron.

25. Rapid oxidation of the dissolved carbon, silicon, manganese, phosphorous, and iron occurs. The carbon in the steel bath combines with the oxygen to produce CO_2 and CO gases which are released from the furnace. The silicon, manganese, phosphorous, etc. oxidize into the slag. Fluoropar (CaF_2) is added to the bath mixture to maintain a fluid slag. Burnt lime is added to aid in the production of a floating slag.

26. A BOF installation is generally equipped with two units, although three or more may be found in a few instances. In a dual furnace facility

one furnace is operating while the other is in either the furnace reheat or brick relining mode. Some plants practice "swing" blowing, where one furnace is being blown with oxygen while the other furnace is being charged with raw materials.

Waste Sources and Characteristics

27. The waste products from the basic oxygen steelmaking process include heat, airborne fluxes, slag, carbon monoxide and dioxide gases, and oxides of iron emitted as micron dusts. Also, when the hot iron is poured into ladles or the furnace, submicron iron oxide fumes are released and some of the carbon is precipitated out as graphite. Fumes and smoke are also released when steel is poured into holding ladles from the furnace. Basic oxygen furnaces are equipped with some type of air pollution gas cleaning systems for containing, cooling and cleaning the large volumes of hot gases and submicron fumes that are released.

28. During the oxygen blowing cycle, the primary gas constituent emitted is carbon monoxide(CO). The CO will burn outside the furnace if allowed to come in contact with air, but combustion can be retarded by preventing contact of the CO with the outside air. This is referred to as "suppressed combustion."

29. Because the CO gas will burn when in contact with air, electrostatic precipitators cannot be used due to arcing in the electric plates and the potential of an explosion. Suppressed combustion systems always utilize wet-type scrubber systems, since there is always some air leakage into the cleaning systems. An open hood mounted above the furnace mouth conveys gases and fumes to the air pollution cleaning systems.

30. Four principal types of gas cleaning systems are currently in use: dry, semi-wet, wet open combustion, and wet suppressed combustion. The wet suppressed combustion systems are the most widely used today.

31. In a dry precipitator system, an exact balance is maintained between water applied to cool the gases and that evaporated in the cooling process. No effluent is discharged in this case. Particulate matter is collected as dry dust. In the semi-wet method an excess of water is supplied to a chamber (spark box) to cool the furnace gases, thus producing a liquid discharge. The particulate matter is also collected as a dry dust.

32. The wet gas cleaning systems involve the use of quenchers and high-energy Venturi scrubbers. The hot gases, containing large amounts of

particulates generated in the steel production process pass through a primary quencher. The function of the quencher is to cool the gases with water and remove the heavier particles contained in the gas stream. After the quenchers, the gases pass to the Venturi scrubbers for final cleaning. Particulate matter is removed as the result of a pressure drop across the throat of the scrubber. Water is applied to the scrubber to entrap the particulates, and the resulting effluent is pumped to the primary quencher. The quencher effluent is discharged to a treatment facility.

33. Wet scrubber systems are used in both the open and suppressed combustion type furnaces. Open combustion units require a greater pressure drop across the scrubber throat than is the case in suppressed combustion units. The particulate matter generated by a suppressed system is larger and easier to remove from the gas stream. On the other hand, open systems allow for more complete combustion due to the presence of excess air and thus result in smaller particles in the gas streams.

34. The fume collection scrubber and gas cleaning systems are the only contact cooling discharge from steelmaking. Other water uses are for non-contact cooling, and these are not contaminated as they flow through the process. Suspended solids, fluorides, and pH are the quality parameters of greatest significance. Raw effluent characteristics of typical waste-water from scrubber and gas cleaning systems are given in Table 3.

TABLE 3 - Characteristics of Typical Raw Waste Waters from Basic Oxygen Furnaces

Source	Flow L/Mg	Fluorides mg/L	Susp. Sol. mg/L	pH
Semi-Wet	1790	2.4	300	11.6
Wet-Open Comb.	3000	8.6	4000	9.9
Wet-Suppr. Comb.	3380	-	810	9.8

Effluent Limitations

35. Gas and fume emissions can be adequately removed from the system, and hence there should be no discharge of air pollutants from a basic oxygen furnace operation. Stack discharges of particulates should be maintained at 50 mg/m³ or less.

36. Effluent limitations for wastewaters are presented in Table 4. These limitations are based on application of best practicable treatment currently available.

TABLE 4 - Effluent Limitations - Basic Oxygen Furnace Wastewaters

	Flow l.	Fluoride	Susp.	pH
		g	Sol. g	
	Per Megagram Produced			
Semi-Wet		(No wastewater Discharges)		
Wet-Open Comb.	630	-	31	6-9
Wet-Suppr. Comb.	210	-	5	6-9

Control and Treatment of Wastes

37. Fume and gas cleaning systems discussed above, normally used with basic oxygen furnaces, are effective in controlling and essentially eliminating air emissions from the operation.

38. Liquid wastes from a semi-wet system undergo primary sedimentation in a thickener, to which coagulant aids are usually added. The thickener sludge is dewatered by a vacuum filter, and the filter cake disposed of to landfill or other appropriate means. The filtrate from the vacuum units is returned to the thickener. The thickener overflow is completely recycled to the process, thus resulting in zero discharge of effluent.

39. Liquid wastes from a wet-open combustion system undergo solids separation in a clarifier, as a first step. Wastewater is then pumped to a thickener for sedimentation, where coagulant acids may be added. The underflow (or sludge) from the thickener is dewatered in vacuum filters, and the filter cake conveyed to landfill disposal. The filtrate is returned to the thickener. About 85 percent of the thickener overflow is recycled to the process. The remainder is acid neutralized and discharged. Makeup water is added to the recycle systems to compensate for blowdown and evaporation losses.

40. Wastewaters from a wet-suppressed combustion system are first subjected to primary treatment in a clarifier to separate the solids. It then flows to a thickener, to which a coagulant has been added. Thickener sludge goes to the vacuum filters, from which the cake goes to landfill

disposal and the filtrate is returned to the thickener. Some 95 percent of the thickener overflow is recycled to the process. The remaining 5 percent undergoes further clarification. The sludge from this unit goes to the vacuum filters, while the effluent is acid neutralized and discharged.

41. Fluoride levels are not significantly affected by the treatment methods discussed above. The levels generally found are higher than would be acceptable for a receiving water used for public water supplies. Therefore, existing fluoride levels should be considered in terms of the use to be made of the receiving waters. Fluoride reduction can be achieved through application of lime reduction methods.

42. Disposal of sludges, filter cakes, and other solids may be to landfill or to process recycling via the sintering plants. For landfill disposal the sludge is often dried to a higher solids content to reduce the volume. In some cases the presence of zinc in the sludges may make them unsuitable for the sinters, since they could cause damage in the blast furnace operations.

ELECTRIC ARC FURNACES

Manufacturing Process

43. The electric arc furnace receives iron from the blast furnace, along with scrap metals and fluxing materials to produce steel. Until recently, this process was used primarily for production of alloy steels, but it is now used to produce a wide range of carbon and specialty steel compositions.

44. High quality and alloy steels are produced in refractory-lined cylindrical furnaces, utilizing a cold steel scrap charge and fluxes. Sometimes a lower grade of steel will be produced in the open hearth or basic oxygen furnace and charged to the electric unit. This is known as duplexing.

45. The heat for the furnace is provided by passing an electric current through the scrap or steel bath, by means of three triangularly spaced cylindrical carbon electrodes inserted through the furnace roof. The electrodes are consumable and oxidize during the process. Furnaces range in charge capacity from about 20 to nearly 400 metric tons. Diameters range from 2 to 9 meters; heat cycle time is 4 to 5 hours.

46. Production of some high-quality steels requires the use of two different slags for the same heat, referred to as oxidizing and reducing slags. The first slag is removed from the furnace and new fluxes added for the second slag. The heat cycle generally consists of charging, meltdown, molten metal period, oxidizing, refining, and topping (or pouring). Pure oxygen is sometimes lanced across the batch to speed up the oxidation cycle which, in turn, will reduce the consumption of electrical power.

47. Within the past decade a new process, called the Argon Oxygen Decarbonization (AOD) process has been used in conjunction with electric arc furnaces. When the electric furnace is used in conjunction with the AOD, the electric arc unit functions as a carbon steel scrap smelter. The hot metal charge is then transferred to the AOD unit for final refining. This eliminates the double slag process required when electric arc furnaces are producing stainless and alloy steels. The AOD process allows for better control of the alloy steel composition.

Waste Sources and Characteristics

48. Waste products discharged from the electric arc furnace process include smoke, slag, carbon dioxide and monoxide gases, and oxides of iron emitted as submicron fumes. Other contaminants, such as zinc oxides from galvanized scrap, will also be discharged depending upon the type and quality of scrap used. Scrap containing large quantities of oil will yield heavy reddish-black smoke as the oils are burned off at the start of the meltdown cycle. Nitrogen oxide and ozone are discharged from the arcing of the electrodes.

49. Gases and particulate matter can be effectively removed by various types of gas cleaning systems, which will limit or eliminate the discharge of these contaminants. Three types of gas cleaning systems are most widely used: dry, semi-wet, and wet. Some of the gas cleaning and resulting operations, however, will result in a contaminated wastewater discharge.

50. Dry gas cleaning systems are generally of two types: baghouses and electrostatic precipitators. A baghouse consists of a series of cloth or fiberglass bags which filter the water-cooled furnace gases. The furnace gases are first quenched by water sprays in a spray chamber and are then introduced to the baghouse. The bags are periodically shaken free of the dust which is then collected in hoppers located at the bottom of the baghouse structure. The dry dust thus collected is removed and landfilled. Another dry method of gas cleaning is the electrostatic precipitator, which involves the use of electrically charged metal plates to capture the charged particulate matter entrained in the gas stream. As for the baghouse method, the gases must be water cooled prior to precipitator cleaning. Cooling of the furnace gases is accomplished in an evaporation chamber to which water is applied. The dust captured by the electrostatic precipitator is collected in a hopper and conveyed to landfill. Neither of these two gas cleaning systems result in an aqueous discharge and therefore do not require any water pollution control equipment.

51. The semi-wet system also involves the use of electrostatic precipitators but results in an aqueous discharge. This system water-cools the furnace gases in a spark box chamber which is about one-third the size of the evaporation chamber used for a dry system. Water is oversupplied to the spark box to ensure adequate cooling and thus results in an effluent from the system.

52. Wet gas cleaning systems generally involve the use of high energy Venturi scrubbers. The hot particulate-laden gases emanating from the furnace are conveyed to Venturi scrubbers for cooling and cleaning. Particulate matter is removed as a result of a pressure drop across the throat of the scrubber. Water is supplied to the scrubber to entrap the particulates and to cool the gases. The resulting water effluent is discharged.

53. Wastewater characteristics are affected mostly by the type of gas cleaning system used, the principal difference being in the quantity of fume particulates. The electric arc furnace has two main water systems: (a) electric arc furnace door, electrode ring, roof ring and cable and transformer cooling; and (b) fume collection scrubber and gas cooling. Only the scrubber and cooling system is important from the pollution standpoint, since all other water uses are for noncontact cooling purposes.

54. The parameters of major interest are the suspended solids and pH levels in the effluent. Characteristics of a typical wastewater effluent are shown in Table 5.

TABLE 5. Characteristics of Typical Electric Arc Furnace Wastewaters

Type of System	Flow L/Mg	Susp. Solids mg/L	pH
Dry	(No liquid discharges)		
Semi-Wet	630	2200	6-9
Wet	8800	3400	6-9

55. Wastewaters may also contain fluorides, zinc, copper, lead and other pollutants depending upon raw materials used, extent of recycling, and other factors.

56. Dusts, particulates, sludges, and other solid materials will be produced as part of the operation and waste control processes. These will vary in quantity and must be considered on a plant-by-plant basis.

Effluent Limitations

57. As previously stated, an effective fume and gas cleaning system will eliminate the discharge of any emissions to the atmosphere. Gaseous emissions are to be maintained at or below the limitations shown in paragraph 13, above. The limitations on wastewaters from semi-wet and wet gas systems,

based on using best practicable treatment currently available, are shown in Table 6.

TABLE 6. Effluent Limitations - Electric Arc Furnace Operations

Source	Suspended Solids g/Mg		pH
Semi-wet System	(No wastewater discharges)		
Wet System	26	50	6-9

Control and Treatment of Wastes

58. Gas cleaning systems, as described above, will adequately control or prevent the discharge of gaseous and particulate emissions to the atmosphere. Where semi-wet or wet systems are used the materials are transferred to the liquid medium and therefore require treatment of the resulting wastewaters.

59. The treatment components required for discharges from the two gas cleaning systems are essentially the same. The basic treatment uses a clarifier or thickener for primary sedimentation, following a classifier or other primary solids separation device to remove the heavier solids. The thickener underflow (or sludge) is dewatered in vacuum filters. Filtrate from the vacuum unit is returned to the thickener. Chemical flocculation can be used to aid in the settlement of solids and the removal of toxic metals and fluoride. In the semi-wet system the thickener overflow is completely recycled. In the wet gas system a part of the thickener overflow is discharged to receiving waters.

60. Additional levels of treatment may be required, where significant quantities of inorganic toxic pollutants and fluorides are present. Several methods have been successful in controlling these substances. These methods include lime and polymer flocculation, lime precipitation, and precipitation with sulfide compounds. The use of sulfide compounds has been more useful in reducing effluent metal concentrations than in the case of lime flocculation.

61. Significant quantities of sludge are generated from sedimentation of gas cleaning system wastes. These may be disposed of to landfill or to the sintering plant, following drying to a fairly high solids content. The presence of zinc in the sludge may make it unsuitable for recycling to the sinter plant without dezincing. The dusts collected in the dry system baghouse may be transferred to a landfill site for disposal.

BIBLIOGRAPHY

1. "Environmental Control in the Iron and Steel Industry," International Iron and Steel Institute, Brussels (1978).
2. "The Making, Shaping and Treating of Steel". Ed. by H.E. McGannon. Ninth Edition. United States Steel Corporation. Pittsburgh (1971).
3. Russel, C.S. and Vaughn, W.J. "Steel Production: Processes, Products and Residuals". Resources for the Future. The Johns Hopkins University Press, Baltimore and London (1976).
4. United Nations Development Organization, Development and Transfer of Technology Series No. 11 "Technological Profiles of the Iron and Steel Industry". United Nations, New York (1978).
5. U.S. Environmental Protection Agency "Draft Development Documents for Proposed Effluent Limitations Guidelines and Standards for the Iron and Steel Industry". Doc. EPA 440/1-79/024a. Washington. (October 1979): Vol. IV - Basic Oxygen Furnace and Open Hearth Furnace Subcategories. Vol. V - Electric Arc Furnace, Degassing, and Continuous Casting Subcategories.
6. U.S. Environmental Protection Agency "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds". Dec. EPA-450/3-79-024 Washington (April 1979).
7. U.S. Environmental Protection Agency. "Industrial Guide for Air Pollution Control". Doc. EPA-625/6-78/004. Washington (June 1978).
8. Jarrault, P. "Limitation des Emissions de Polluants et Qualite de L'Air - Valeurs Reglementaires dans les Principaux Pays Industrialises". Institut Francais de l'Energie. Paris (1978).
9. APHA, AWWA, WPCF. "Standard Methods for the Examination of Water and Wastewater". 14th Edition. American Public Health Association. New York (1975).
10. United Kingdom Department of the Environment, "Analysis of Raw, Potable, and Waste Waters". H.M. Stationery Office, London (1972).
11. U.S. Environmental Protection Agency. "Handbook for Monitoring Industrial Wastewaters". Washington (August 1973).
12. U.S. Environmental Protection Agency. "Water Quality Criteria". Doc. EPA-R3-73-033, Washington (March 1973).

THE WORLD BANK

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OFFICE OF ENVIRONMENTAL AFFAIRS

LEAD SAMPLING AND ANALYSES

1. This document covers the sampling and analyses for determining inorganic lead concentrations in the gaseous and liquid wastes from industrial operations as well as other sources discharging to the environment. For gaseous and particulate discharges, both stationary and ambient sources will be discussed.

2. Stationary sources consist mainly of primary and secondary lead smelters. Primary plants are those producing lead from lead sulfide ore concentrates by pyrometallurgical processes. Secondary plants are those producing lead from scrap materials, such as manufacturers of storage battery components. Ambient source monitoring measures the discharges reaching the environment from these installations, as well as discharges from automobile exhausts and other similar sources.

STATIONARY SOURCE AIR MONITORING

Sampling

3. Stack sampling ports are used for this purpose. These are to be located at least eight stack diameters "downstream" of any bends, constrictions, abatement equipment, or other flow disturbances. If this is not possible, then the sampling location should be at least two stack diameters "upstream" of any flow disturbances. Where these criteria cannot be met a stack extension beyond the discharge and may be required. Ports should be installed flush with the stack wall, and extend outward from the exterior wall for between 5 and 20 centimeters, unless additional extension is required for installation of gate valves or other appurtenances.

4. If the sum of the stack inside diameter plus one port length is less than 3 meters, two ports should be installed on diameters 90 degrees apart. If the sum is greater than 3 meters, then four ports should be installed on diameters 90 degrees apart.

5. Because particulates exhibit inertial effects and are not uniformly distributed within a stack, the sampling procedure is more complex than for gaseous pollutants. Samples are taken at several traverse points along the stack diameters (or cross-section). For a rectangular cross section the equivalent diameter is to be determined from the equation

$$D_e = \frac{2LW}{(L+W)}$$

where D_e = the equivalent diameter, L = the length, and W = the width of the cross-section.

6. When the eight and two-diameter criteria can be met, the minimum number of traverse points should be (a) twelve, for circular or rectangular stacks with diameters (or equivalent diameters) greater than 0.61 meter; (b) eight, for circular stacks having diameters between 0.30 and 0.61 meter; and (c) nine, for rectangular stacks having equivalent diameters between 0.30 and 0.61 meter.

7. The stack sampling train for determining inorganic lead when using the atomic absorption spectrophotometer procedure is shown schematically in Figure 1. It is important in the sampling of particulates that samples be withdrawn isokinetically, i.e. the linear velocity of the gas entering the nozzle should be equal to the velocity of the undisturbed gas stream at the sample point.

8. The filter holder uses a glass fiber filter. A temperature of $120 + 14^\circ \text{ C}$ is to be maintained by a suitable heating system surrounding the filter holder. The very fine particles and the vapor fraction which pass through the filter are trapped by the impingers.

9. The sampling period is to be at least one hour's duration, and longer if required to extend over a complete project cycle. The minimum volume should be in the range of 0.85 to 0.9 dry standard cubic meter (dscm) per hour.

10. When using the dithizone analytical procedure, a different sampling train is used. This is shown schematically in Figure 2. The train consists of a 0.45 micron membrane filter, or equivalent, (to capture larger particles) followed by a sampling tube containing activated carbon (to capture particles smaller than 0.45 microns). Generally, a total sample of not over 150 to 200 cubic meters is collected.

Analyses

11. The preferred methods of analysis for stack samples is "Method 12", as designated by the U.S. Environmental Protection Agency. In this method the particulate and gaseous lead emissions (consisting mainly of lead oxides) are withdrawn from the source and collected on a filter and in dilute nitric acid. The collected samples are digested in acid solution and analyzed by atomic absorption spectrophotometry, using an air acetylene flame. On the basis of tests on samples with concentrations ranging from 0.61 to 123.3 mg Pb/m³, the within-laboratory precision of the method varies from 0.2 to 9.5 percent.

12. High concentrations of copper may interfere with the Pb analysis at the 217.0 nm line of the instrument. This interference can be avoided by analyzing the sample at the 283.3 nm line. (nm = nanometer = 10^{-9} meter)

13. Where atomic absorption spectrophotometry cannot be used, due to unavailability of equipment or for other reasons, the colorimetric dithizone method, as published by ASTM, may be used. The method measures particulate lead concentrations ranging from 0.01 to 10.0 micrograms per cubic meter. It will also measure the vaporous lead, captured on the activated carbon column, at concentrations below 0.5 microgram per cubic meter.

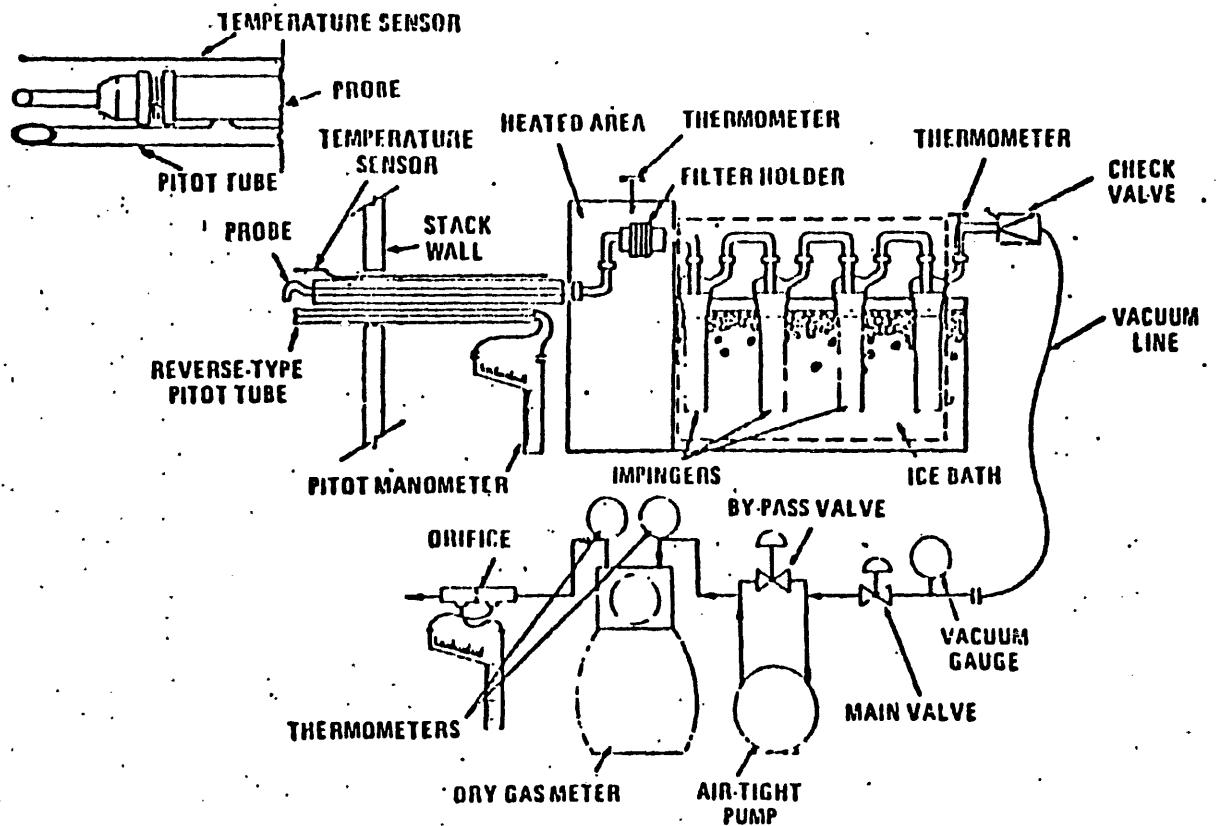


Figure 1 - Inorganic Lead Sampling Train (From U. S. Federal Register, p. 16576, April 16, 1982).

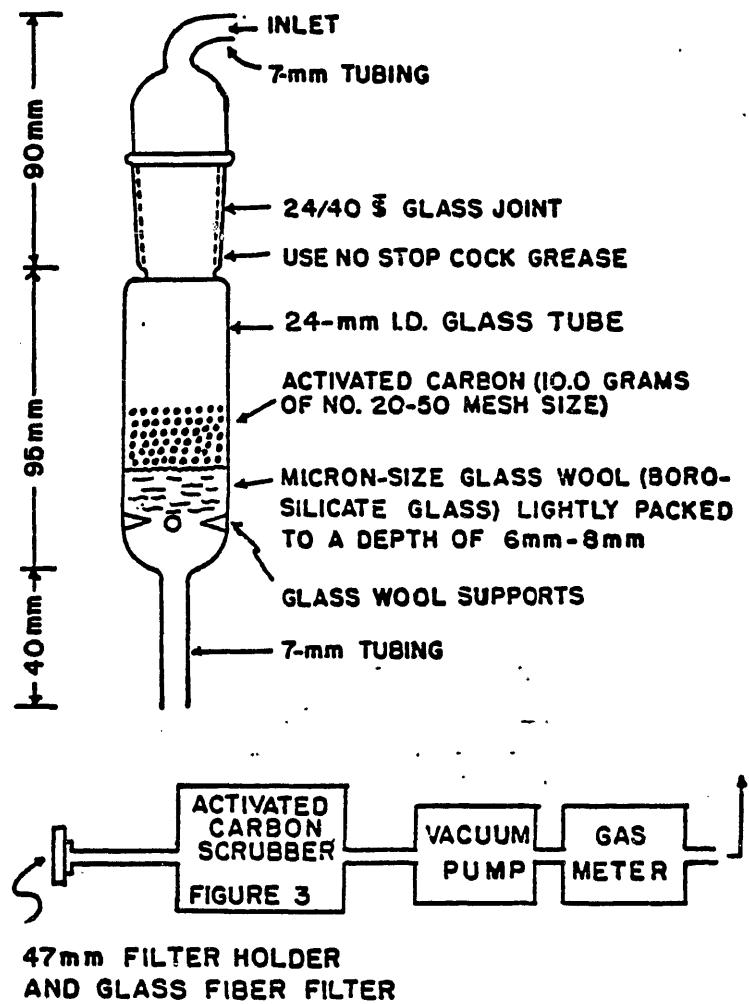


Figure 2 - Activated Carbon Scrubber and Sampling Train (From ASTM Test Method D3112-77)

14. For the dithizone method, the filter sample is digested with nitric and perchloric acid, and the dissolved lead then determined colorimetrically. For the carbon column portion of the samples, the lead is separated from the activated carbon with hydrochloric and nitric acids, filtered, and the lead in the filtrate determined colorimetrically.

15. In the presence of weak ammoniacal-cyanide solution (pH 8.5 to 9.5) dithizone gives colored complexes with bismuth, stannous tin, monovalent thallium, and indium. In strong ammoniacal-citrate-cyanide solutions (at pH of about 11.0), the dithizonates of these ions are unstable and are only partly extracted with chloroform-dithizone solution. The method has been found to be without interference from 20 micrograms of bismuth, 20 of monovalent thallium, 100 of stannous tin, and 200 micrograms of trivalent indium. The ASTM procedure includes various steps to reduce the effects of these and other interfering ions.

AMBIENT AIR MONITORING

Sampling

16. When the atomic absorption spectrophotometer is to be used for the analyses, ambient air samples are best collected with a high-volume air sampler. This type of sampler utilizes a vacuum-like device to draw large volumes of air through a fiber glass filter on which particulates are collected for measurement and analysis. The sampler must be capable of passing environmental air through a 406.5 cm^2 portion of a clean glass fiber filter at a rate of at least $1.70 \text{ m}^3/\text{min}$. The motor must be capable of 24-hour continuous operation, which is usually the normal sampling period.

17. The glass-fiber filters should have a collection efficiency of at least 99 percent for particles 0.1 to 100 microns in size. If other filter materials are used, care must be taken to use filters that contain very low background concentrations of the pollutant being investigated, which in this case would be lead.

18. The total air flow through the sampler is based on rotameter readings taken at the beginning and end of the sampling period. The procedure assumes that the decrease in flow is linear with time and that the 24-hour rate as recorded is a representative average of the entire sampling period.

19. While the high-volume sampler does not entrap all of the vapor fraction it is considered that the portion not entrapped is widely dispersed and highly diluted by the time the plume reaches the ground. Ambient sampling, for the most part, is done outside the plant fence. Therefore, it is generally assumed that the particulates collected by the sampler contain essentially all of the lead present in the ambient air.

20. When the dithizone analytical method is to be used, the sampling train shown in Figure 2, and briefly described above, is to be used.

Analyses

21. The U.S. Environmental Protection Agency procedure designated as "Reference Method for the Determination of Lead in Suspended Particulate Matter Collected from Ambient Air" is the method of choice for determining the lead-content of samples collected on the high-volume glass-fiber filter.
22. Lead in the particulate matter collected by the fiber-glass filter is solubilized by extraction with nitric acid (HNO_3) facilitated by heat, or by a mixture of HNO_3 and hydrochloric acid (HCl) facilitated by ultrasonication, which will extract metals other than lead from the particulate matter.
23. The lead content is determined by atomic absorption spectrophotometry, using an acetylene flame, the 283.3 or 217.0 nm lead absorption line, and the optimum instrumental operating conditions recommended by the manufacturer.
24. The typical range of the method is 0.07 to 7.5 micrograms Pb/m³, assuming an upper linear range of analysis of 15 micrograms/ml and an air volume of 2400 m³.
25. Both chemical and light scattering interferences are possible with this method. Most analysts report an absence of chemical interferences. Where interferences do occur, the published method includes the steps necessary to reduce or eliminate both types of interferences.
26. When the USEPA method cannot be used due to lack of proper instrumentation or for other reasons; then the ASTM dithizone method may be used. The procedure is briefly described above.

WASTEWATER MONITORING

Sampling

27. Wastewater sample collections should be based on the actual process operations. Composition of the effluents will vary either with time or flow. Composite samples, consisting of portions collected at intervals over a 12 to 24-hour period, are considered to be most representative, although grab or spot samples may be collected for special purposes.
28. Where the composition varies according to time, the samples should be of equal volume. Where the samples vary according to the flow, the sample size should be in proportion to the flow. For situations when samples must be collected at frequent intervals over long periods, the use of automatic samplers is recommended.
29. Preliminary sampling throughout the plant, to include all important sources of the pollutant, will indicate the location and minimum number of sampling stations. It is important to know the lead content of individual waste streams within the plant, as well as in the final effluent. Since flows must also be determined, it is considered best to combine the flow measurement station with the sampling station whenever possible.

30. Sampling stations should be located so that (a) the flow of the waste streams is known or can be determined; (b) the station is easily accessible, with no safety hazards for personnel; and (c) the wastewater is thoroughly mixed. When flumes are used for measuring flows, the sample is usually well-mixed. If weirs are used to measure flows, the waste stream may not necessarily be well-mixed, since solids tend to settle behind the barrier while floating material passes over the weir.

31. The total volume of sample to be collected will depend upon the analytical procedure to be used. The volume should be sufficient to allow for repeating the analysis, supplying samples to other laboratories for check purposes where indicated, and similar factors. Care should be taken to properly preserve the samples during the sampling period and in transporting to the laboratory, so that the composition does not change between collection and analysis.

Analyses

32. Atomic absorption spectrophotometry is the method of choice for routinely determining lead in waste waters, as is the case with air-borne effluents. The method is rapid, sensitive, and specific for the particular metal involved. The procedure is described in detail in the Fifteenth Edition of "Standards Methods for the Examination of Water and Wastewater".

33. Where the atomic absorption spectrophotometer is not available, lead concentrations may be determined by the dithizone method, also described in "Standard Methods". In this procedure, an acidified sample of lead is mixed with ammoniacal citrate-cyanide reducing solution and extracted with dithizone in chloroform, to form a cherry-red lead dithizonate. The color of the mixed solution is then measured colorimetrically. The procedure may be subjected to interference from bismuth, stannous tin, and monovalent thallium. Modifications are provided to avoid interference from these elements, particularly excessive quantities of bismuth or tin.

BIBLIOGRAPHY

1. U.S. Code of Federal Regulations, Title 40, Sub-Chapter C, Part 60, Subpart L, "Standards of Performance for Secondary Lead Smelters" and Subpart R, "Standards of Performance for Primary Lead Smelters". Office of the Federal Register, GSA, Washington, (July 1, 1981)
2. U.S. Federal Register. "Standards of Performance for New Stationery Sources; Lead-Acid Battery Manufacture". Vol. 47, No. 74, pp 16564-16579. Washington. (April 16, 1982).
3. American Society for Testing and Materials (ASTM). "Standard Test Method for Lead in the Atmosphere by Colorimetric Dithizone Procedure". ANSI/ASTM D-3112-77. Philadelphia (1977).
4. U.S. Code of Federal Regulations, Title 40, Subchapter C, Part 50. "National Primary and Secondary Ambient Air Quality Standards". Office of the Federal Register, GSA, Washington (July 1, 1981).

5. American Public Health Association. "Standard Methods for the Examination of Water and Waste water". 15th Edition. New York (1980).
6. "Treatment of Industrial Effluents". Edited by A.G. Callely, C.F. Forster, and D.A. Stafford. Halsted Press Division of John Wiley & Sons, Inc. New York (1976).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AND HEALTH AFFAIRS

MEAT PROCESSING AND RENDERING

INDUSTRIAL WASTE DISPOSAL

1. Meat processing plants are those whose operations are confined to dressing and curing of carcasses, to preparing specialty and other products, and to canning, following slaughter of the animals. The raw input generally consists of carcasses of cows and hogs. Processing operations may be carried out in conjunction with a slaughterhouse or at a separate location. Slaughterhouses will not be covered in these guidelines since they are the subject of a separate document.
2. A rendering plant is one which converts the inedible and discarded remains of the animals (such as fats, bones, heads, blood, and offal) into useful by-products such as lard, tallow, oils and proteinaceous solids. Rendering may be done on-site as an adjunct to processing operations or off-site as an independent operation.

INDUSTRIAL PROCESSES

3. Meat processing produces a number of products which may be generally grouped as follows:

- Meat cuts and related products (such as steaks, chops, roast and hamburgers) for hotels, restaurants and private consumers;
- Hams and bacon, requiring curing in pickling solutions followed by cooking and smoking, cooling, and slicing or other preparation prior to packaging and marketing;
- Comminuted meat products, requiring substantial size reduction and mixing. The final product will be in a casing or container, such as sausages or sausage meat; and
- Canned products such as hams, sandwich spread and pet foods.

4. Most plants will produce a mix of these, although some do confine themselves to one specialty only.

5. Plant waste waters usually discharge through catch basins, grease traps, or flotation units. While there is a waste reduction benefit, the basic purpose of this procedure is to separate the greases for later by-product recovery, rather than to provide waste treatment per se.

6. In the rendering operation, the bulk material (offal, bones, trimmings, etc.) are dumped into a pit and then conveyed to a grinder, when grinding is necessary. The raw mixture is next heated or cooked to melt the tallow or grease and permit separation from the proteinaceous materials. The proteinaceous material, also known as "cracklings", is normally screened and ground to produce a meat and bone product. Both edible and inedible by-products result from the rendering operation, depending upon the composition and freshness of the raw materials and on the procedures used.

SOURCES AND CHARACTER OF WASTES

7. Liquid wastes, carrying various amounts of solids are the major concern in this industry. Solid wastes, resulting mainly from screening and housekeeping, may also be of concern but this will depend upon the degree of separation and by-product recovery practiced at the individual plant. Other than odor problems, gaseous wastes are not significant. The purely hazardous types of components, such as heavy metals and pesticides, are not normally found in meat processing effluents.

8. The most important parameters applicable to liquid effluents are 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), oils and greases (O + G), hydrogen-ion concentration (pH), and fecal coliform organisms. In addition, phosphorous may be of concern in meat processing while ammonia may be of significance in rendering operations.

9. Odors can originate from both point and non-point sources. They generally result from bacterial activity on organic matter, the heating of animal materials, and the handling of warm animal residues.

10. The processing of carcasses and remains adds to the waste loadings as follows:

- Preparation of meat materials. Large volumes of highly contaminated waste are generated in thawing raw materials by water immersion. The breaking, cutting, trimming, and boning of meats for further processing generates very little flow and waste load. Waste loads originate primarily from cleaning the equipment used for grinding, mixing, blending, and emulsifying the processed materials into other products. Additional wastes are generated from extrusion, stuffing, or molding operations related to forming or containerization of the product mixture prior to cooking.
- Pickling or curing operation. This involves use of a solution for pickling hams, bacon and other products. Wastes result from the nature of the process and the washing down of floor areas.
- Product cooking. Products are generally cooked in ovens (smokehouses) or in wet cookers using live steam or hot water. Wastes are generated principally from the spraying applied to drench the products after cooking and from equipment cleaning.

— Canning. Large volumes of water are generated in the canning operation. Plants using automated canning lines will discharge less water and wastes from this source.

11. In the rendering industry the major waste sources are from raw materials receiving, condensing cooker vapors, plant cleanup, and truck and barrel washing. These mainly contain organic matter and suspended solids, along with various inorganic substances. The waste materials found in the effluents include blood, meat and fatty tissue, body fluids, hair, dirt, manure, hide curing solutions, tallow and grease, meal products, and caustic or alkaline detergents.

12. Typical raw waste characteristics for various types of operations are shown in Table 1.

Table 1. Typical Raw Waste Characteristics - Meat Processing and Rendering.

Type of Plant	Flow (Liters)	BOD ₅ (Kg)	TSS (Kg)	O + G <u>a/</u> (Kg)
Per Megagram of Final Product (FP) [*]				
Small Processor <u>b/</u>	3,330	1.1	0.80	0.49
Meat Cutting	600	0.52	0.64	0.12
Sausage and Lunch Meats	9,600	2.6	3.5	1.2
Ham Processing	10,600	5.5	3.3	2.4
Meat Canning	11,200	12.	4.5	2.1
Per Megagram Raw Material Input (RM)				
Rendering <u>c/</u>	3,260	2.2	1.1	0.72

a/ O + G = Oils and Greases

b/ Total production = less than 2,700 Kg/day

c/ Following in-plant materials recovery using catch basins, skimmers, etc.

* 1 megagram = 1 metric ton

Table 2. Daily Maximum Effluent Limitations - Meat Processing and Rendering Plants

Type of Plant <u>a/</u>	BOD ₅ (Kg)	TSS (Kg)	Oils + Greases (Kg)
	Per Megagram of Final Product (FP)		
<u>Small Processor b/</u>	(No discharge allowable) <u>c/</u>		
Meat Cutting	0.02	0.02	0.01
Sausage and Lunch Meat	0.28	0.38	0.20
Ham Processing	0.32	0.42	0.22
Meat Canning	0.34	0.44	0.26
Per Megagram Raw Material Input (RM)			
<u>Rendering Plant d/</u>	0.14	0.20	0.10

a/ For all plants: pH = 6 to 9; Fecal Coliform MPN 400/100 ml.

b/ Total Production = less than 2,700 kg/day.

c/ May be discharged to municipal system with adequate pretreatment.

d/ For plants where hide curing is carried out, the following additive adjustments are to be made:

$$\text{BOD}_5 = \frac{6.2 \times (\text{no. of hides})}{(\text{Kg of RM})}$$

$$\text{TSS} = \frac{12.6 \times (\text{no. of hides})}{(\text{Kg of RM})}$$

CONTROL AND TREATMENT OF WASTES

13. As has already been stated, the principal and usually only air pollution problem connected with the meat processing and rendering industries is that of odors, particularly in the rendering operations. Other possible sources are the smokehouse operation and the dryers. Air scrubbers are most commonly used for odor control. To avoid increasing the liquid waste loading the scrubber water may be recycled if the air is not too heavily loaded with smoke and grease particles.

14. Liquid waste discharges to receiving waters can be reduced in volume and concentration through effective water management, in-plant waste controls, process modifications, and by the use of treatment systems. The wastes may also be released to municipal systems provided that certain pretreatment measures are taken prior to discharge from the industry.

15. In-plant control techniques include the use of screening, skimming, or settling (alone or in combination) to reduce the discharge of solids. Because these solids, to a large degree, can be processed into saleable by-products this treatment step is routinely employed in most plants. Excess solids can be hauled to a landfill. Where possible, steps should be taken to prevent useful materials from reaching the floor in order to reduce general cleanup operations. This conserves water and reduces effluent flows. Catch basins can be employed for separation of greases and other solids. Dissolved air flotation systems have also been effective in removing grease and finely suspended solids.

16. Biological systems can generally be effective for treating these wastes, particularly where in-plant "primary" treatment for recovery of useful solids is being utilized. Secondary treatment, such as anaerobic processes, aerobic lagoons, the activated sludge process, and high-rate trickling filtration are the techniques most frequently used.

17. If treatment beyond "secondary" is required the effluent may be subjected to slow sand filtration, microstraining, spray-irrigation, ion-exchange, or other tertiary systems.

SUGGESTED REFERENCES

1. "Information Sources on the Meat Processing Industry", UN Industrial Development Organization. Doc. UNIDO/LIB/SER.D1/Rev.1 New York (1976)
2. Jones, Harold R. "Pollution Control in Meat, Poultry, and Seafood Processing". Noyes Data Corporation., Park Ridge, N.J., and London (1974).
3. Levie, Albert, "The Meat Handbook", AVI Publishing Co. Westport, Conn. (1963).
4. U.S. Environmental Protection Agency-Development Documents for Effluent Limitations Guidelines and New Source Performance Standards for the Meat Products and Rendering Processing Point Source Category, as follows:

- (a) Doc. EPA-440/1-74/031, Processor Segment (August 1974)
- (b) Doc. EPA-440/1-74/031-d, Group 1. Phase II, Renderer Segment (January 1975)

5. U.S. Environmental Protection Agency "Upgrading Meat Packing Facilities to Reduce Pollution", EPA Technology Transfer Seminar Publication. 3 Vols. Washington (October 1973).

THE WORLD BANK

JULY 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

GUIDELINES

STRIP (SURFACE MINING OPERATIONS)
SEDIMENT AND EROSION CONTROL (LAND RECLAMATION)

1. Control of erosion and sedimentation has assumed a new importance in view of world-wide industrial expansion and increased energy needs. Greater reliance is being placed on coal as a major energy source. Many mineral ores and coal supplies are readily accessible through strip (or surface) mining operations. Therefore measures are necessary to protect the environment from uncontrolled soil movement and offsite damage that could result from such operations.
2. Measures are also necessary to ensure the safety of workers and others who are required to be at or near the site. On March 24, 1981, 19 persons were buried alive when their homes, located at the edge of an open cast tin mine, were destroyed by a landslide. The ground on which the homes were standing slipped 60 meters downhill into an excavation. This tragic event occurred at Puchong, Selangor State, Malaysia.
3. Each Bank appraisal report should include a complete and detailed proposal, with a timetable, for controlling erosion and sedimentation which could result from projects. The plan should provide for initiating land reclamation and other necessary measures in the early project stages, and in no case later than three (3) years following the start of mining operations.
4. These guidelines present basic concepts and sources of sediment pollution, principles of control, and the planning needed for effective control measures.

CONCEPTS AND SOURCES OF SEDIMENT POLLUTION

5. Surface mining, like any large-scale earth-moving operation, can generate large volumes of sediment. If the sediment can be contained within the mining site, then no problems are created. However, if the sediments are not contained but are allowed to reach adjacent waterways, as is most frequently the case, then they become pollutants.
6. As pollutants, the sediments can have a number of detrimental effects, such as:

- Reducing storage capacity in reservoirs;
- Filling lakes and ponds;
- Clogging stream channels;
- Destroying aquatic habitats;
- Increasing water treatments costs; and
- Acting as carriers of other pollutants (such as plant nutrients, insecticides, heavy metals and disease organisms).

7. The major sources of sediment pollution are those land-disturbing activities associated with mining, construction, agriculture, and forestry. It has been reported that active surface mining and construction operations cause the highest rates of erosion.

8. The major sources of sediment in surface mining operations are the areas being cleared, grubbed (removal of stumps and roots), and scalped (removal of vegetation cover); roadways; spoil pits; and active mining areas.

9. Soil losses from clearing, grubbing and scalping operations are caused by:

- Failing to install perimeter control measures prior to start up of operations;
- Exposing soils or steep slopes;
- Clearing too far above the unexcavated face of the overburden;
- Clearing and grubbing too far ahead of the open cut;
- Improperly placing or protecting the salvaged or stock-piled materials; and
- Creating a surface that impedes infiltration or concentrates surface runoff, such as leaving bulldozer cleat marks that run up and down a slope.

10. Roadways are often the major source of sediment, and may function as conduits for sediment washing down from other areas into the natural drainage systems. This includes the roadways within the mining area itself as well as the access roads outside the actual mine site.

11. Long access roads can adversely disrupt the natural drainage systems by intercepting, concentrating and diverting runoff. This will result in severe soil losses from roadway surfaces, ditches, cut slopes and safety berms.

12. Accelerated onsite and offsite erosion will occur after the mine ceases operations if steps are not taken to permanently stabilize exposed surfaces with vegetation and to otherwise lessen disruption of the normal drainage patterns.

13. In area strip mining operations, carried out in level or gently rolling topography, the spoil accumulating below the outcrop line has the greatest potential for causing offsite sediment damage. Water pumped from the pit during rainfall can also contribute significant quantities of sediment and other contaminants.

14. Contour strip mining, carried out in steep or mountainous terrain has a much greater potential for sediment damage. Since contour mines have a narrow, linear configuration more of the spoil area tends to discharge directly into the natural drainage systems. Another contributing factor is that the receiving waterway is generally closer to the sediment source and separated by relatively steep terrain. Additionally, the mine site receives erosive runoff from undisturbed areas above it.

15. Mountain-top removal mining has, in recent years, been an alternative to strip mining. The most critical areas at this type of operation are the spoil slopes around the perimeter, mine roadway exits, and valley fills. The fills are highly susceptible to piping (subsurface removal of soil) and to landslides. Another serious problem can be the soil losses from the face of the slope due to rainfall and runoff. Chemical and acid pollution can also cause serious problems.

16. Certain reclamation practices contribute significantly to environmental damage if not properly carried out. Configuration of the graded areas, the pattern of reestablished drainageways, revegetation measures, tillage practices, and followup maintenance will all influence the long term soil losses and offsite damages.

PRINCIPLES OF EROSION AND SEDIMENT TRANSPORT

17. As applied to mining operations the most important types of erosion are those caused by a stormwater runoff. Three basic types are of major significance:

- Sheet erosion - resulting from rain striking a bare soil surface, and displacing soil particles;
- Rill and gully erosion - removal of soil by water through small, well-defined channels; and
- Stream channel erosion - scouring of the stream channel by sediment reaching the stream from land surfaces.

18. The erosion potential of any area is determined by climate (precipitation, temperature and wind); vegetative cover; soil characteristics (structure, texture, organic matter, moisture, and permeability); and topography. While these factors must be considered separately, it is their combined effects which determine the total erosion potential.

19. Sediment transportation and deposition are influenced by the flow patterns of the water and the nature of the particles being transported. As velocity and turbulence increase, more sediment is transported. Small, light particles such as fine sand, silt and clay are easily transported. Conversely, coarser and heavier particles are more readily deposited.

CONTROL TECHNOLOGY

20. Stormwater runoff, which is the basic cause of soil erosion, can be controlled through applications of proper vegetative and structural practices, and construction measures that control the location, volume, and velocity of runoff. To this should be combined a suitable program of scheduling mining operations to minimize problems related to seasonal climatic fluctuations.

21. Control may be accomplished through one or more of the following:

- Reduction and detention of the runoff;
- Interception and diversion of the runoff; and
- Proper handling and disposal of concentrated flow.

22. Soil stabilization is another means of preventing soil erosion. Stabilization measures may be either vegetative or non-vegetative, short term or long term, or a combination of these. Vegetative stabilization utilizes different types of vegetation to protect the soil from erosion. Non-vegetative stabilization employs a multitude of measures that depend on materials other than vegetation to prevent erosion. Frequently the two types are used together.

23. Mulching and chemical stabilization are the two major types of short term measures applied. Mulching, with organic materials such as straw, hay, wood chips, wood fiber or other products, is most often used. Chemical stabilizers serve to coat and penetrate the soil surface and bind the soil particles together. These are most effective for dry, highly permeable spoil or in-place soils subject to sheet flow.

24. Mulching and channel stabilization are most frequently used for long term stabilization. However, mulching in this case involves the use of fiber glass, plastics, or other non-biodegradable material to protect seed beds during the germination and early plant development periods. In general, structural channel stabilization involves the use of stone riprap (broken rock) or other durable material to stabilize ditches and other waterways. Stone surfacing is sometimes used to stabilize highly toxic surfaces or excessively wet seepage areas on slopes.

25. Sediment is the product of erosion and hence must be contained, and every effort should be made to control sediments at, or as close to, the source as possible. The procedures used successfully for trapping (such as sandbags and straw bales), settling basins and chemical coagulation.

26. All erosion control and sediment containment facilities must receive proper maintenance during their design life in order to perform effectively. They should be located in a highly visible area so as not to be overlooked. They must also be readily accessible to personnel and equipment for regular inspections, and for the performance of routine and emergency repairs.

27. Once the mining operation is finished, all sediment control structures should be disposed of in such a way as to prevent both the structures and the accumulated sediments from becoming nuisances and contributing to environmental deterioration.

EFFLUENT LIMITATIONS

28. Runoff and drainage from surface mining operations should not exceed the following limitations prior to discharge into surface waters:

Total Suspended Solids:	30 - 100 mg/L
Total Iron	4 - 7 mg/L
pH	6 - 9
Alkalinity	Greater than acidity
Soluble Toxicants	None

CONTROL PLANNING

29. An erosion and sediment control plan serves as the basis for operating the mine and at the same time minimizing or eliminating environmental damage.

30. Preparation of a control plan requires five basic steps:

- Identification of legal and technical requirements;
- Collection and evaluation of site information;
- Development of a control strategy;
- Interdisciplinary review of the feasibility of the preliminary plan; and
- Revision and finalization of the control plan

31. Table 1 presents a list of the major components which should be considered in formulating an erosion and sediment control master plan. This should be made an integral part of the overall mining operation.

LAND RECLAMATION

32. Surface mine reclamation shall be performed in such a manner that the lands are returned to conditions capable of supporting prior land uses or uses that are equal to or better than prior land use. The operator must backfill and grade to cover all acid and toxic materials. Highwalls and spoil piles must be eliminated and the approximate original contour restored. All surface areas must be stabilized and protected in order to control slides, erosion, subsidence and accompanying water pollution. Water impoundments, retention facilities, dams, or settling ponds shall be adequate for intended land use. These facilities cannot produce significant adverse effects to adjacent water resources. Operators must use best practicable commercially available technology to minimize, control, or prevent disturbances to surface or underground water quality, quantity, or flow. Mining wastes and rubbish must be properly disposed of so as to minimize, control, or prevent water pollution.

33. It is important that land reclamation be started as soon as possible and at the latest 3 years after the opening of the mine. The Bank Mission should receive concrete and detailed proposals on the reclamation program and on the means necessary to achieve it.

BIBLIOGRAPHY

1. Grim, E.C. and R.D. Hill. "Environmental Protection in Surface Mining of Coal". U.S. Environmental Protection Agency - Technology Series, Doc. EPA-670/2-74-093. Washington (October 1974).
2. U.S. Environmental Protection Agency "Erosion and Sediment Control". (2 Vols.) Doc. EPA-625/3-76-006. Washington (October 1976).
3. "Guidelines for Reclamation and Revegetation, Surface-Mined Coal Areas in Southwest Virginia". Virginia Polytechnic Institute and State University, Extension Division. Blacksburg, Virginia (February 1973).

Table 1. Components to be Considered for Preparation of Erosion and Sediment Control Plans a/

Background information:	Schedule of activities—continued:
1. General: <ul style="list-style-type: none">Location of projectExtent of area to be affectedType of mining operationEvidence of compliance with State's legal requirements	Mining operations—continued:
2. Site inventory: <ul style="list-style-type: none">TopographyGeologic analysisSoil analysisClimatic analysisHydrologic analysisVegetative analysisLand use analysis	2. Overburden handling:
Schedule of activities:	Method of overburden handling
Site preparation:	Handling of first cut
1. Access roads: <ul style="list-style-type: none">Plan view (location)Typical cross sectionProfilesMaintenance requirements and schedule	Plan view of overburden storage areas
2. Drainage and sediment control structures: <ul style="list-style-type: none">Plan view (location)Typical cross sectionsDetails (where needed)Design computations (where needed)Maintenance requirements and schedule	Stormwater handling in overburden storage areas
3. Clearing and grubbing: <ul style="list-style-type: none">Plan views of limits of areas to be clearedDescription of procedureMachinery to be usedMethod of disposing of timber, brush, and waste materialsIdentification of critical areas requiring temporary stabilization	Temporary stabilization measures
Mining operations:	Permanent stabilization measures
1. Scalping: <ul style="list-style-type: none">Method of scalping topsoil materialEquipment to be usedPlan view of topsoil storage areasTemporary vegetative stabilization of stockpile areas	Reclamation operations:
	1. Handling of toxic material:
	Method of handling toxic material
	Equipment to be used
	2. Spoil rehandling and grading:
	Typical cross section of regrading
	Equipment to be used
	Method of spreading topsoil or upper
	horizon material on the regraded
	area, including approximate
	thickness of the final surfacing
	material
	Method of drainage control for the
	final regraded area
	3. Revegetation:
	Method to be used
	Surface preparation
	Type of vegetation
	Fertilizer application (method and
	rate)
	Seasonal revegetation schedule and
	rate
	Mulch application (method and rate)
	Maintenance requirements and sched-
	ule
	4. Mine abandonment:
	Method for disposal and stabilization
	of drainage structures not cov-
	ered above, particularly sediment
	basins
	Method for stabilization and/or aban-
	donment of haul road
	Assignment of responsibility for any
	permanent structures left behind
	Maintenance program and schedule
	for any permanent structures left
	behind

THE WORLD BANK

FEBRUARY 1981

OFFICE OF ENVIRONMENTAL AFFAIRS

UNDERGROUND COAL MINING

EFFLUENT GUIDELINES

1. Many of the world's mineral resources are extracted from the earth through underground mining operations. The principal ones include coal, and to a lesser degree, copper, lead, zinc, molybdenum, uranium, and others. This document will be confined to the environmental effects of underground coal production and its associated operations.

MINING PROCESSES

2. Underground mining is a highly complex operation, involving basically working beneath a thick overburden, connected to the outside by shafts and passageways which are sometimes hundreds of meters long. Major problems which are not found or are of lesser importance in surface mining include roof supports, ventilation, lighting, drainage, methane release, equipment access and coal conveyance.

3. Once a main access portal has been established, parallel entries are driven into the coal deposit to provide corridors for haulage, ventilation, power and other operational needs. Cross-corridors then reach to the sides of the mine, leaving pillars in a checkerboard fashion to support the roof and overburden. The deeper the mine, the larger the pillars must be relative to the mined out areas. Where large pillars are required for support during operations it may be desirable to mine the pillars as the equipment retreats back toward the main tunnel. The roof must then be supported by other means or allowed to collapse.

4. Equipment used in underground mining ranges from relatively simple to highly automated machinery. Many small mines still rely primarily on hand labor. Coal is blasted from the face of the seam and loaded into shuttle cars, using mechanical techniques in most cases. This involves undercutting, drilling, blasting and loading. Shuttle cars, filled by portable conveyor belts, take the coal either to an underground transfer point or directly out of the mine.

5. These operations produce large amounts of dust and liberate methane trapped in the coal, requiring that exposed areas be kept essentially free of particulates or open flames to prevent coal dust or methane explosions. Machines are usually connected to a water supply to provide a spray for dust control. Frequent methane testing is required at the seam face to avoid danger to the workers.

6. Continuous machines are employed in many locations. Basically a rotating head digs into the coal and loosens it while arms scoop it onto a conveyor belt for loading into a shuttle car.

7. Longwall mining has been used in Europe for many years and is now gaining popularity in other regions. Corridors about 100 to 200 meters apart are driven into the coal and interconnected. The longwall of the interconnection is then mined in slices. The roof is held up by steel supports while the cutter makes a pass across the face. The roof supports are advanced with the shearing machine to make a new pass, while the roof in the mined out area collapses behind the supports.

8. For most uses, the mined coal must be processed to meet consumer needs in terms of size, moisture, mineral concentrations, heat content and other properties. This may be done by either physical or chemical procedures, and usually takes place at the mine site.

9. Physical coal cleaning involves crushing, grinding, sizing, solids separation, washing and flotation in various combinations. These techniques remove portions of the sulfur and ash contents. Although the sulfur exists in the coal in both the organic and inorganic forms, physical cleaning is effective only in reducing the inorganic portion. Because of partial ash removal, the procedure also increases the per kilogram heat content.

10. Chemical coal cleaning or desulfurization involves treating coal with a reagent capable of converting the sulfur to a soluble or volatile form. Leaching solutions such as nitric acid, hydrofluoric acid, chlorine, ammonia, and organic solvents have been reported to be successful. However, this cleaning procedure is still in the experimental stage and is not currently being applied commercially.

SOURCES AND CHARACTERISTICS OF WASTES

11. Coal mining operations and equipment choices vary widely, and are generally selected on the basis of local geology and other natural conditions. The specific environmental effects will depend upon the mining techniques utilized and the existing geological or geochemical characteristics.

Air Emissions

12. Air pollutants from coal mining operations are not considered to be significant. Dusts originate from drilling and blasting procedures, but these are generally controlled by water sprays at the working face. Methane is controlled through effective ventilation with air in order to reduce the gas concentrations to levels below the flammable or toxic limits, and thus avoids the possibility of underground explosions. The methane problem increases with greater depths because the methane has less opportunity to diffuse to the surface over geologic time. It has been estimated that at mining levels methane is produced at an average rate of 5 cubic meters per ton of coal mined.

Liquid Effluents

13. The principal environmental pollutant resulting from underground coal mining operations is acid mine drainage. The acidity results when naturally occurring pyrite (FeS_2) in the coal seam and wastes is oxidized in the presence of air and water to form sulfuric acid (H_2SO_4) and iron sulfates ($FeSO_4$ and $Fe_2(SO_4)_3$). This very acidic (pH 2 to 3) effluent must be treated for pH and dissolved iron before release to water courses. At the low pH values heavy metals (such as iron, manganese, cadmium, copper, zinc, and lead) are more soluble and can create serious water pollution problems. Continuous acid discharges will seriously affect aquatic ecosystems. Acid waters containing heavy concentrations of dissolved heavy metals will support only a limited water flora, such as acid-tolerant molds and algae, and will not support fish. Acid waters are not suitable for human consumption nor for most industrial uses.

14. The amount and rate of acid formation and the quality of water discharged will depend upon the amount and type of pyrite in the overburden and in the coal, time of exposure, characteristics of the overburden, and amount of available water. It has been estimated that in the Appalachian bituminous coal mining regions of the eastern United States an average of 1200 liters of acid mine water is discharged for each metric ton of coal mined.

15. Water is supplied to coal mines primarily for suppressing dust (continuous mining and conveyor belt operation) and for equipment cooling. Rain water can enter mine areas through infiltration. Hence, continuous water removal is required to assure continuity and efficiency of the mining process.

16. In coal preparation the water is deliberately introduced into the unit process operations which include wet screening, tables, cyclones, gravity separation and heavy media separation. Water is also used for dust control, equipment cooling, and transporting coal in the washing process.

17. The parameters of principal concern in underground coal mining operations and for coal preparation plants include hydrogen ion concentrations (pH), total suspended solids (TSS), total iron, and total manganese. Average levels of these parameters found in typical underground mining and coal preparation plants are given in Table 1.

Solid Wastes

18. Solid wastes are generated both during underground mining and during the preparation process. The solid waste from underground mines (commonly referred to as "gob") results from the digging required to reach the coal seams. Normally this material is transported to the surface and dumped in piles on the land. Its composition in general corresponds to the overburden found in the mining area.

Table 1. Average Quality of Raw Effluents From Acid Mine Drainage and Coal Preparation

Parameter	Acid Drainage	Coal Preparation
Total Susp. Sol. - mg/L	158	218,000
Total Manganese - mg/L	4.9	8.4
Total Iron - mg/L	135	733
pH - Units	5.7	7.0

19. Refuse from the coal extraction and preparation, consisting of solid wastes and other impurities, is also generally disposed of by dumping on nearby land areas.

20. The waste piles are unsightly, causing degradation of local property values and destruction of aesthetics. The refuse contains flammable material readily susceptible to spontaneous combustion and difficult to quench. This burning produces particulate matter and fumes high in sulfur dioxide. Acid mine drainage and siltation can also result from runoff from the piles. Siltation is influenced by the steepness, compaction, drainage control structures, and cover material of the pile.

WASTE DISCHARGE LIMITATIONS

Air Emissions

21. Dust and methane gas are the principal air pollutants of concern in underground mining. Particulates should be controlled by water sprays. Methane gases should be controlled by efficient ventilation systems bringing outside air to the working areas.

22. Coal preparation plants can be sources of discharges of particulate matter to the atmosphere. Pneumatic cleaning and thermal drying are the chief sources. Particulates should be limited to:

Ann. Geom. Mean	75 $\mu\text{g}/\text{m}^3$
Max. 24-hours	260 $\mu\text{g}/\text{m}^3$
(outside the mine fence at ground level)	

Liquid Effluents

23. Liquid effluents from subsurface mining and coal preparation operations should conform to the limitations shown in Table 2.

Table 2 - Effluent Limitations for Acid Mine Drainage and Coal Preparation

Parameter	Limitation
Total Susp. Sol. - mg/L	70
Total Manganese - mg/L	4
Total Iron - mg/L	6
pH - Units	6 to 9

CONTROL AND TREATMENT OF WASTES

Air Emissions

24. Dust control in the mines is effected by continuous spraying of the working face. The methane is diluted with air to less-than-flammable limits to avoid the possibility of underground explosions. In some instances the methane can be drained from the coal seam before mining. Such an operation recovers the gas for use as a fuel and at the same time reduces the danger of mine explosions.

25. Particulate matter from coal preparation originates from crushing, pneumatic cleaning and thermal drying. These emissions can be effectively controlled by use of baghouses or other dust collection devices.

Liquid Effluents

26. The acidity in the acid mine drainage may be controlled through pH adjustment and chemical precipitation. Hydrated lime ($\text{Ca}(\text{OH})_2$) is most commonly used for this purpose, and can be introduced as an aqueous slurry or as a dry powder. In large installations calcined lime (CaO) (also termed "unslaked" or "quick" lime) or limestone (Ca CO_3) may be more economical to use. Caustic soda (Na OH) or soda ash (Na_2CO_3) can also be used, but are much more expensive.

27. Control of the pH will also result in a reduction of the iron and manganese levels in the effluent, by causing oxidation which converts the ferrous iron to ferric iron and thus precipitates it out of solution. The upward adjustment of the pH causes a solubility decrease and precipitation of the heavy metals in the effluent. The precipitates can then be removed by settling.
28. The effectiveness of neutralization and settling in controlling the effluent is governed by the reagents used, the influent and effluent pH, temperature, volume of flow and the presence of any side reactions, including metal chelation and mixed-metal hydroxide complexing.. (Chelation is a chemical reaction in which a central metallic ion is captured in a complex within a ring containing several atoms).
29. Oxidation of certain components common to coal mine wastewaters (such as ferrous ions) to easily removed compounds can also be accomplished by aeration, either mechanical or simple cascading flow. The resulting sludge and other solids are readily settled in settling basins.
30. Wastewater from coal preparation plants may be satisfactorily treated by settling. If the settling pond capacity is limited it may be necessary to use a coagulant. The overflow from the ponds is generally suitable for recycling through the preparation systems, resulting in little or no discharge to surface waters. Where sufficient land area is available two or more ponds are used on an intermittent basis. As a pond is filled with settled solids, it is taken out of service for removal and disposal of the sludge.

Solid Wastes

31. Refuse from the mining operation may be left underground but in most cases it is brought to the surface and dumped nearby. Refuse from the coal cleaning is generally collected and also dumped near the site.
32. Steps should be taken to assure that leachate and surface runoff from the piles does not cause harm to surface waters or groundwater supplies. Leaching, which should be monitored, can be minimized or prevented by careful composition and layering of the refuse material. Leaching water will be treated if need be.
33. Sludges from the settling ponds can be dredged and conveyed to a refuse pile and sludge lagoon. Where sufficient pond capacity is provided, the sludge may be allowed to dry in the lagoon. This will reduce the volume and facilitate removal and final disposal.

COAL SLURRY PIPELINES

34. Although it is not being widely applied at this time, coal slurry pipeline technology has already proven to be a commercially successful alternative for transportation of coal. Because use of this technology is expanding,

it is considered advisable to outline the possible environmental effects. Guidelines on use of pipelines for transportation of petroleum and its derivatives have been prepared by the Bank's Office of Environmental Affairs.

35. The major risks of environmental damage occur during the construction phases of slurry pipelines. The environmental effects and measures that can be taken to minimize these effects are shown in Table 3. Coal pipelines may extend for distances of as much as 500 to 2000 kilometers. The facilities are usually buried underground and hence cause no permanent esthetic damage.

Table 3 - Environmental Effects of Coal Pipeline Construction ^{a/}

Activity	Environmental Effects	Mitigation Measures
(1) Clearing and grading	Destroys wildlife habitat Encourages runoff and erosion Degrades esthetics	Revegetate quickly Slow runoff Leave screening vegetation
(2) Ditching	Potential runoff from spoil pile Covering top soil may produce rock rubble	Close ditch as soon as possible Separate top soil and set aside Haul to appropriate disposal site
(3) Hauling and Stringing Pipe	Increased truck traffic	Limit haul hours and route
(4) Welding Pipe	None	None
(5) Coating Pipe	Accidental spill of coating materials	Normal care in operation and availability of cleanup materials
(6) Backfill	Extra top soil or ditch "padding" soil may be needed	Use existing or properly sized borrow pits
(7) Clean-up	Erosion of right-of-way	Adequate revegetation program Restore drainage patterns Monitoring of recovery
(8) Testing System	Requires large volumes of water	Careful selection of water source and discharge

^{a/} From EPA Document EPA - 600/7-77-015 (See Bibliography)

36. The risk of spills from such facilities is considered to be negligible. The control and prevention of corrosion are well developed technologies because of extensive use of these underground systems to transport petroleum, natural gas, and other resources.

37. Operational impacts are affected by the coal preparation, pumping stations, and dewatering facilities. Problems are associated with preparation of the coal slurry, inter-basin transfer of large quantities of water required, and discharge or disposal of the separated water at the destination.

38. Since preparation of the slurry is generally done at the site of coal preparation, as previously discussed, the handling of wastes is generally included in the measures otherwise taken at the site. To prevent settling and possible obstruction in the system, ponds are provided at intervals for emptying the line in case of a system breakdown or other interruption.

39. At the discharge end, the coal slurry goes into agitated tank storage, from which it is conveyed to the dewatering systems. Dewatering is done by natural settling, vacuum filtration, or by centrifuge. Additional thermal drying is required before use of the coal. The finely ground coal still remaining in the water is generally removed by chemical flocculation. The reclaimed water may be used for cooling or other purposes.

BIBLIOGRAPHY

1. Lajzerowicz, J. "Environmental Factors and the Requirements for Control of Effluents", in "Economica of Mineral Engineering". Inter-regional Seminar organized by the United Nations in cooperation with the Government of Turkey, held at Ankara, April 1976. Mining Journal Books Ltd. London (1976).
2. Lajzerowicz, J. "Institutional Aspects Related to Coal Development in Canada". Presented at United Nations Symposium on World Coal Prospects, Katowice, Poland, October 15-23, 1979.
3. Alexanderson, G. and Klevebring, B.-I. "World Resources: Energy, Metals, Minerals". Walter de Gruyter. Berlin and New York (1978).
4. "The Direct Use of Coal-Prospects and Problems of Production and Combustion". Office of Technology Assessment, Congress of the United States. Washington (1979).
5. U. S. Environmental Protection Agency". Monitoring Environmental Impacts of the Coal and Oil Shale Industries: Research and Development Needs". Doc. EPA-600/7-77-015. Washington (February 1977).

6. U. S. Environmental Protection Agency. "Development Document for Proposed Effluent Limitations Guidelines, New Source Performance Standards, and Pre-treatment Standards for the Coal Mining Point Source Category". Preliminary Contractor's Draft. Washington (January 1980).
7. "Standards of Performance for New Sources — Coal Mining Point Source Category". U.S. Federal Register, V.44, 9. pp 2536-2592. Washington. (January 12, 1979).
8. "World Glossary of Mining, Processing, and Geological Terms". Ed. by R.S.M. Wyllie and G. O. Argall, Jr. Miller Freeman Publications. San Francisco (1975).
9. Powers, Philip W. "How to Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation. Park Ridge, New Jersey and London (1976).
10. "Pollution Control Objectives for the Mining, Smelting, and Related Industries of British Columbia". British Columbia Ministry of Environment, Pollution Control Board. Victoria (1979).

THE WORLD BANK

NOVEMBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

NITROGEN OXIDE EMISSIONS
GUIDELINES

1. Oxides of nitrogen present in the atmosphere originate from both natural and man-made sources. Natural sources include lightning, volcanic eruptions, and bacterial action in the soil. Although these natural emissions far exceed those generated from man-made activities they are not considered significant. They are distributed over the entire earth, and the resulting air concentrations are practically negligible. The background concentration of nitrogen dioxide in land areas generally ranges between 0.4 and 9.4 micrograms per cubic meter.
2. This document will concern itself with those oxides of nitrogen discharged from man-made sources. They include nitric oxide (NO) and nitrogen dioxide (NO₂). At the point of discharge the predominant form is nitric oxide, but this is readily converted to nitrogen dioxide through chemical reactions in the atmosphere.

SOURCES AND EFFECTS

3. The principal source of man-made emissions is the combustion of fossil fuels. In this context fossil fuels include coal, oil and its derivatives, and natural gas. The predominant oxide of nitrogen emitted by combustion processes is nitric oxide, with small amounts of nitrogen dioxide. Emissions originate from both stationary and mobile sources. Specifically, emissions originate from transportation (principally automobile exhausts); fuel combustion for power generation and industrial production; and certain non-combustion sources. Home combustion of fuels may also make significant contributions in some locations. Other industrial sources include fertilizers, glass, iron ore preparation (sintering and pelletizing) plants, and petroleum refineries.
4. Stationary combustion sources will generally account for 50 percent or more of the total nitrogen oxide emissions. For example, the proportions are estimated to be 60 percent in Japan, 59 percent in the Netherlands, 82 percent in the United Kingdom, but only 44 percent in the United States. Home combustion of fuels is said to contribute between 5 and 6 percent of the emissions in the United Kingdom and the United States.
5. Transportation sources include personal automobiles, buses, trucks, railroad vehicles, aircraft, and ships on inland waterways. Gasoline powered vehicles are by far the largest contributors among these. Of the total emissions, transportation facilities contribute approximately 40 percent in Japan, 41 percent in the Netherlands, 18 percent in the United Kingdom, and 51 percent in the United States.

small portion of the total nitrogen oxide emitted, they can be significant in certain local situations. The manufacture of nitric acid is the most important of these. Other examples include electroplating and processes using concentrated nitric acid, such as the manufacture of explosives or the production of sulfuric acid by means of the chamber process.

7. Oxides of nitrogen formed in combustion processes are usually due either to thermal fixation of atmospheric nitrogen in the combustion air (resulting in "thermal NO_x") or to the conversion of chemically bound nitrogen in the fuel (resulting in "fuel NO_x"). For natural gas and distillate oil firing, nearly all NO_x emissions result from thermal fixation. For residual oil and coal, the contribution from fuel-bound nitrogen can be significant, and even be predominant under certain operating conditions.

8. When a mixture of oxygen and nitrogen (such as air) is heated above 1600° C, oxides of nitrogen will result. Normal combustion temperatures in car engines are well above this level. As a result, over 0.3 percent of the exhaust can consist of a mixture of NO and NO₂. Emissions are lowest at lower engine speeds. The character of the emissions will depend upon the operating characteristics of the engine, such as temperature, duration of the combustion cycle, air/fuel ratio, etc. Diesel engines also are emission sources but to a much lesser degree because of the lower combustion temperatures in the cylinders. Gas turbines and other similar engines are also less significant as sources.

9. Automobile exhausts will also release unburned hydrocarbons into the atmosphere. While hydrocarbons are not in themselves generally harmful, they can form photochemical oxidants commonly known as smog when released in the presence of oxides of nitrogen and exposed to sunlight. Photochemical smogs can occur anywhere, but they have been most severe in Los Angeles, California, where they are a year-round phenomenon due to frequent temperature inversions.

10. Ozone is the main constituent of photochemical oxidants and can have severe effects on the respiratory system. Smog can irritate the lungs and seriously aggravate asthma or other respiratory diseases. Coughing, eye irritation, headaches, and throat pain are commonly experienced during exposure to smog.

11. The nitrogen oxides from man-made sources can also exist as primary pollutants in areas not subject to formation of smog. Such exposure is believed to increase the risks of acute respiratory disease and susceptibility to chronic respiratory infection. Nitrogen dioxide (NO₂) contributes to heart, lung, liver, and kidney damage, and can be fatal at high concentrations.

12. Nitrogen oxides are also toxic to vegetation. Although many plants can metabolize low concentrations of NO_x, the higher concentrations will reduce growth and the fertility of seeds.

13. Nitrogen oxides can also affect the environment by contributing significantly to the acid rain problem. Through complex atmospheric reactions, these oxides can be converted to nitric acid, which is then deposited with rain or snow. In the United States acid precipitation, much of which is due to nitric acid, has reduced or destroyed commercially and recreationally important species of fish in several areas.

EMISSION SAMPLING AND ANALYSES

14. The unit of measurement used to denote the ambient concentrations of nitrogen oxides in the atmosphere, after emission from either stationary or mobile sources, is expressed as weight per unit volume of air or, specifically, as micrograms of nitrogen dioxide (NO_2) per cubic meter ($\mu\text{g}/\text{m}^3$). This unit is to be used in all World Bank project reports.

15. Plant emissions, prior to reaching the atmosphere may be expressed in terms of plant input or output. Examples of these limitations, as applied to fossil fuel and nitric acid plants, are given below.

16. Sampling and analytical procedures for determining nitrogen oxides are covered in a separate guideline issued by the Office of Environmental Affairs.

ACCEPTABLE STANDARDS

17. Two types of standards are generally used -- ambient and emissions. Ambient standards express the allowable concentration of a contaminant in the air (in this case) surrounding the industrial site, following discharge and mixing. Ambient levels are essential for determining possible environmental damage and for evaluating adverse physical, health, and other effects upon the surrounding area and its inhabitants.

18. Emission standards express the allowable concentrations of a contaminant at the point of discharge, before any mixing with the surrounding medium (air). Emission levels are necessary for identifying specific pollution sources and designing remedial works.

19. For all Bark projects ambient air concentrations of nitrogen oxides, expressed as NO₂, should not exceed the following:

Annual Airth. Mean: 100 $\mu\text{g}/\text{m}^3$
(0.05 ppm)

20. For guidance purposes, emission levels for stationary source discharges, before mixing with the atmosphere, should be maintained as follows:

- (a) For fuel fired steam generators, as Nanograms (10^{-9} gram) per Joule of heat input:

Gaseous fossil fuel	86
Liquid fossil fuel	130
Solid fossil fuel	300
Lignite fossil fuel	260

(b) Nitric acid plants:

1.5 Kg NO₂/metric ton acid produced.

21. In special situations, strict adherence to these standards may be difficult for a number of reasons. Where this occurs, Bank missions should very thoroughly document such cases, with sufficient information to allow a judgement to be made. Examples of situations where these standards could not be met, with acceptable modifications, include:

- Expansion of existing plants — The Annual Arithmetic Mean and the maximum 24-hour peak resulting from the combination of the old units with the new ones should be no greater than the values existing prior to operation of new units. In addition, the new units by themselves should meet established standards.

More simply, emission plumes from new and existing sources should not mix to the extent that combined ambient concentrations exceed maximum ambient concentrations obtained from the existing source alone. This may be accomplished by (a) increasing the stack height of the new source, (b) changing the stack location of the new source, or (c) reducing the new source emission levels. Furthermore, if plume mixing is not a problem the new source units should, by themselves, meet the above standards.
- Revamping of existing plants — Every effort should be made to decrease existing pollution levels and provide measures which will minimize concentrations without placing unreasonable economic burdens on the industry.
- Inversions — When the NO_x source location is in a valley or surrounded by mountains, inversion layers which may occur during certain seasons of the year could trap the stack emissions. These same emissions can drop back to ground level, stagnate there, and damage crops sensitive to both SO₂ and NO_x. In World Bank financed projects it may be impossible to change the site location (i.e. in the case of an expansion of an existing plant). To protect human and plant life in such cases, the peak concentration should be decreased from 500 µg/m³ during any 24-hour period down to 350 µg/m³ during 4 hours, unless it can be shown that the effluent will not be trapped by the inversion layer.

CONTROL TECHNOLOGY

22. Emission control measures must be designed for each individual plant, particularly since the system must be capable of reducing more than one pollutant in most situations.

23. The most common method currently used to reduce NO_x emissions from automobile exhausts (which are the major sources) is the catalytic converter. The method utilizes a catalyst instead of high temperatures to achieve simultaneous oxidation of the remaining fuel, and reduction of NO_x to N₂. The catalyst achieves the double goal of decreasing concentrations of both NO_x and hydrocarbons on a metal catalyst deposited on ceramic material.

24. Mobile source emissions are also reduced through changes in combustion chamber design (such as lower compression ratios), spark retardation (including both basic timing and a "slower" advance curve), and exhaust gas recirculation.

25. The NO_x emissions from oil-fired combustion systems can be reduced by mixing water with the oil before it is sprayed into the burners. Water decreases the combustion temperatures, and can reduce NO_x emissions from light-weight oils by as much as 15 percent. Energy-wise, however, the method is considered to be costly.

26. Emissions from stationary sources, such as utility and industrial combustion installations, can be reduced by a number of methods. Among these, staged combustion, low excess air operation, and flue gas recirculation are widely used..

27. Staged combustion is effective for control of both thermal and fuel nitrogen oxides. The method consists of initially providing less than the amount of air (O₂) required for complete combustion. After a time delay more air is added in one or more steps or stages. The method is applicable to a wide range of fuels and facilities, from pulverized coal burners to small scale industrial boilers. Addition of this method to existing coal-buring installations has resulted in a 30 to 50 percent reduction of NO_x emissions.

28. In the low excess air method, the principal mechanism is also the lack of available oxygen for combining with either thermal activated or cracked fuel activated nitrogen atoms. This method can be combined with the staged combustion process, and can reduce nitrogen oxide emissions by 40 to 70 percent, without seriously increasing carbon monoxide emissions.

29. Flue gas recirculation has been effective in controlling thermal nitrogen oxides. The recirculation of exhaust gases to the flame regions reduces peak temperatures and oxygen availability, thus reducing nitric oxide formation. This method is more difficult to apply, since it requires increased operation controls and greater capital investment.

30. A number of methods are under further study for stationary source emissions. These include burner design changes, water/steam injection, wet scrubbing with aqueous ammonia, and fluid bed combustion.

BIBLIOGRAPHY

1. World Health Organization "Oxides of Nitrogen". Environmental Health Criteria 4. Geneva (1977).
2. Organization for Economic Cooperation and Development. "Photochemical Smog-Contribution of Volatile Organic Compounds". Paris (1982).
3. U.S. Environmental Protection Agency. "Technology Assessment Report for Industrial Boiler Applications - NO_x Combustion Modification". Document EPA-600/7-79-178f. Washington (December 1979).
4. Diamant, R.M.E. "The Prevention of Pollution". Pitman Publishing. London (1974).
5. U.S. Environmental Protection Agency. "Research Summary-Controlling Nitrogen Oxides". Document EPA-600/8-80-004. Washington (February 1980).
6. Jarrault, P. "Limitations des Emissions de Polluants et Qualite de L'Air. Valeurs Reglementaires dans les Principaux Pays Industrielles". Institut Francais de L'Energie. Paris (1978).
7. World Health Organization. "Air Quality Criteria and Guides for Urban Air Pollutants". WHO Technical Report Series No. 506. Geneva (1972).
8. U.S. Code of Federal Regulations, Title 40, Sub-Chapter C, Part 60, Subpart D "Standards of Performance for Fossil-Fuel Fired Steam Generators for Which Construction is Commenced After August 17, 1971". Office of the Federal Register, GSA. Washington (July 1, 1981).
9. U.S. Code of Federal Regulations, Title 40, Sub-Chapter C, Part 50.. "National Primary and Secondary Ambient Air Quality Standards". Office of the Federal Register, GSA, Washington (July 1, 1981).
10. Organization for Economic Cooperation and Development. "Photochemical Oxidant Air Pollution". Paris (1975).

THE WORLD BANK

NOVEMBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

NITROGEN OXIDE SAMPLING AND ANALYSES

1. This document supplements a companion Bank document, titled "Nitrogen Oxide Emissions". It provides procedures required for sampling and analysis of stack emissions and the ambient atmosphere to determine compliance with NO_x pollution limits for Bank projects.
2. Major man-made emissions of nitrogen oxides are fossil fuel combustion in stationary sources (heating, power generation, etc.) and exhausts from motor vehicles and any movable sources utilizing internal combustion engines.
3. Land areas normally have natural background concentrations of nitrogen dioxide in the range of 0.4 to 9.0 micrograms per cubic meter. In urban areas, world-wide, average annual background concentrations may vary from 20 to 90 micrograms per cubic meter.
4. Oxides of nitrogen, for purposes of this document, include nitric oxide (NO) and nitrogen dioxide (NO₂). At point of discharge from man-made sources, the principal oxide is nitric oxide. This is rapidly converted to nitrogen dioxide by atmospheric chemical reactions. Nitric oxide and nitrogen dioxide can be measured separately or collectively by various techniques.

STATIONARY SOURCE MONITORING

Sampling

5. Stationary source samples are collected through openings provided for that purpose in stacks or other ducts carrying emissions from combustion chambers. Sampling ports should be located at least eight stack diameters beyond any bends, constrictions, abatement equipment, or other causes of flow disturbance. If this is not possible then the sampling location should be at least two stack diameters ahead of the flow disturbance. Where these conditions cannot be met, it may be necessary to extend the stack.
6. Sampling ports should be flush with the stack walls, and extend outward from the exterior wall for 5 to 20 centimeters. However, additional extension may be required for installing valves or other appurtenances.

7. The sampling apparatus is shown schematically in Figure 1. The sampling probe may be placed at any location across the stack diameter, and a grab sample collected in an evacuated flask containing a dilute sulfuric acid-hydrogen peroxide solution. This solution reacts with the nitrogen oxides. The volumetric flow rate and moisture content of exhaust gas stream must be determined for calculating the total mass emission rate.

8. Each grab sample is obtained rapidly (15 to 30 seconds) and four grab samples constitute a run. A minimum of three runs should be taken, or a total of 12 grab samples. An interval of 15 minutes should elapse between each grab sample.

9. Since a grab sample collects a relatively small amount of material over a relatively short period of time, the result obtained will be essentially an instantaneous measure of the nitrogen oxides. It will be representative of the emissions only if the gas stream is well mixed and the concentration is constant with time. Multiple samples are therefore necessary.

Analyses

10. Nitrogen oxide levels are determined by the EPA procedure designated as "Method 7". Nitrogen oxides (except for nitrous oxide-N₂O) are measured colorimetrically using the Phenoldisulfonic Acid Procedure. The method is applicable for measurement of nitrogen oxides (as NO₂) from stationary sources in the range of 2 to 400 milligrams per dry standard cubic meter, without having to dilute the sample.

11. A similar method has been developed by the American Society for Testing and Materials, designated as Method ANSI/ASTM-D-1608-77. This method is applicable to concentrations ranging from 4 to several thousand milligrams per dry standard cubic meter.

AMBIENT AIR MONITORING

Sampling

12. The number of sampling points required for an ambient air monitoring network will depend upon program objectives, effluent requirements, meteorological conditions, topography, and other related factors. For a small source, particularly if one wind direction predominates, only two sites are required. One site would be for monitoring source effects while the other would provide upwind or background concentrations. Where wind directions are variable several sampling points are required.

13. It is desirable to place collection devices in areas most likely to receive the highest ground-level concentrations of pollutants. Plume trajectory from emission source to the point of ground-level impact may be predicted roughly from a knowledge of predominant wind directions. A convenient tool for performing such an analysis is the "wind rose"; a chart which plots wind directions and percentage of time, annually, that wind is blowing from that direction. Where more precise information is required for site selection, computerized atmospheric dispersion models may be necessary.

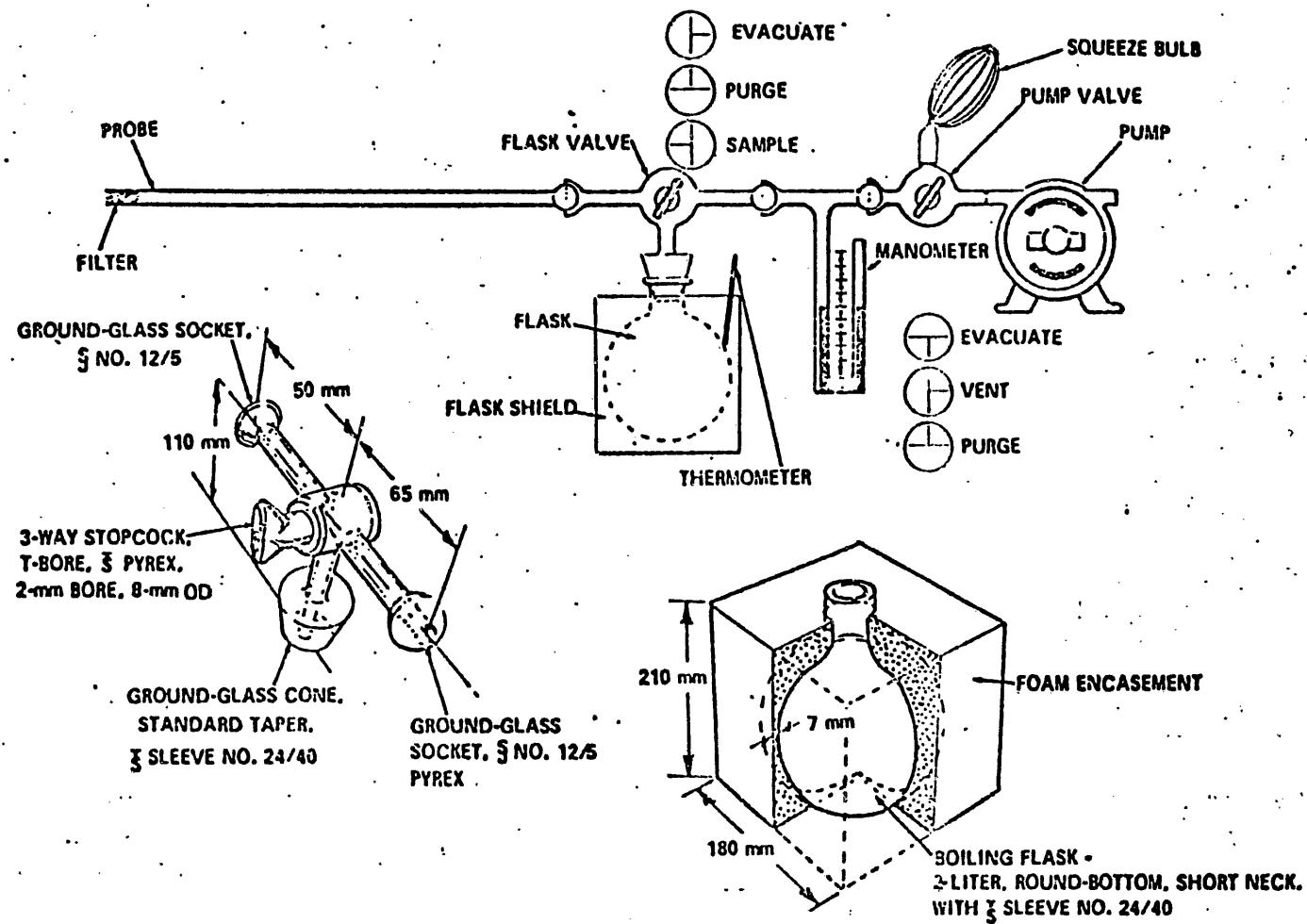


Figure 1. - Nitrogen Oxide Sampling Train for Stationary Sources
(From U.S. Code of Federal Regulations, Title 40, Part 60, Appendix A-July 1, 1981).

14. The principal factors in selecting the sampling locations are topography and meteorology. Other considerations include:

- (a) Location of the sampling site, relative to pollutant source, accessibility, and operation.
- (b) Sample delivery to laboratory facilities.
- (c) Proper handling of samples to prevent deterioration or conversion that would produce inaccurate results.
- (d) Availability of suitable analytical procedures and instrumentation for generating acceptable quantitative and qualitative data.
- (e) Legal restrictions (such as effluent limitations) affecting the discharges from existing sources.

15. Preferably, ambient levels should be monitored continuously. Continuous samples may be obtained by a variety of instrument techniques and are particularly suitable for averaging over long time periods. Non-automatic (or dynamic) samples may be used when continuous types of equipment are not available.

16. A typical continuous monitoring device consists of an inlet section, gas pretreatment section, detector, photomultiplier, spectrometer, and readout device. Depending upon conditions of the gas to be analyzed, pretreatment could include pressure adjustment, particulates removal (usually by filter), moisture removal (usually with silica gel column) and temperature adjustment (usually by condenser).

17. Basic components for a dynamic sampling unit (shown in Figures 2 and 3): include inlet, fritted bubbler, drying tube, temperature gauge, dry test meter, pump, and manometer.

Analyses

18. The chemiluminescent method, adopted by the U.S. Environmental Protection Agency, and cited in the Bibliography, is the preferred analytical method for determining nitrogen dioxide levels in ambient air samples. This is an automated continuous method which records a measurement every few seconds, and readily permits determination of specific time average levels. The method is applicable to measurements in the range of zero to about 2,000 milligrams per cubic meter.

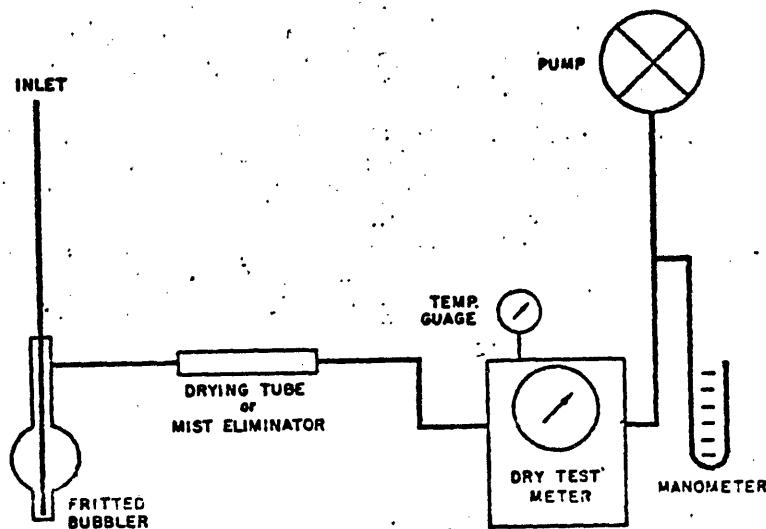


Figure 2 - Nitrogen Dioxide Sampling Train (From ASTM Method D-1607-76).

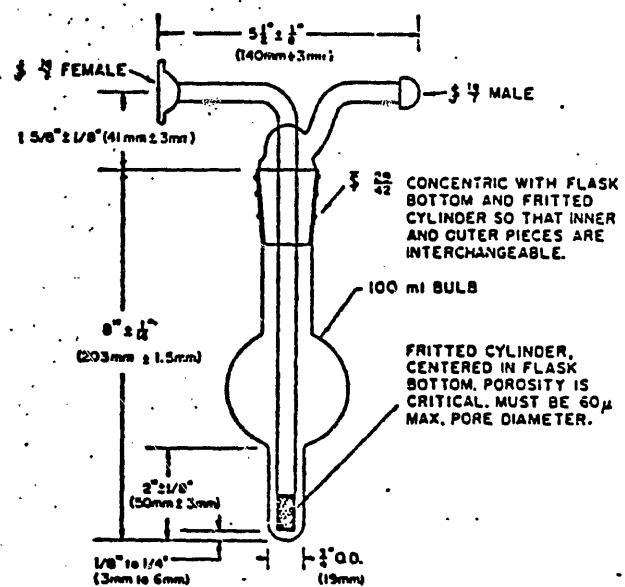


Figure 3 - Fritted Bubbler for Sampling Nitrogen Dioxide (From ASTM Method D-1607-76).

19. Chemiluminescence analyzers will respond to other nitrogen containing compounds, such as peroxyacetyl nitrate. Atmospheric concentrations of these potential interferences are generally low relative to NO₂, and hence valid NO₂ measurements may be obtained. Where levels of interfering substances (such as sulfur dioxide and ozone levels) are suspected of being high, then an alternate method should be used.
20. Nitrogen dioxide levels may be determined manually by the Griess-Saltzman Method, adopted by the American Society for Testing and Materials, and cited in the Bibliography. The sampling train shown in Figures 2 and 3 should be used for this purpose. Sampling periods should be between 15 and 30 minutes, at a flow rate of about 0.4 liter/per minute. The method is applicable for levels in the range of 4 to 10,000 micrograms per cubic meter.
22. In the Griess-Saltzman Method, NO₂ is absorbed in an azo-dye-forming reagent. A red violet color is produced within 15 minutes, and its intensity measured spectrometrically at 550 nanometers.
23. A ten-fold ratio of sulfur dioxide to nitrogen dioxide produces no effect. A 30-fold ratio slowly bleaches the color to a slight degree. Addition of acetone to the reagent retards fading, and permits reading the color intensity within 4 to 5 hours instead of 45 minutes required without acetone. A 5-fold ratio of ozone to nitrogen dioxide will cause a small interference, with the maximal effect occurring within 3 hours. Other nitrogen oxides and other gases that may be present in polluted air could also interfere with the accuracy of the manual method.

BIBLIOGRAPHY

1. World Health Organization "Oxides of Nitrogen". Environmental Health Criteria 4. World Health Organization. Geneva (1977).
2. U.S. Code of Federal Regulations, Title 40, Part 60, Appendix A, Method 7, "Determination of Nitrogen Oxide Emissions from Stationary sources". Office of the Federal Register. Washington (July 1, 1981).
3. U.S. Environmental Protection Agency. "Handbook-Industrial Guide to Air Pollution Control". Document EPA-625/6-78-004. Washington (June 1978).
4. American Society for Testing and Materials. "Standard Test Method for Oxides of Nitrogen in Gaseous Combustion Products (Phenol-Disulfonic Acid Procedures)". Method ANSI/ASTM D-1608-77. Philadelphia (1977).
5. Organization for Economic Cooperation and Development. Photochemical Oxidant Air Pollution". Paris (1975).

6. U.S. Code of Federal Regulations, Title 40, Part 50, Appendix F. "Measurement Principle and Calibration Procedure for the Measurement of Nitrogen Dioxide in the Atmosphere (Gas Phase Chemiluminescence)". Office of the Federal Register. Washington (July 1, 1982).
7. American Society for Testing and Materials. "Standard Test Method for Nitrogen Dioxide Content of the Atmosphere (Griess-Saltzman Reaction)". Method ANSI/ASTM D-1607-76. Philadelphia (1976).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

NOISE

1. Bank missions will be concerned with noise and its environmental effects in various types of projects. Among these are highway and railway projects, airports, agricultural enterprises (from operation of farm machinery), and industrial installations.

BASIC CONCEPTS

2. Noise may be described as sound without agreeable musical quality, or as "unwanted sound". Generally, noise is produced when an object or surface vibrates rapidly enough to generate a pressure wave or disturbance in the surrounding medium. From the standpoint of environmental effects the medium of greatest concern is air, although sound may also be transmitted through liquids and solids.

3. Sound is transmitted by wave motion. It propagates as the result of the elastic interactions between the molecular components of the medium through which it travels. The speed of sound, therefore, depends upon the mass of molecules (density) and their elastic reactions (pressure). The human ear responds to the pressure fluctuations set up in the surrounding medium. Air-borne sound travels at a speed of 344 meters per second at a temperature of 20°C. In seawater sound travels at the rate of about 1490 meters per second.

4. The decibel (dB) is used to measure the relative pressure of different sounds. The decibel is equal to 20 times the logarithm of the ratio of sound pressure to a reference pressure of $20 \mu\text{Pa}^*$, or:

$$\text{Sound pressure level (dB)} = \log_{10} \frac{\text{Measured Pressure}}{\text{Reference Pressure}}$$

Thus, a sound with 10 times the pressure of another is considered to be 20 dB louder, and each succeeding 10-fold increase adds another 20 dB to the sound level. Relative sound pressure levels for various degrees of "loudness" are presented in Table 1.

5. The quality of sound (or noise) is measured by flow of energy per unit area. Frequency is a measure of the number of complete vibrations occurring per second, and is measured in "hertz" (Hz). Thus, 1 Hz equals 1 cycle per second. Normally, the human ear cannot detect sounds above 15,000 Hz (ultrasound). The lower limit of human detection depends more on the quantity of sound. At 65 Hz the human ear does not normally detect sounds below 60 dB.

* 1 Pascal = 10 dyne per square centimeter.

Table 1. Relative Sound Pressure Levels for Various Sources of Noise a/.

Apparent Loudness	Examples	Relative Sound Pressure Levels		Pascals
		dB	Ratio to 0 dB	
Deafening	Jet aircraft	140	10,000,000	200
	Threshold of feeling	130	3,162,000	
Very loud	Elevated train, thunder	120	1,000,000	20
	Subway train, riveter	110	316,200	
	Noisy Ind. Plant	100	100,000	
	Loud street noise	90	31,620	
	Noisy office	80	10,000	
Loud	Av. Street noise	70	3,162	0.02
	Av. office	60	1,000	
Moderate	Mod. restaurant clatter	50	316	0.002
	Private office	40	100	
Faint	Rustling leaves	20	10	0.0002
Very faint	Normal breathing	10	3	0.00002
	Threshold audibility	0	1	

a/ From "Sound Control Construction" U. S. Gypsum Co.

MEASUREMENT OF NOISE

6. The basic goal in quantifying sound is to determine the time and location variations of noise in the environment throughout a community and to assure that the data can be used as a measure of the effects of environmental noise on people.

7. The Sound Level Meter (SLM) is the basic instrument for measuring sound or noise. While such instruments are available from a number of manufacturers, all meters to be used for this purpose must meet the American National Standards Institute (ANSI) specification S1.4-1971, or the latest ANSI issuances. Both Type 1 (Precision) and Type 2 (General Purpose) meters are acceptable. The Type 2 meter has broader performance tolerances, and is usually less bulky, lighter, and less expensive than the Type 1.

8. A sound level meter electronically weighs the amplitude of the various frequencies in accordance with a person's hearing sensitivity and sums the resulting weighted spectrum into a single number. The typical meter contains three different response weighting networks: A, to match the response of the ear to sound of low intensity; B, to match response to sound of moderate intensity; and C, to match response to sound of high intensity. The A scale is most commonly used, since it most closely approximates the human perception of sound. The weighted sound level unit, at the A setting is commonly designated as dB (A).

9. The SLM A-setting measures the sound level at a frequency of 1,000 Hz. Where frequency readings differ from the standard of 1,000 Hz, then a correction must be made to convert "flat" response readings to the A levels. The term "flat" response designates the uniform response of an instrument over a wide frequency range, up to 20 K Hz.

Table 2. Corrections from "Flat" Response Levels to A Levels.

Octave Band Center Frequency (Hz)	Correction (dB)
31.5	- 39.5
63	- 26
125	- 16
250	- 8.5
500	- 3.0
1000	0
2000	+ 1.0
4000	+ 1.0
8000	- 1.0
16000	- 6.5

EFFECTS OF NOISE

10. A universal effect of noise is its interference with the understanding of speech. This is one aspect of "masking" — an interaction of two acoustic stimuli whereby one of them changes the perceived quality of the other, shifts its apparent location or loudness, or makes speech completely inaudible. Various factors enter into the degree of speech interference, such as speech, age, and hearing of individuals. Children have less precise speech than do adults, while older persons are more susceptible to interference from background noise.
11. Noise can elicit a variety of physiological responses, but no clear evidence exists to indicate that continued activation of these responses leads to permanent health effects. Sounds of sufficient intensity can cause pain to the auditory nervous system. It can be presumed that noise exposure can cause general personal stress, either by itself or in combination with other stress sources. Noise exposure to moderate intensities that may be found in the environment does have some effect on the cardiovascular system, but no definite permanent effects on the circulatory systems have been demonstrated. Moderate noise levels have been known to cause vasoconstriction of the peripheral areas of the body and pupillary dilation, but there is no evidence that these effects can lead to harmful consequences over a period of time.
12. Continuous noise levels above 90 dB (A) have detrimental effects on human performance, especially in so-called "noise-sensitive" functions, such as vigilance tasks, information gathering, and analytical processes. Noise levels below 90 dB (A) can be disruptive, particularly if they have predominantly high frequency components, and are intermittent, unexpected and uncontrollable.
13. Frequencies below 16 Hz are referred to as infrasonic, and include such sources as earthquakes, wind, thunder, and distant jet aircraft. Man-made infrasound occurs at higher intensity levels than those found in nature. Effects associated with infrasound resemble mild stress reactions and bizarre auditory sensations, such as pulsating and fluttering. Ultrasonic frequencies are those above 20,000 Hz, and are produced by a variety of jet engines and industrial equipment. Above 105 dB, the effects of high intensity ultrasounds resemble those observed during stress situations.
14. Noise has the same general effects on wildlife and other animals as it does on humans. Noise of sufficient intensity can disrupt normal patterns of animal existence. Exploratory behavior can be curtailed, avoidance behavior can limit access to food and shelter, and breeding habits can be disrupted. Hearing loss and the masking of auditory signals can complicate an animal's abilities to recognize its young, detect and locate prey and evade predators. Physiological effects of noise exposure—such as changes in blood pressure and chemistry, hormone balance, and reproductivity—have been demonstrated in laboratory animals and, to some extent, in farm animals.
15. Secondary effects of noise on the health and welfare of man include three general types: sonic boom effects, noise induced vibration and sonic fatigue. Sound can also cause buildings to vibrate, and this can have a direct effect on humans. Some booms of sufficient intensity not only can break windows,

but they can also damage building structures. However, sonic booms can be controlled to levels which are innocuous in relation to buildings and structures. Noise induced vibrations near rocket launch sites can also cause window breakage. Construction activities may have similar effects. Sonic fatigue is also a problem where material is used near intense sound sources, but such problems can be avoided by proper design and this type of fatigue does not usually cause environmental problems.

NOISE CONTROL TECHNIQUES

16. Noise control techniques fall into two general categories: control at the source and control of the path of sound. Within the urban environment noises originate principally from aircraft and airport operations, industrial operations, construction activities and highway traffic.

17. Aircraft related noises mainly affect the populations living near airports or in the flight paths of low flying airplanes. Although many new types of jet-powered ships introduced since 1972 emit less noise than earlier models, noise continues to be the most serious constraint currently facing airport operations.

18. A number of techniques may be applied, alone or in combination, to the reduction of aircraft noises and their effects. The principal ones include:

- Operational measures designed to limit the production of noise by aircraft. This could involve special take-off and landing procedures, restrictions on the total noisy aircraft traffic, banning of night traffic, diversion of part of the traffic to other regional airports, and application of local airport noise regulations.
- Measures aimed at changing the land use in areas exposed to heavy noise. This requires close coordination of airport planning with regional and local land use policy. Such an approach is most easily implemented in the case of new airports in areas not yet intensely developed. However, even around existing airports it is possible to re-zone the heavily impacted areas over a period of time and minimize noise exposures for private dwellings, schools, hospitals and recreation areas.
- Measures aimed at reducing the impact of noise at the point of reception. This will require sound-proofing of private residences, hotels, offices and other structures. Such measures should be taken as a last resort, since they do nothing to eliminate the source of the noise or to improve the outdoor environment.

19. Noises resulting from industrial operations are generally confined within the plant structure. Machinery and equipment are the main sources, and the effects are felt mostly by the individual workers. Controls may be accomplished through measures at the source (relocation, vibration, vibration control,

etc.); installation of acoustical shields, enclosures, or other barriers to interrupt the path of the sound; or through limiting the duration of the exposure by the receiver. The first two of these measures will help reduce the noise levels in the environment outside the plant.

20. While construction operations are not permanent, large projects are carried out over relatively long time periods, and measures are frequently required to reduce noise emissions. Construction noises can originate from such sources as crane and hoisting equipment, air compressors, concrete mixers, tractor and bulldozing equipment and materials delivery vehicles.

21. Noise control at construction sites will require an analysis of each individual situation to determine which measures should be applied. The general measures which can be effective include:

- Assurance that the manufacturer has designed, built and equipped the unit to conform with existing noise control regulations.
- Adequate operation and maintenance of equipment.
- Limiting the time of day during which equipment may be operated.
- Limiting the places or zones in which equipment may be used.

22. The effect of vehicle noise on populations is usually dependent upon traffic concentrations rather than on any one individual vehicle. Although trucks are normally fewer in number, they tend to contribute the largest share of the noise. Motorcycle traffic can also be a significant contributor. For highway vehicles, noises originate from the exhaust systems, engines, special features (such as loading machinery on solid waste carriers and other heavy duty trucks), and other individual characteristics.

23. Noise abatement measures are similar to those for construction equipment, as given in paragraph 21. Additional controls may be imposed through licensing and inspection procedures, and through driver education on operational procedures.

ACCEPTABLE NOISE LIMITATIONS

24. There are considerable variations in the recommended allowable noise levels emitted by the many individual sources existing in the environment. The limitations presented in Table 3 represent the net effect of cumulative contributions from all sources. The levels given are considered adequate for protecting the health and welfare of the general public in the specific environmental situation. The term "public health and welfare" denotes personal comfort and well-being as well as the absence of hearing damage or other clinical symptom.

Table 3. Yearly Average Equivalent Sound Levels Required for Protection of Public Health and Welfare 1/

	<u>Measure 2/</u>	Indoor Activity Inter- ference	Hearing Loss Considera- tion	To Protect Against Both Ef- fects (b)	Outdoor Activity Inter- ference	Hearing Loss Considera- tion	To Protect Against Both Ef- fects (b)
Residential with Out-side Space and Farm Residences	L_{dn} $L_{eq(24)}$	45	70	45	55	70	55
Residential with No Outside Space	L_{dn} $L_{eq(24)}$	45	70	45			
Commercial	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Inside Transportation	$L_{eq(24)}$	(a)	70	(a)			
Industrial	$L_{eq(24)(d)}$	(a)	70	70(c)	(a)	70	70(c)
Hospitals	L_{dn} $L_{eq(24)}$	45	70	45	55	70	55
Educational	$L_{eq(24)}$ $L_{eq(24)(d)}$	45	70	45	55	70	55
Recreational Areas	$L_{eq(24)}$	(a)	70	70(c)	(a)	70	70(c)
Farm Land and General Unpopulated Land	$L_{eq(24)}$				(a)	70	70(c)

Code:

- a. Since different types of activities appear to be associated with different levels, identification of a maximum level for activity interference may be difficult except in those circumstances where speech communication is a critical activity.
- b. Based on lowest level.
- c. Based only on hearing loss.
- d. An $L_{eq(8)}$ of 75 dB may be identified in these situations so long as the exposure over the remaining 16 hours per day is low enough to result in a negligible contribution to the 24-hour average, i.e., no greater than an L_{eq} of 60 dB.

1/ From Ref. 4

2/ L_{dn} = Day-night average A - weighted equivalent sound level, with a 10-decibel weighting applied to night time levels.

$L_{eq}(24)$ = Equivalent A-weighted sound level over 24 hours.

BIBLIOGRAPHY

1. Peterson, A.P.G. and E.E. Gross, Jr. "Handbook of Noise Measurement" General Radio Inc. Concord, Mass. (1974).
2. U.S. Department of Commerce/National Bureau of Standards. "Quieting: A Practical Guide to Noise Control", NBS Handbook 119. Washington (1976)
3. U.S. Environmental Protection Agency. "Public Health and Welfare Criteria for Noise". Doc. 550/9-73-002. Washington (July 27, 1973).
4. U.S. Environmental Protection Agency. "Information on Levels of Environmental Noise Requisite to Protect Public Health and Welfare with an Adequate Margin of Safety". Doc. 550/9-74-004. Washington (March 1974).
5. United States Gypsum, "Sound Control Construction-Principles and Performance 2nd Ed. Chicago (1972).
6. United Auto Workers, "Noise Control-A Worker's Manual". Detroit (February 1978).
7. U.S. Federal Register, "Noise Emission Standards for Construction Equipment-New Wheel and Crawler Tractors". Vol. 42, No. 132, pp. 35804-35820. Washington. (July 11, 1977).
8. "Transportation Noises", A Symposium on Acceptability Criteria. Ed. by James D. Chalupnik. University of Washington Press. Seattle and London (1970).
9. "Airports and the Environment". Organization for Economic Cooperation and Development. Paris (1975).
10. U. S. Environmental Protection Agency. "Fundamentals of Noise: Measurement, Rating Schemes, and Standards". Doc. NTID 300.15. Washington (December 31, 1971).

THE WORLD BANK

FEBRUARY 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

NON-FERROUS METALS INDUSTRY

ALUMINUM PRODUCTION

ENVIRONMENTAL GUIDELINES

1. The non-ferrous metals category includes a large number of metallic elements, but only a few are of concern to World Bank operations at this time. Those most frequently encountered in Bank activities are covered in four separate documents in the series, as follows: (a) aluminum; (b) lead and zinc; (c) copper and nickel; and (d) silver, tungsten, columbium, and tantalum. This document will concern itself with aluminum production.
2. Both primary and secondary aluminum will be discussed, the classification being based upon the raw materials used in the production. Normally, the primary metal is produced from the raw ore, while the secondary metal is produced from manufacturing scrap, discarded consumer items, and other residues containing economically recoverable quantities. The manufacturing process and waste sources are shown in Figures 1 and 2.
3. Aluminum is considered to be the most abundant metal in the earth's crust. The aluminum industry is international in scope, and its manufacture, fabrication, and use are currently worldwide. The wastes resulting from the industry's operations are of significant proportions, and hence their effects must be considered in environmental impact assessments.

MANUFACTURING PROCESSES

4. The basic material used in the manufacture of aluminum metal is bauxite ore. Major sources of the mineral are South America, the Caribbean and Australia. Specific sources include Jamaica, Haiti, Costa Rica, Surinam, Guyana, French Guiana, Brazil, Ghana, Guinea, Sierra Leone, Cameroon, Sumatra, Java and Borneo.
5. The most commonly used method for the production of aluminum metal from bauxite ore is the Bayer Process, followed by the Hall-Heroult Process. Thus, aluminum production may be considered a two-step process.
6. In the Bayer Process the bauxite is digested with a hot, strong alkali solution (generally sodium hydroxide) to form a sodium aluminate solution and an undissolved residue commonly called "red mud". The red mud is separated by filtration and reworked for recovery of additional alumina. The sodium aluminate solution is hydrolyzed to aluminum hydroxide by cooling and dilution, and the hydroxide then induced to crystallize by seeding with alumina crystals. The precipitate (which is the aluminum hydroxide) is separated from the liquor, clarified in tray thickeners, washed with hot water, and filtered. As the final step the hydroxide is calcined

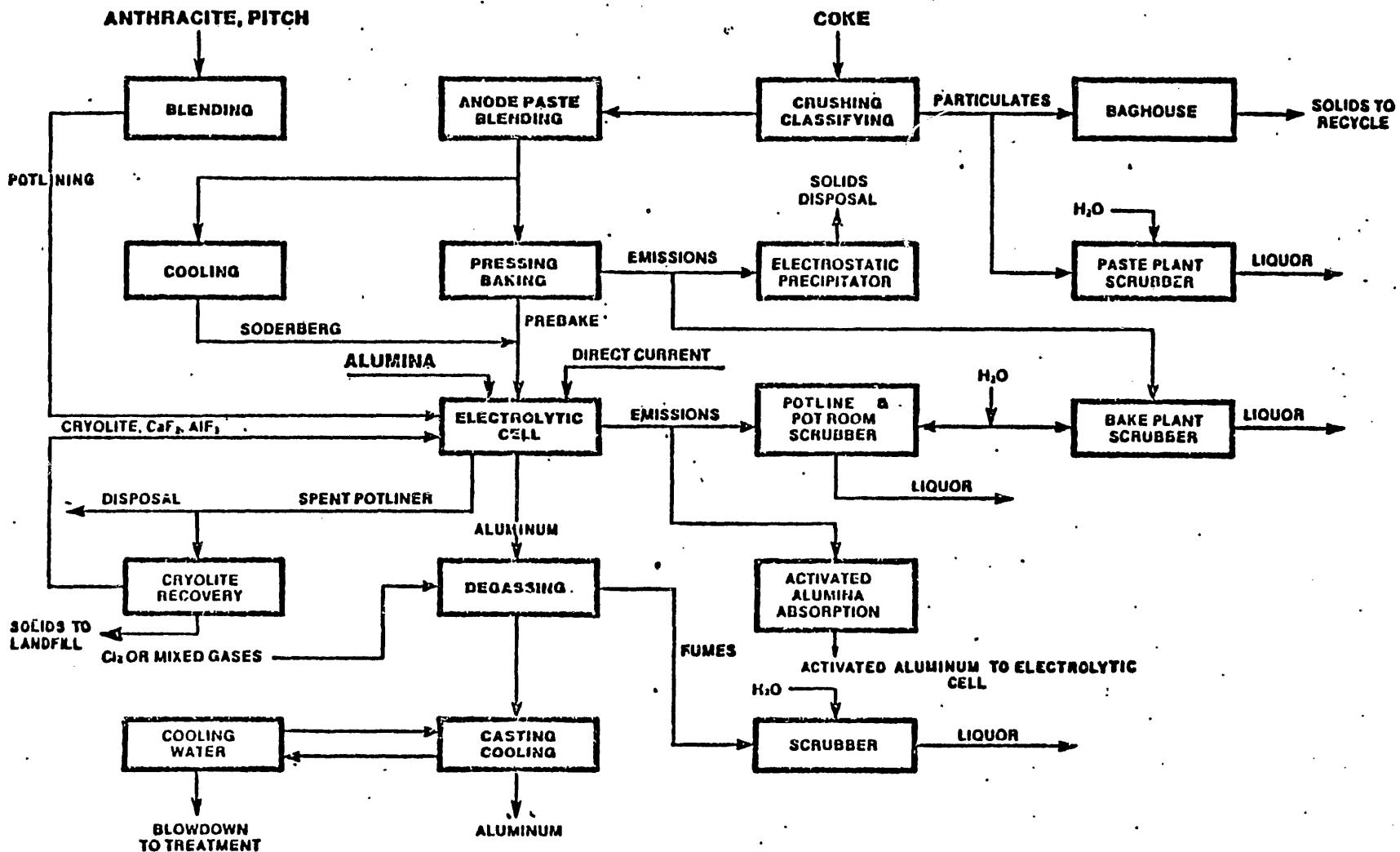


Fig. 1 - Primary Aluminum Reduction Process
(From US EPA Document EPA 440/1-79/019a)

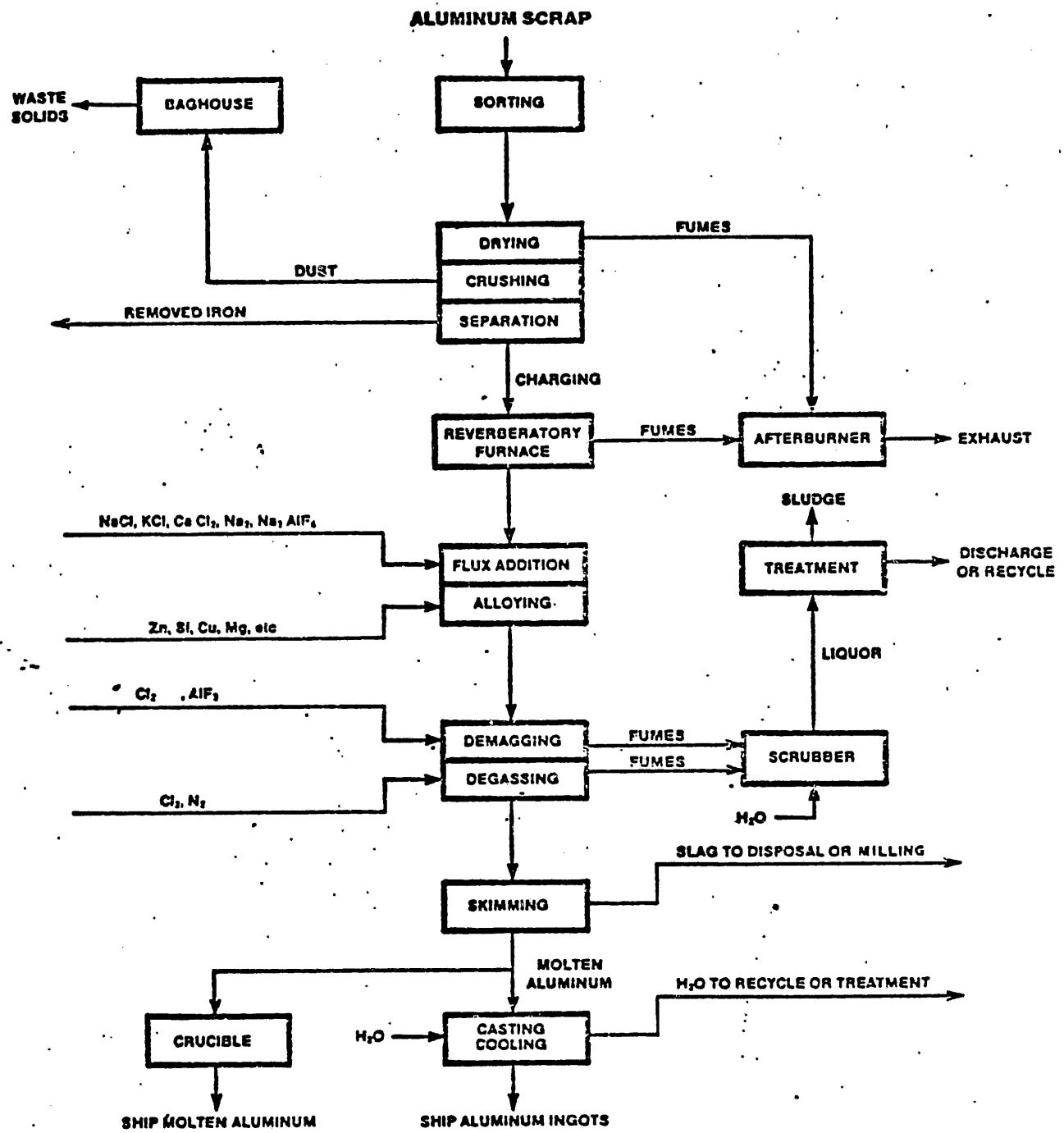


Fig. 2 - Secondary Aluminum Smelting Process
(From US EPA Document EPA 440/1-79/019a)

in rotary kilns, at temperatures up to 1800°C to produce alumina (Al_2O_3), cooled, and shipped to reduction plants.

7. The alumina is then reduced electrolytically by the Hall-Heroult Process, to produce aluminum. This involves the electrolysis of alumina dissolved in a fused salt electrolyte consisting of cryolite ($\text{Na}_3\text{Al F}_6$), with minor additions of other fluoride salts. The process is carried out in a cell (pot) — consisting of a carbon anode, a cathode, and the electrolyte — contained in a carbon-lined steel box. This is followed by alloying and casting into ingots. The ingots are then shaped for final use by casting, rolling, forging and/or extrusion.

8. For secondary aluminum production, the raw materials include new clippings; forgings and other solids; borings and turnings; residues; old castings and sheets; and high iron scrap.

9. The smelting process for secondary aluminum generally consists of six steps: charging scrap into the furnace, addition of fluxing agents, addition of alloying agents, mixing, demagging (magnesium removal) or degassing, and skimming. Some plants also process residues to recover a high aluminum fraction for smelting and a low aluminum fraction for use by steel manufacturers as ingot topping. High-iron scrap undergoes presmelting treatment for iron removal.

WASTE SOURCES AND CHARACTERISTICS

10. The major environmental concerns in bauxite mining operations are land erosion, runoff water control, and dust control. In the processing of bauxite to produce aluminum the principal environmental concerns include: (a) disposal of bauxite residue (red mud); (b) dirt losses (c) emissions from fuel burning; and (d) waste liquid and slurry streams.

Air Emissions

11. In the primary aluminum industry, gaseous emissions originate from the potlines, potroom, paste plant, anode bake plant, and the degassing operation. Most plants effectively collect and remove the various emissions and therefore very little escapes to the atmosphere. In the secondary aluminum category, emissions originate in the demagging (magnesium removal) operations and from processing of furnace residues. These also are effectively collected and removed.

12. The emissions, in both primary and secondary plants, will contain dusts, fluorides, sulfur compounds, fuel combustion products, certain organic pollutants, phenols, cyanides (in cryolite recovery) and organic carbon in varying amounts.

Liquid Wastes

13. The conventional water pollution parameters (biochemical oxygen demand, chemical oxygen demand, total organic carbon, oils and greases, etc.) have limited values in the non-ferrous metals industry. High concentrations of metals, a characteristic of the wastes, will inhibit biological activity and render these tests ineffective and of limited value.

14. In primary aluminum production the significant parameters are total fluorides, total suspended solids, and pH. For secondary production these are also significant, but to them must be added ammonia nitrogen, aluminum, and copper.

15. Process wastewater in primary aluminum production originates from the wet scrubbers used for air pollution control in the potline, potroom, paste plant, anode bake plant, and the degassing operation. Other waste streams originate from the cryolite recovery, ingot cooling, and cathode making. For secondary aluminum operations the wastewater results from demagging, wet milling of residues, and contact cooling.

Solid Wastes

16. Solid wastes include bauxite residues (red mud), residues from air pollution control devices (precipitators and scrubbers), and the waters used to cool the ingots and castings. The cathodes, consisting of carbon liners which hold the molten aluminum, are replaced periodically and require disposal. Spent cathodes will have a significant fluoride content, and water runoff from storage areas used for the spent units will contain fluorides. Scrubbers, furnaces, and ingot cooling are the principal solid waste sources in secondary aluminum production.

EFFLUENT LIMITATIONS

AIR EMISSIONS

17. Control measures should be such that there will be very minor or no emissions to the atmosphere. The dusts and gases are usually collected for recycling and byproduct recovery, or for discharge with the wastewater streams.

18. Where gaseous emissions are discharged to the atmosphere, the following limitations are to be observed:

Sulfur Dioxide (SO_2)

Inside Plant Fence	Ann. Arith Mean	$100 \mu\text{g}/\text{m}^3$
	Max. 24-hour Peak	$1000 \mu\text{g}/\text{m}^3$
Outside Plant Fence	Ann. Arith Mean	$100 \mu\text{g}/\text{m}^3$
	Max. 24-hour Peak	$500 \mu\text{g}/\text{m}^3$

Fluorides (as HF)

	Ann. Arith Mean	$10 \mu\text{g}/\text{m}^3$
	Max. 8-hour Peak	$100 \mu\text{g}/\text{m}^3$

Particulates

	Ann. Geom. Mean	$75 \mu\text{g}/\text{m}^3$
	Max. 24-hour Peak	$60 \mu\text{g}/\text{m}^3$

Liquid Effluents

19. Discharge limitations, based on the best practicable control technology currently available, are as follows:

Primary Aluminum - Smelting

Max. 24-hour

Fluorides (total)	0.05 Kg/Mg*	Aluminum
TSS	0.10 "	"
pH	6 to 9 units	

Secondary Aluminum - Smelting

Max. 24-hour

Fluorides (total)	0.4 Kg/Mg *	Aluminum
TSS	1.5 "	"
NH ₃ (as N)	0.01 "	"
Al	1.0 "	"
Cu	0.003 "	"
pH	6 to 9 units	

* 1 Mg = 1 Megagram = 1 Metric ton.

Solid Wastes

Bauxite Mining

- (a) There is to be no disposal of mine tailings to waterways or to the sea, except under very special circumstances and very carefully controlled conditions.
- (b) A reclamation program is to be established for handling mine tailings. The project sponsor is to submit a proposed plan of action, which will be evaluated as part of the project appraisal.
- (c) The reclamation program is to be initiated within three (3) years of the start of project operations.

Bauxite Processing and Refining

There is to be no disposal of red mud into either the waterways or into the sea.

CONTROL AND TREATMENT OF WASTES

Air Emissions

20. The industry makes extensive use of both wet and dry methods for control of particulates and gases. Liquid effluents from the wet systems are discharged with the wastewater, except where there is byproduct recovery or utilization. Dry systems are preferable to wet systems, since removals are just as effective and liquid waste flows are reduced.

Liquid Effluents

21. In-plant controls should be carefully considered as the first step in reducing wastewater loadings and volumes. In-plant measures include improvement of housekeeping practices, byproduct recovery, wastewater recycling (with or without treatment), and others.

22. Technology applicable to primary aluminum wastes includes treatment of wet scrubber water and other fluoride-containing effluents to precipitate the fluorides. This is followed by settling of the precipitate and recycling of the clarified liquid to the wet scrubbers. Recycling will control the volume of wastewater discharged.

23. Wastewaters containing fluorides will originate from the potline, potrooms, anode bake plant, used cathode disposal, used cathode storage area, and storm water runoff. Precipitation of these effluents may be accomplished by addition of cryolite or lime. Holding ponds or lagoons should be provided for settling of that portion of the flow not recycled.

24. In secondary aluminum production, wastewaters originate from metal cooling, fume scrubbing, and residue milling. Metal cooling flows may be reduced or eliminated through air cooling of ingots or recycling. Fume scrubber wastewaters may be recycled after pH adjustment and settling. Effluents from residue milling should be given three or four-stage settling, pH adjustment, and total impoundment.

Solid Wastes

25. While a number of disposal methods for bauxite residues have been investigated, some form of dumping is currently considered to be the best method, including (a) land impoundment; (b) ocean dumping by ships, barges, or pipelines; and (c) seashore reclamation.

26. Land impoundment in a diked impervious area is most frequently used, and is the method to be generally employed for Bank-supported projects. Care must be taken to avoid contamination of ground waters. The settling ponds can remove 30 to 60 percent of the solids. In some cases, water from the impoundment area can be returned to the process as make-up water.

27. Sea disposal is practiced in a number of areas. At some sites in the Mediterranean, the residue is discharged via pipelines into underwater canyons at depths of over 2,000 meters. In Japan sea dumping is permitted, but only to areas and by methods specified by government regulations, with disposal areas being located over 300 kilometers from shore. Use of bauxite residue for seashore reclamation is permitted in Japan on a limited basis, but has been found to be very costly. For Bank-sponsored projects sea disposal may be used in special cases only, under carefully controlled conditions, and with the assurance that there will be no harmful effects on sea life.

28. Sludges from settling or other treatment of waste streams are transferred to contractors or reprocessors for recovery of metals. Drying beds, lagoons, landfills, or incineration are also used. Gravity thickening, vacuum filtration, or other conditioning may be applied ahead of ultimate disposal.
29. Particulate matter from dry scrubbers is burned, dumped on land, or recycled for byproduct recovery.

BIBLIOGRAPHY

1. "The Aluminium Industry and the Environment." UNEP Industry Sector Seminars, Aluminium Meeting, Paris, 6 to 8 October, 1975. Papers and Documents. (1975)
2. "Environmental Aspects of the Aluminium Industry - An Overview." UNEP Industry Programme. Paris (May 1977)
3. "Environmental Recommendations for Siting and Operation of New Primary Aluminium Industry Facilities." International Primary Aluminium Institute. London (1977)
4. "Air Pollution Control in the Primary Aluminum Industry." Singmaster & Breyey. New York (1973)
5. U.S. Environmental Protection Agency. "Environmental Considerations of Selected Energy Conserving Manufacturing Process Options." Alumina/Aluminum Report. Doc. EPA 600/7-76-034 h. Washington (December 1976)
6. U.S. Environmental Protection Agency. "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Bauxite Refining Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA 440/1-74-019-c. (March 1974)
7. U.S. Environmental Protection Agency. "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Primary Aluminum Smelting Subcategory of the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA-440/1-74-019-d. (March 1974)
8. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Secondary Aluminum Smelting Subcategory of the Aluminum Segment of the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA-440/1/74-019-e. (March 1974)
9. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA-440/1-79/019-a. (September 1979)

10. "Standard Methods for the Examination of Water and Wastewater." 15th Edition. American Public Health Association. New York (1980)
11. "Code of Federal Regulations - Protection of Environment," Title 40, Parts 400 to 424, U.S. Government Printing Office. Washington (July 1, 1981)
12. Atkins, M.H. and J.F. Lowe. "The Economics of Pollution Control in the Non-Ferrous Metals Industry." Pergamon Press. Oxford (1979)
13. Boodson, K. "Non-Ferrous Metals - A Biographical Guide." Macdonald & Co. (Publishers) Ltd. London (1972)

THE WORLD BANK

MARCH 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

NON-FERROUS METALS INDUSTRY

COPPER AND NICKEL PRODUCTION

ENVIRONMENTAL GUIDELINES

1. The non-ferrous metals category includes a large number of metallic elements, but only a few are of concern to World Bank operations at this time. Those most frequently encountered in Bank activities are covered in four separate documents in this series, as follows: (a) aluminum; (b) lead and zinc; (c) copper and nickel; and (d) silver, tungsten, columbium, and tantalum. This document will cover the production of primary and secondary copper, and primary nickel.

MANUFACTURING PROCESSES

COPPER

2. Smelting is the first step in the production of primary copper from the ore. One of two main process schemes is generally used: roasting, smelting, and converting; or simply smelting and converting. Roasting is used where numerous types of ores are processed, in order to reduce the content of sulfur and other impurities in the feed stock. Ore concentrates of uniform consistency frequently do not require the roasting step.

3. Smelting is carried out in either a reverberatory furnace or an electric furnace. The smelting and refining processes are illustrated in Figures 1 and 2. The end product is a molten copper-iron-sulfide material called matte. The matte goes to a converter, while the slag containing the impurities is skinned off as waste material for disposal.

4. In the converting step, the iron-sulfide component of the matte is oxidized to sulfur dioxide and iron oxide. The sulfur dioxide is carried off in the exhaust air streams. The iron oxide further reacts with silicate (added as a fluxing agent) to form iron-silicate slag. This slag contains significant amounts of copper and is thus recycled to the smelting step. The product from the converter units is called blister copper.

5. Blister copper, which contains various impurities, is cast into anodes and sent to electrolytic refining for purification. A small percentage of plants use fire refining to produce refined copper. Insoluble slimes are generated during the electrolytic process. These may contain economically significant amounts of copper, selenium, tellurium, lead, silver, and other precious metals. The slimes are usually treated off site, but may be treated on site, for byproduct recovery.

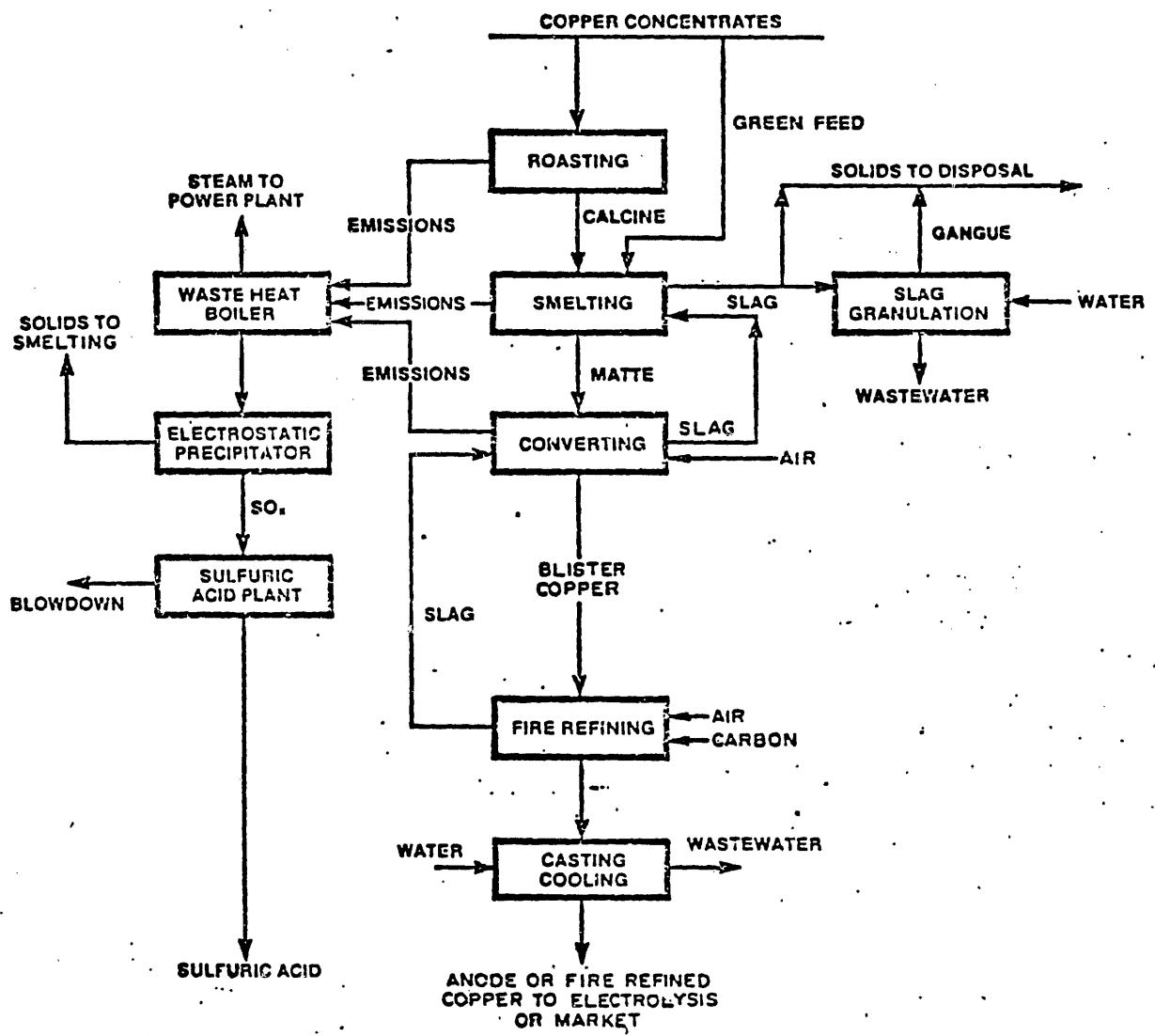


Figure 1. Primary Copper Smelting and Fire Refining Processes.
(From U.S. EPA Document EPA 440/1-79/019a)

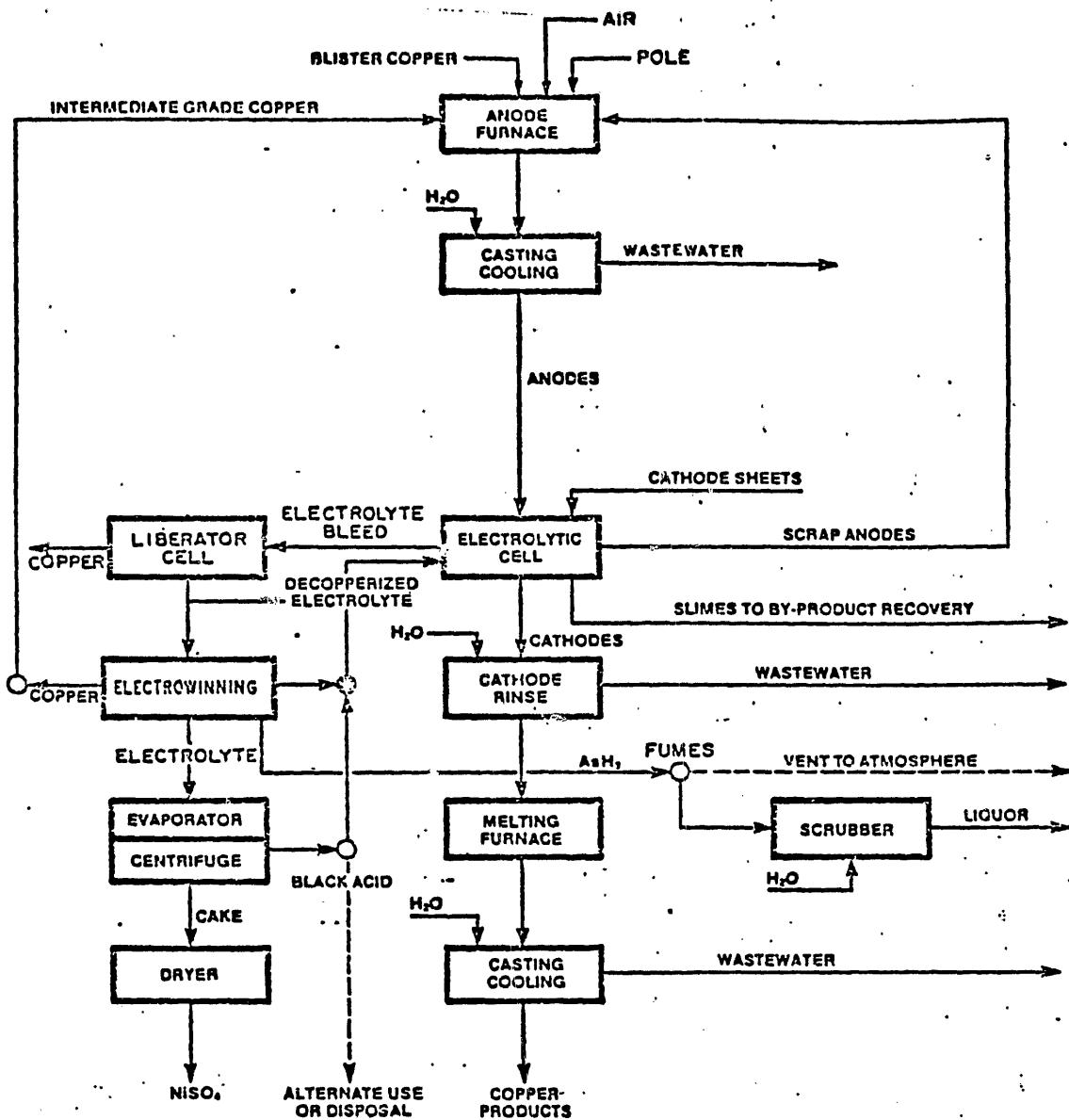


Figure 2. Primary Copper Electrolytic Refining Process.
(From U.S. EPA Document 440/1-79/019a)

6. Industrial copper-bearing scrap, discarded consumer items, and residues from melting and refining are the basic raw materials used in secondary copper production. The manufacturing process consists of pretreatment of scrap, smelting, and refining. The processing depends upon the raw materials used and the desired end product. The process is illustrated in Figure 3.

NICKEL

7. The nickel extraction industry may be divided into two major segments, based on the composition of the raw ore. Those ores which are mined underground are mainly sulfide ores. The nickel minerals are concentrated by physical methods, and the concentrates then smelted by pyrometallurgical methods.

8. Nickel oxide ores (also known as laterite ores) come from open pit mines, at or near the surface at maximum depths of some 30 meters. The nickel deposits from open mines cannot be concentrated by physical means. The metal is extracted either in a chemical form by leaching or as ferro-nickel by smelting.

9. Nickel sulfide concentrates are smelted with a flux to produce a copper-nickel-iron matte. The resulting furnace matte is treated to remove iron slag and part of the sulfur as sulfur dioxide gas, and to produce a sulfur-deficient copper-nickel matte.

10. The copper-nickel matte is slowly cooled to form copper and nickel sulfide crystals, plus a nickel-copper alloy containing significant quantities of precious metals. The crystal mass is pulverized to separate the components from each other. The nickel-copper alloy in the pulverized mixture is extracted magnetically and then refined electrolytically. The nickel-copper sulfide minerals are separated by flotation.

11. In one type of process the nickel sulfide concentrate is treated by selective leaching with ammonia, under pressure, and the solution then heated to precipitate the copper. Nickel and cobalt are recovered separately, as metal powders, by hydrogen reduction of the purified solution.

12. The carbonyl process can be also used to recover nickel from the nickel-sulfide concentrate. The sulfide is roasted to produce nickel oxide, and this is reduced with water gas to form crude sponge nickel. The sponge is then treated with carbon monoxide to form nickel carbonyl. Heat is applied to the carbonyl to decompose the Ni (CO)₄ mixture and produce nickel pellets or nickel powder. Iron sulfide concentrate, the residue from the carbonyl process, is further treated to recover nickel oxide as a marketable product.

13. Nickel oxide laterite ore, after drying and screening, is processed by smelting with coke, limestone, and gypsum to form an iron-nickel matte. The matte is then treated in the same way that mattes with similar composition are smelted and refined in the processing of sulfide ores.

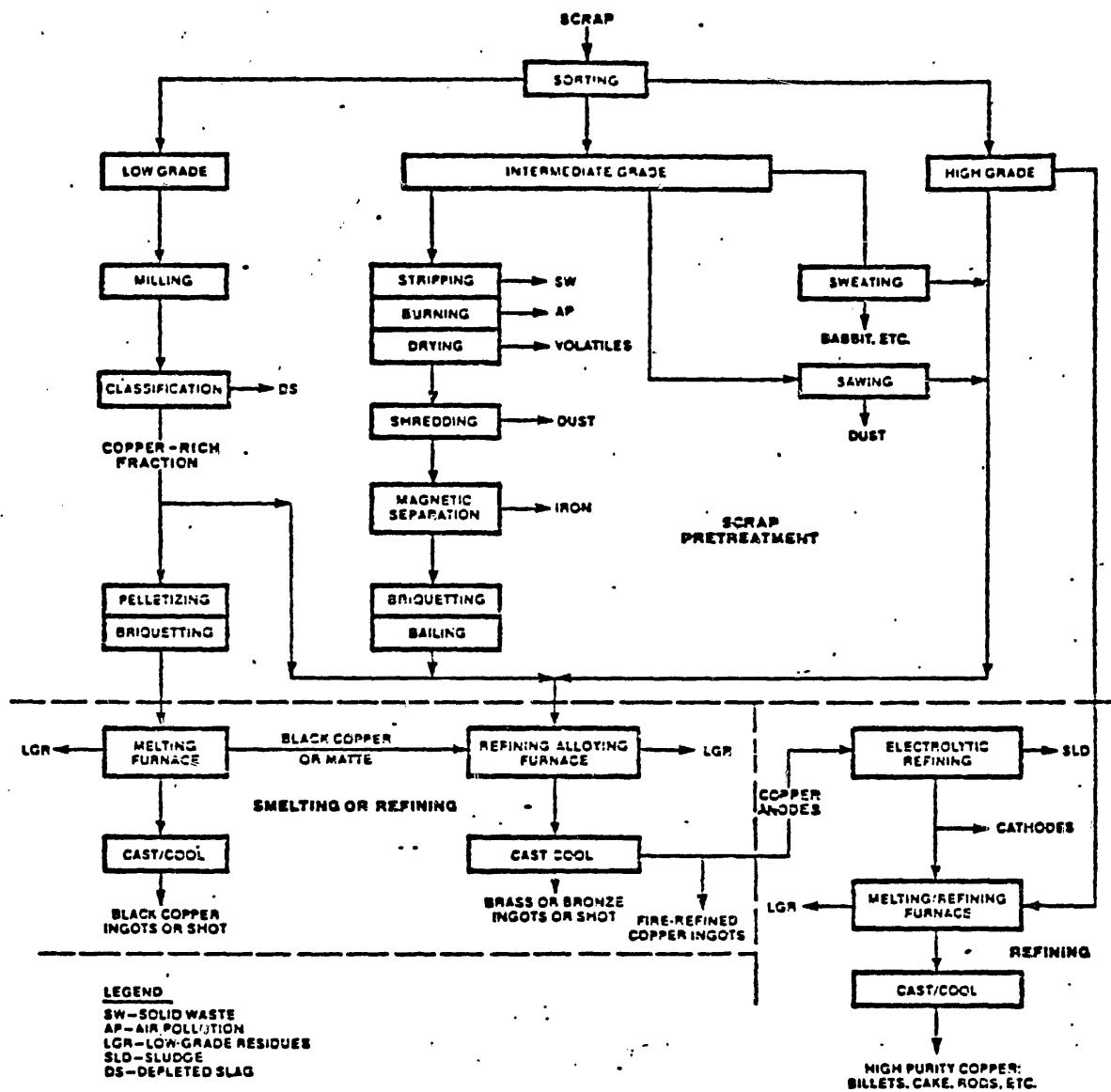


Figure 3. Secondary Copper Production Process.
(From U.S. EPA Document EPA 440/1-79/019a).

14. Another method of processing laterite ores is to smelt them with coke and limestone, or other carbon reductant, to produce ferronickel. The ferronickel is refined by dephosphorization, and removal of the silicon and chromium as a slag. The refined product is marketed.

15. Oxide ores may also be processed by leaching with ammonia or with sulfuric acid. Ammonia leaching will produce nickel oxide, which can be marketed or further refined by the methods used for sulfide ores. In sulfuric acid leaching the nickel and cobalt are precipitated as sulfides by hydrogen sulfide. The crude sulfide is leached in a weak acid solution to redissolve the nickel and cobalt, then neutralized with ammonia and processed for recovery of nickel and cobalt powders.

WASTE SOURCES AND CHARACTERISTICS

COPPER

Air Emissions

16. Emissions from the copper smelting and refining operations originate in the roasting, smelting, and converting processes. Sulfur dioxide and particulates are the principal pollutants. In some plants these gases pass through a boiler for heat recovery and then through a low-velocity flue device to settle out the heavier particulates. The smaller particles are usually removed by electrostatic precipitators or by baghouses.

17. Where gases are not burned in a boiler, the sulfur dioxide is recovered as liquid SO₂ or as sulfuric acid. Gases are preconditioned by electrostatic precipitators or scrubbing towers to remove the particulates and prevent the buildup of soluble salts such as metallic sulfates and chlorides. In secondary copper production, some emissions result from burning, drying, and shredding of the raw stock, but these are not considered to be significant.

Liquid Effluents

18. Wastewater from smelting in primary copper production originates from the acid plant blowdown, contact cooling, and slag granulation. In the refining facilities the effluents consist of waste electrolyte and cathode wash, anode wash, and contact cooling waters. Sources within a secondary copper plant include slag milling and classification, smelter air pollution control, contact cooling, electrolyte, and slag granulation.

Solid Wastes

19. Solids are produced mainly from air scrubbers and precipitators, furnaces (as slag), and scrap pretreatment in the case of secondary copper.

NICKEL

Air Emissions

20. Emissions from the processing of nickel sulfide ore concentrates contain significant amounts of both particulates and gases. These originate mainly from the roasters, smelters, and converters as well as from power generation facilities which may be part of the production facility. The character of the particulates depends upon the source. Gases will include one or more of the following: Sulfur oxides, nitrogen oxides, carbon monoxide, and water vapor. Some nickel oxide is carried to the atmosphere from roasting of precipitated nickel carbonate to remove carbon dioxide. Normally there will be no visible emissions from a well-operated nickel electrolytic refining operation.

21. Emissions from processing of nickel oxide ores will also contain significant amounts of particulates and gases. Sources and composition are similar to the emissions from nickel sulfide ore processing, but levels will differ. In furnaces which produce ferronickel, for example, sulfur oxides are a much lesser problem. Ammonia and sulfuric acid leaching operations are generally carried out in closed systems and hence contribute no emissions to the atmosphere.

Liquid Effluents

22. The major sources of liquid effluents will be the waters used for cooling at various points in the process. This would include the converter matte, furnace matte, converter slag, driers, reduction kilns, pelletizers, and wet scrubbers, where used for emissions control. Power generation facilities, if operated as part of the installation, may also be a source of cooling water.

23. Significant parameters governing discharges to adjacent waters will be temperature and total suspended solids. Oils and greases should also be considered in case of equipment leakages, spills from oil storage facilities, or other possible sources.

Solid Wastes

24. Solid wastes will originate periodically from emission control devices, settling in cooling pits, and sludges from waste treatment facilities.

EFFLUENT LIMITATIONS

Air Emissions

25. Wet or dry systems for removal of particulates, combined with collection of the gases for recycling or product recovery, will normally provide sufficient control to drastically reduce or eliminate discharges to the atmosphere. Where discharges are made to the environment then emission levels, for both copper and nickel production, are to be maintained at or below the following levels:

Sulfur Dioxide (SO₂)

Inside Plant Fence Ann. Arith. Mean 100 ug/m³
Max. 24-hour Peak 1000 ug/m³

Outside Plant Fence Ann. Arith Mean 100 ug/m³
Max. 24-hour Peak 500 ug/m³

Particulates

Ann. Geom. Mean 75 ug/m³
Max. 24-hour Peak 260 ug/m³

Nitrogen Oxides (as NO₂)

Ann. Arith. Mean 100 ug/m³

Carbon monoxide (CO)

Max. 8-hour Aver. 10 ug/m³
Max. 1-hour Aver. 40 ug/m³

Nickel Compounds (as Ni)

All processes Maximum 20 mg/m³

Liquid Effluents - Copper

26. Plants which engage in the smelting of primary copper from ore or ore concentrates are those whose operations include, but are not limited to, roasting, converting, leaching (if preceded by a pyrometallurgical step), slag granulation and dumping, fire refining, and the casting of products from these operations.

27. Based on the application of the best practicable control technology currently available, there should be no discharge of process wastewater to surface or ground waters. Effluents may be impounded, with or without pretreatment, and recycled in most cases.

28. Where impoundment is not practicable or there must be periodic releases, then the following effluent limitations apply:

	Max. 24-hour	Consecutive 30-day Aver.
	<u>Mg/Liter of Effluent</u>	
TSS	50	25
As	20	10
Cu	0.5	0.25
Pb	1.0	0.5
Cd	1.0	0.5
Se	10	5
Zn	10	5
pH	6 to 9 Units	6 to 9 Units

29. Plants engaged in the electrolytic refining of copper are those whose operations include, but are not limited to, anode casting (performed at refineries which are not located onsite with a smelter), product casting, and by-product recovery.

30. On the basis of best practicable control technology currently available, wastewater effluents from such plants should not exceed the following limitations:

	Max. 24-hour	Consecutive 30-day Aver.
	<u>Kg/Metric Ton of Product</u>	
TSS	0.10	0.05
Cu	1.7×10^{-3}	0.8×10^{-3}
Cd	6×10^{-5}	3×10^{-5}
Pb	6×10^{-4}	2.6×10^{-4}
Zn	1.2×10^{-3}	0.3×10^{-3}

31. Plants engaged in secondary copper production are those which recover, reprocess, and remelt new and used copper scrap and residues to produce copper metal and copper alloys. There should be no discharge of liquid effluent from this source. Wastewaters may be impounded and in many cases recycled, either with or without pretreatment.

32. Where impoundment is not practicable, or periodic releases are necessary, then discharges should meet the following limitations:

	Max 24-hour	Consecutive 30-day Aver.
	<u>Mg/Liter of Effluent</u>	
TSS	50	25
Cu	0.5	0.5
Zn	10	5
Oil & Grease	20	10
pH	6 to 9 Units	6 to 9 Units

Liquid Effluents - Nickel

33. Based on best practicable control technology currently available, wastewater discharges from primary nickel production may be impounded and recycled in many cases, with or without pretreatment. Where impoundment is not possible then discharges are to meet the following limitations, based on results achieved at Canadian plants:

	<u>Consecutive 30-day Aver. Mg/Liter</u>
TSS	15
Cu	0.2
Ni	0.5
Fe	0.5
pH	6 to 9 Units

CONTROL AND TREATMENT OF WASTES

34. As a first step in developing measures for control of emissions, wastewaters, and other sources of wastes, a critical analysis should be made of plant operations to determine what internal measures can be taken to reduce discharges to the environment. This includes utilization or recycling of waste products, process changes, isolation of highly concentrated waste streams for separate treatment, improved housekeeping procedures, control of water use, and other similar measures.

Air Emissions

35. Gaseous and particulate emissions can be controlled by wet or dry scrubbers, cyclone filters, electrostatic precipitators, or other devices. Discharges from wet systems are added to other liquid process wastes and receive the same treatment. Dry systems are preferable where possible, since they are generally as effective and do not add to the volume of wastewaters. The collected dusts and particulates are more readily disposable or reusable in the dry state. Tall chimneys (with heights in the 75 to 125 meter range) may be needed in addition to the scrubbers or other emission systems.

Liquid Effluents

36. Scrubber waters from primary copper smelters can be treated by settling, combining the supernatant with the cooling water, applying chemical precipitation, and recycling. Contact cooling waters from primary copper refineries may be recycled. Acid plant blowdown waters should receive chemical precipitation and filtration, and the filtrate recycled.

37. Slag mill wastewaters in a secondary copper plant can be settled, and the supernatant combined with the contact cooling water for treatment by chemical precipitation. The supernatant may receive further filtration, stored and recycled, thus resulting in zero discharge.

38. Oil leakages, in both copper and nickel production facilities, from machinery, fuel storage, or other sources can be controlled by installing oil trapping and recovery systems. A dike system may be advisable for the oil unloading and storage areas.

39. Most of the liquid discharges in nickel production will come from cooling the mattes and slag casts. These streams will be high in suspended solids and contain varying degrees of nickel, cobalt, iron, and other impurities. The wastewaters should be settled in ponds or tanks, and the supernatant cooled and reused within the plant. Depending upon the suspended solids contents, the supernatant waters may require filtration or other additional treatment before reuse or discharge to surface waters.

40. Where waters are discharged to nearby surface waters temperatures must be reduced in order to avoid interference with other uses of the receiving waters. Discharge temperatures should be about 30°C or lower.

Solid Wastes

41. Solid wastes may contain reusable materials, and this should be the first consideration in developing disposal measures. Sludges, if not sold for reprocessing, may be discharged on-site to drying beds, lagoons, landfills, or similar facilities. Dried sludges, dry particulates, and other similar residues can be piled on land or used for landfill. Care should be taken at dump sites to avoid contaminating ground waters and to prevent the pollution of surface waters by runoff.

BIBLIOGRAPHY

1. National Academy of Sciences. "Medical and Biologic Effects of Pollutants - Nickel." Washington (1975)
2. Canada Department of Mines and Resources, Mineral Resources Division. "Nickel-Canada and the World." Mineral Report 16. Ottawa (1968)
3. United Nations Industrial Development Organization. "Non-Ferrous Metals - A Survey of Their Production and Potential in the Developing Countries." Vienna (1972)
4. Jarrault, P. "Limitation des Emissions de Polluants et Qualite de L'Air." Institut Francais de L'Energie. Paris (1978)
5. U.S. Environmental Protection Agency. "Guidance for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds." Document EPA 450/3/79-024. Washington (April 1979)
6. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA-440/1-79/019-a. Washington (September 1979).

7. Atkins, M.H. and J.F. Lowe, "The Economics of Pollution Control in the Non-Ferrous Metals Industry." Pergamon Press. Oxford (1979).
8. Powers, P.W. "How to Dispose of Toxic Substances and Industrial Wastes." Noyes Data Corporation. Park Ridge, NJ. and London (1976)
9. "Standard Methods for the Examination of Water and Wastewater." 15th Edition. American Public Health Association. New York (1980).
10. Nevala, E.C., H.R. Butler, and H.J. Koehler. "Aqueous Effluent Treatment at the Sudbury Processing Complex of INCO Limited." Presented at 24th Industrial Waste Conference, Toronto, Ontario, May 29 to June 1, 1977.
11. U.S. Code of Federal Regulations. Title 40, "Protection of Environment". Chapter 1, Part 42, "Nonferrous Metals Manufacturing Point Source Category". Washington. Washington (July 1, 1981).

THE WORLD BANK

FEBRUARY 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

NON-FERROUS METALS INDUSTRY

LEAD AND ZINC PRODUCTION

ENVIRONMENTAL GUIDELINES

1. The non-ferrous metals category includes a large number of metals, but only a few are of concern to World Bank operations at this time. Those most frequently encountered in Bank operations are covered in four separate documents in this series, as follows: (a) aluminum; (b) lead and zinc; (c) copper and nickel; and (d) silver, tungsten, columbium, and tantalum. This document will be confined to the production of primary and secondary lead, and primary zinc.

MANUFACTURING PROCESSES

LEAD

2. Galena, cerusite, and anglesite are the principal mineral ores used in the primary lead industry. The manufacturing process includes both refining and smelting. Usually both operations are carried out at the same locations, but are independent of each other. The manufacturing process is shown in Figure 1.

3. The smelting process consists of blending the ore concentrates with recycled products and fluxes. The blend is pelletized and fed to a sintering machine. From the machine, the sinter passes through a breaker for breaking and sizing. Oversized particles are charged to the blast furnace and the small particles returned to the sinter feed operations.

4. The blast furnace is the primary reduction unit of the smelter process. Three molten layers are usually formed in this unit. The top layer consists of a slag containing silicate of iron, calcium, magnesium, trace impurities, and sometimes significant quantities of lead and zinc. The middle layer (which does not always form) is composed of copper and iron sulfide, along with some precious metals. The bottom layer comprises the lead bullion which goes to the refining process.

5. Hard lead (sometimes referred to as antimonial lead) is the principal product of the primary lead industry. The initial step in the refining process is usually called "dross decopperizing" and serves to remove the copper. The dross (or skimmed slag) is treated in a reverberatory furnace to separate the lead. The copper matte from the decopperizing goes to a copper smelter. The separated lead is further processed to remove the antimony, gold, silver, bismuth, zinc, and any other impurities which may be present.

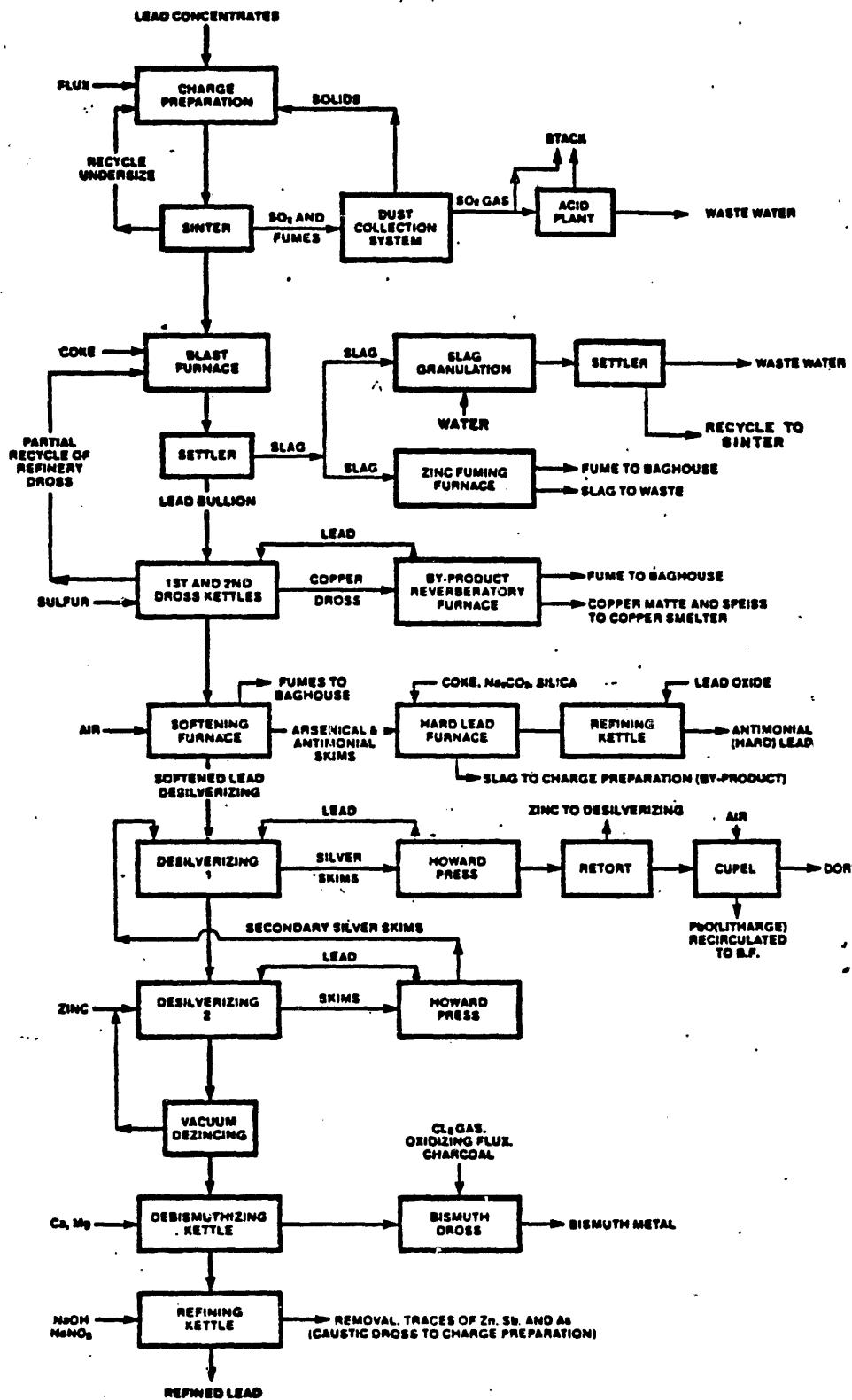


Figure 1 - Primary Lead Manufacturing Process.
(From US EPA Document EPA 440/1-79/019a)

6. The principal raw materials used in the secondary lead industry are storage battery plates and lead residues. Some use is also made of solder, babbitt (an alloy used to line machine bearings), cable coverings, and others. The lead is produced by charging the scrap materials to a reverberatory furnace (to produce soft lead) or to a blast furnace (to produce hard lead). The soft lead may be further refined to produce lead oxide. The hard lead may either be shipped without additional processing or further processed at the site to fill specific needs. A flow diagram for the secondary lead/antimony smelting process is presented in Figure 2.

ZINC

7. The two major sources of raw material for production of primary zinc are the zinc concentrate recovered as a co-product from lead and copper ores and the zinc ores from mining operations. The pyrolytic and electrolytic processes are the two methods in general use for primary zinc production.

8. In the pyrolytic process, shown in Figure 3, the concentrates are roasted after drying and blending to remove sulfur as sulfur dioxide, as well as to remove varying amounts of other volatile impurities such as mercury, lead, and calcium. The roasted concentrate (calcine) is blended with coke, moisture, and sometimes silica sand, and then pelletized. The pellets are sintered and crushed, and then fed to a reduction furnace. Most of the cadmium and lead is removed during sintering.

9. The zinc contained in the sinter is reduced to zinc oxide or metallic zinc in a vertical retort furnace or an electrothermic furnace. In either case, the resulting zinc vapor is condensed and cast into ingots. The uncondensed zinc and carbon monoxide are passed through a wet scrubber. The exhausted carbon monoxide is used as a fuel, and the zinc is removed from the scrubber water for reprocessing.

10. In the electrolytic process, presented in Figure 4, the roasting is followed by leaching of the calcine with spent electrolyte (H_2SO_4) to dissolve the zinc and cadmium. The solids (gangue) are separated by sedimentation and filtration, and sold to other processors for recovery of the lead and copper.

11. The zinc solution is further purified by adding zinc dust (and sometimes scrap iron) in stages. These steps first precipitate copper and other impurities and then cadmium. The pure solution is filtered, cooled and then passed to electrolytic cells, where the zinc is deposited on aluminum cathodes. The purified zinc is stripped from the cathode, melted, and cast into various shapes for marketing.

12. The solids from the filtration step are usually processed on site to recover the cadmium, if they are rich in cadmium, and the residues sent elsewhere to other processors for recovery of other metals. Cadmium-rich solids are leached with sulfuric acid to dissolve the cadmium, and then treated with zinc dust and other reagents to precipitate a cadmium sponge. The sponge is then further processed to produce cadmium metal, which is cast into shapes (usually small spheres) suitable for electroplating.

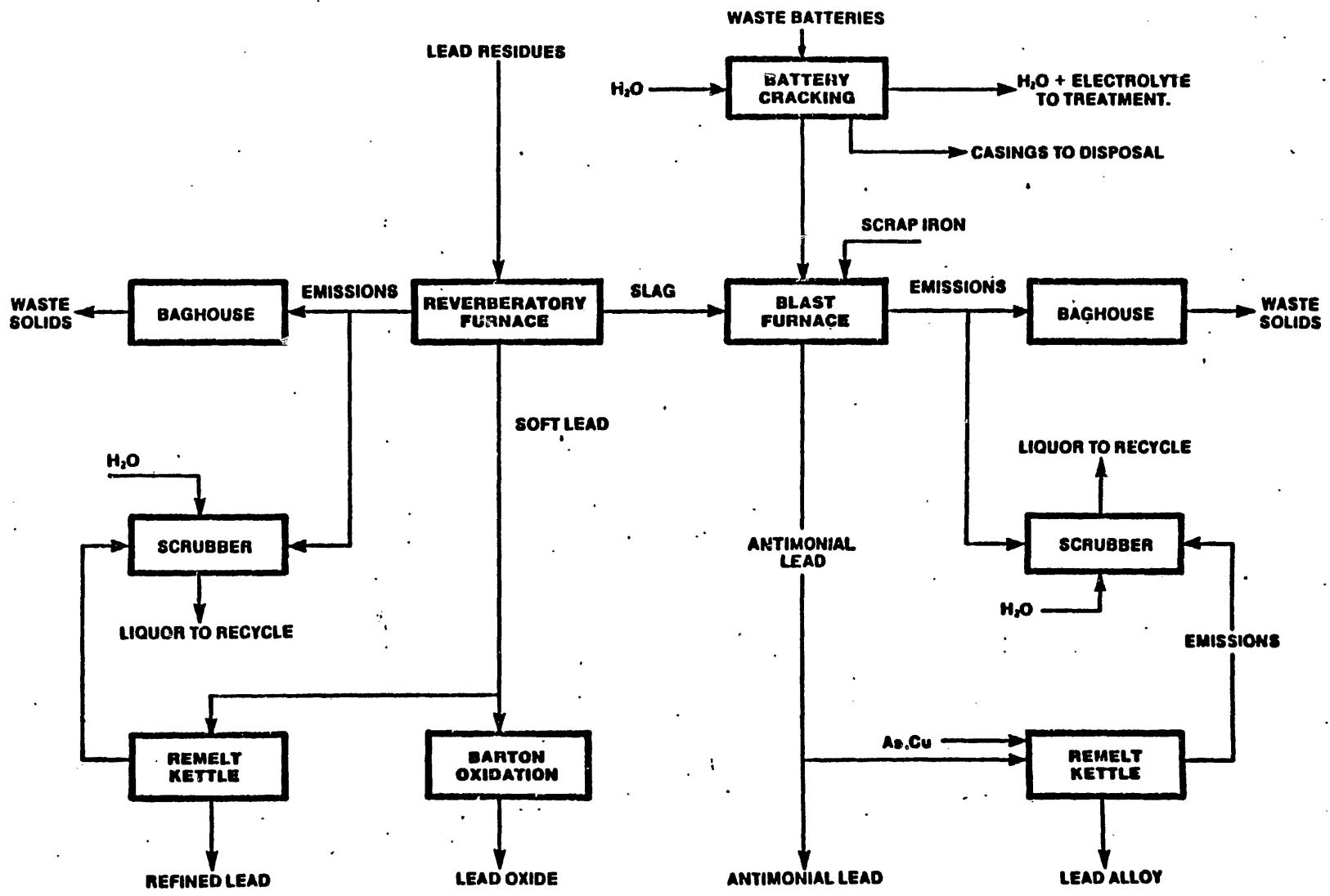


Figure 2- Secondary Lead/Antimony Smelting Process.
(From USEPA Document EPA 440/1-79/019a)

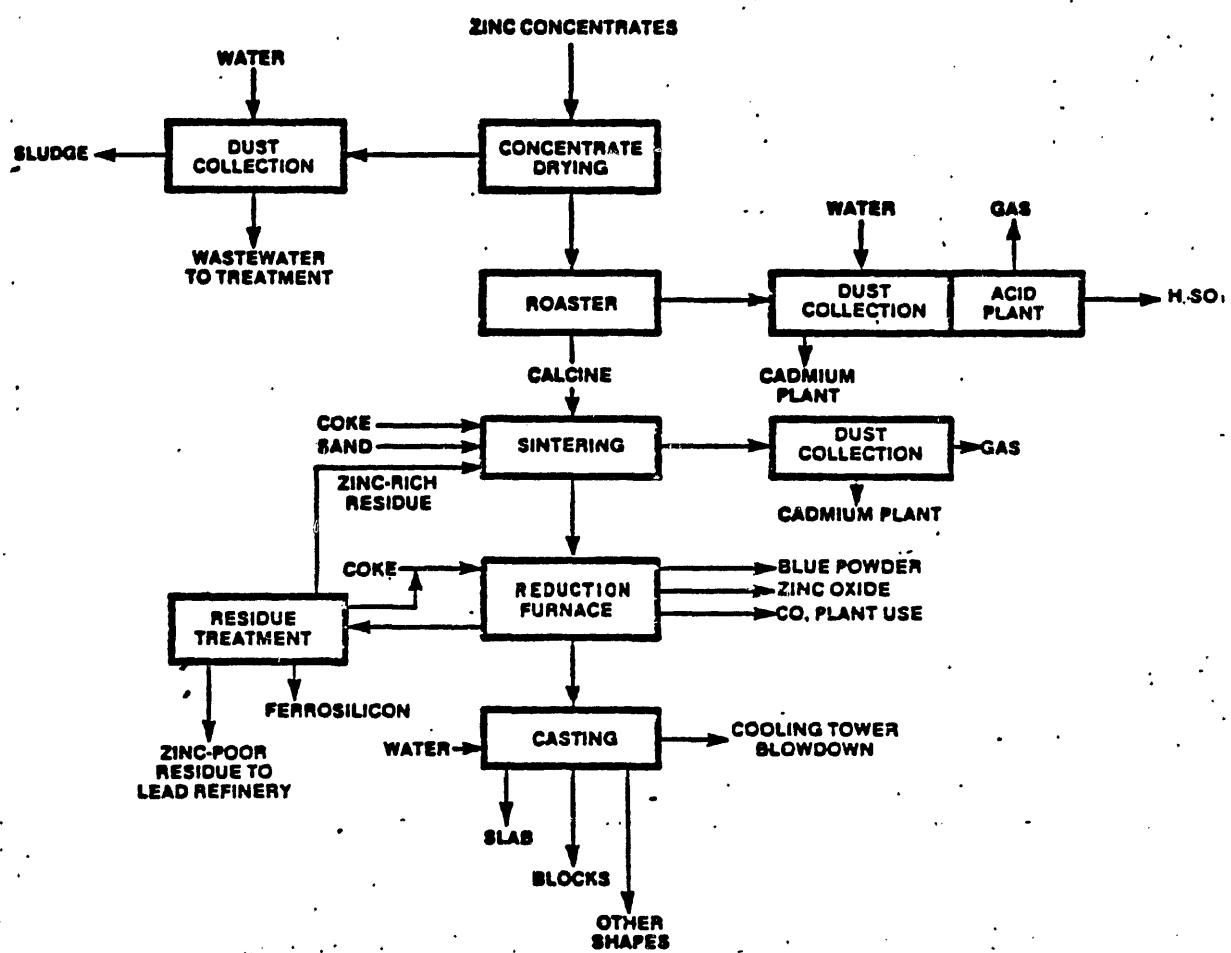


Figure 3- Pyrolytic Zinc Production Process
(From US EPA Document EPA-440/1-79/019a)

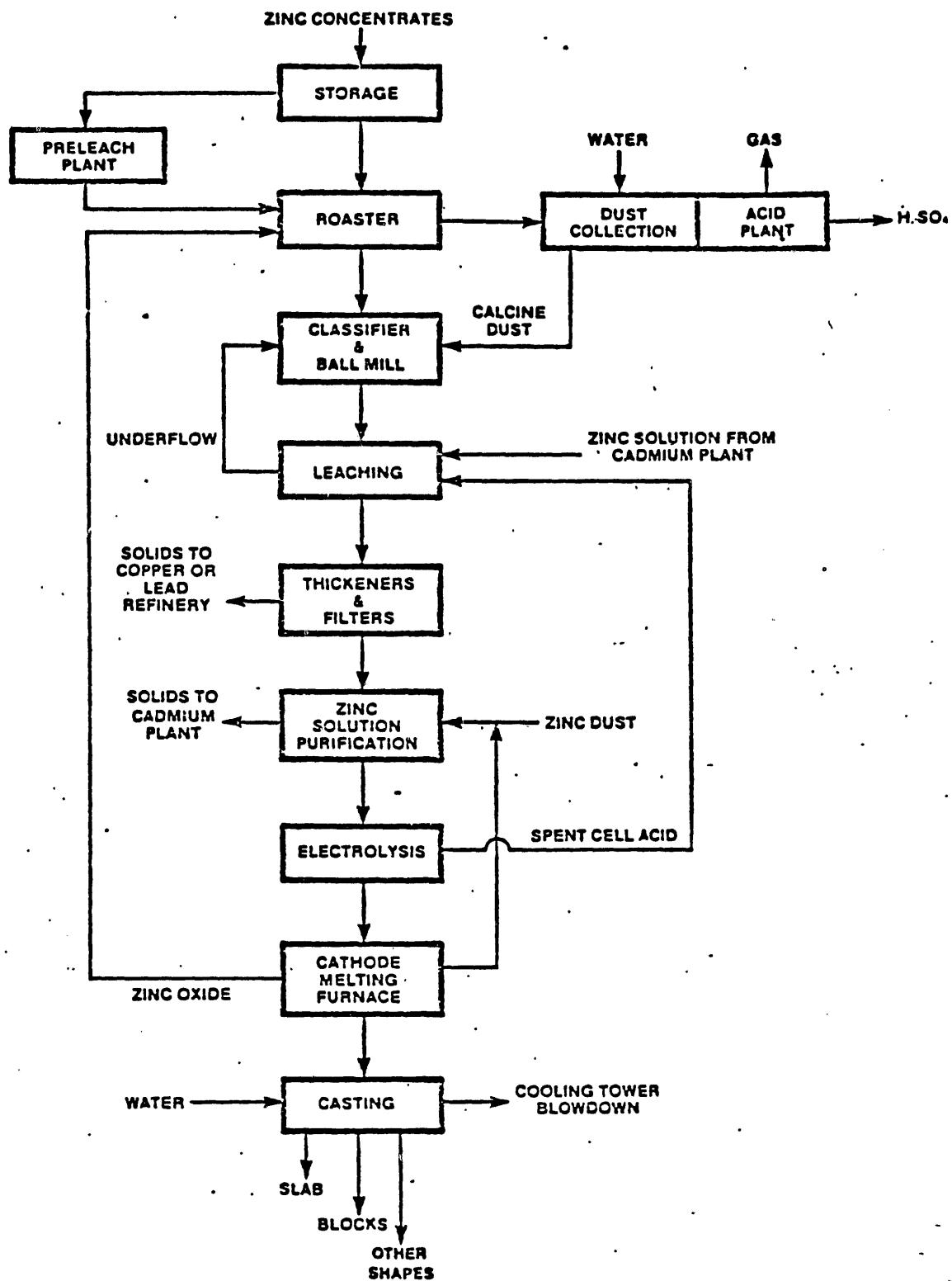


Figure 4- Electrolytic Zinc Reduction Process
(From USEPA Document EPA-440/1-79/019a)

WASTE SOURCES AND CHARACTERISTICS

LEAD

Air Emissions

13. The smelting process in primary lead production generates gaseous emissions of sulfur oxides, arsenic, antimony, and cadmium in the sintering of the ore blends. A highly concentrated SO_x stream produced during the initial phase of the operation may or may not go to a sulfuric acid plant. Particulates are removed by flue, baghouse, or wet scrubbers for recycling to sintering machines.

14. In the refining process, some fumes are produced, mainly by the softening furnace. Established air pollution control devices are used to remove these emissions, and no significant quantities are normally discharged to the atmosphere.

15. Secondary lead, produced mostly from discarded storage battery plates, generates gaseous emissions from both reverberatory and blast furnaces, and the remelt kettles. These are removed by baghouses or scrubbers. Water from the scrubbers is generally recycled.

Liquid Effluents

16. Liquid wastes in primary lead smelting originate from sintering air pollution control units, acid plant blowdowns, blast furnace emission control devices, zinc fuming control units, slag granulation, and dross reverberatory furnace emission control devices. Wastewater in the refining process can originate from wet scrubbers, but this water is usually recycled and no discharge results. Cooling of the castings is usually a non-contact operation and the water is normally recycled.

17. For secondary lead plants the waste streams include battery acid, raw cooling, and washdown from the battery cracking. Furnace and kettle air pollution control devices and contact cooling contribute wastewater in the smelting process. Battery acid streams are strongly acidic and contain significant levels of suspended solids, as well as several metals such as antimony, arsenic, cadmium, lead, and zinc. Metal cooling is usually accomplished by non-contact methods.

Solid Wastes

18. Solid wastes originate from air pollution control devices, preparation of feeds, furnace operations, and other sources. A significant portion of these residues are reused in the process.

ZINC

Air Emissions

19. Emissions originate from the drying process in pyrolite zinc production, from which they are removed by wet scrubbers and discharged with the wastewater. The roaster units remove sulfur as sulfur dioxide, as well as other volatile impurities such as arsenic, lead, and cadmium. The exhaust gases pass through a dust collection system before transfer to an acid plant for conversion to sulfuric acid. The waste solids are later treated to recover cadmium.

20. The blending and pelletizing of the ore concentrate also produces a dust, which is collected and treated to recover cadmium and lead. The reduction of the zinc contained in the sinter to zinc oxide or metallic zinc produces uncondensed zinc and carbon monoxide. These are passed through a wet scrubber, with the carbon monoxide being used as a fuel and the zinc recovered for reprocessing.

21. The roasting furnaces in electrolytic refineries remove sulfur as sulfur dioxide from the ore concentrates, and this goes to a sulfuric acid plant. These emissions may also contain other impurities such as mercury, lead, and cadmium. Calcine dust from the roasters is separated from the sulfur dioxide in the dust collectors and returned to the process.

Liquid Effluents

22. Wastewater flows in primary zinc production originate from the wet scrubbers which collect emissions from the concentrate, roasting, sintering, and leaching units. Other effluents are discharged from the acid plant blowdown, reduction furnace, preleaching, anode/cathode washing, and contact cooling. Depending upon the source, the waste streams will contain varying concentrations of lead, arsenic, cadmium, zinc, and other pollutants. Toxic heavy metals should be removed by neutralization before discharge.

Solid Wastes

23.. In general, the dusts and other solids resulting from zinc production contain significant quantities of other metals, such as lead and copper. These residues are sold to other processors for recovery of valuable components.

24. Cadmium byproduct recovery, nearly always practiced at primary zinc plants, does not generate any significant quantities of solid wastes.

EFFLUENT LIMITATIONS

Air Emissions

25. For both lead and zinc plants, equipment is readily available (such as wet or dry scrubbers) to avoid the discharge of particulates and gases to the atmosphere. However, where these substances cannot be or are not removed, then the following limitations will apply:

Sulfur Dioxide (SO₂)

Inside Plant Fence	Ann. Arith Mean Max. 24-hour Peak	100 $\mu\text{g}/\text{m}^3$ 1000 $\mu\text{g}/\text{m}^3$
Outside Plant Fence	Ann. Arith Mean Max. 24-hour Peak	100 $\mu\text{g}/\text{m}^3$ 500 $\mu\text{g}/\text{m}^3$
Particulates	Ann. Geom. Mean Max. 24-hour Peak	75 $\mu\text{g}/\text{m}^3$ 260 $\mu\text{g}/\text{m}^3$

Arsenic (as As)

Inside Plant Fence	24-hr. Av.	0.006 mg/m ³
Outside Plant Fence	24-hr. Av.	0.003 mg/m ³

Cadmium (as Cd)

Inside Plant Fence	24-hr. Av.	0.006 mg/m ³
Outside Plant Fence	24-hr. Ave.	0.003 mg/m ³

Lead (as Pb)

Inside Plant Fence	24-hr. Av.	0.008 mg/m ³
Outside Plant Fence	24-hr. Av.	0.004 mg/m ³

Liquid Effluents

26. On the basis of best practicable control technology presently available, liquid discharges should not exceed the following limits:

Primary Lead

	Max-24 hour	Consecutive
		30-day Aver.
		Kg/MT Product
TSS	4.2×10^{-2}	2.1×10^{-2}
Cd	8×10^{-4}	4×10^{-4}
Pb	8×10^{-4}	4×10^{-4}
Zn	8×10^{-3}	4×10^{-3}
pH	6 to 9 units	6 to 9 units

Secondary Lead (Battery Cracking)

TSS	5×10^{-2}	2.5×10^{-2}
Cd	4×10^{-5}	2×10^{-5}
Pb	1×10^{-3}	0.5×10^{-3}
As	1×10^{-4}	0.5×10^{-4}
pH	6 to 9 units	6 to 9 units

Consecutive
Max-24 hour 30-day Aver.

Kg/MT Metal Product

Primary Zinc

TSS	0.42	0.21
As	1.6×10^{-3}	8×10^{-4}
Cd	8×10^{-3}	4×10^{-4}
Se	0.08	0.04
Zn	0.08	0.04
pH	6 to 9 units	6 to 9 units

CONTROL AND TREATMENT OF WASTES

Air Emissions

27. Both the lead and zinc industries make extensive use of wet and dry methods for removal of particulates and gases. Liquid effluents from the wet systems are handled with the wastewaters and receive the same treatment. Dry systems are preferable, since removal efficiencies are high and wastewater volumes are reduced. Current trends are toward dry systems for new plants and replacements.

Liquid Effluents

28. The initial step in disposing of wastewaters is to critically examine housekeeping practices. In-plant measures such as process changes, monitoring of water use, byproduct recovery, and recycling can make significant reductions in the amount of liquid effluents that must be treated and discharged.

29. Except for acid plant blowdown water, zero discharge by recycling is achievable in a primary lead plant. Acid plant blowdown waters may be treated by chemical precipitation and filtration.

30. Wastes from secondary lead production from battery cracking can be treated by using lime for pH adjustment, followed by flocculation, precipitation, and settling.

31. Waste streams from primary zinc production can be treated by chemical precipitation, using alumina, and filtration. Cooling waters may be combined with other streams and receive the same treatment. Generally, all effluents can be collected, after treatment, and recycled.

Solid Wastes

32. Sludge disposal is a problem in these industries, since the waste streams may carry large concentrations of metals. Sludges are frequently removed by contractors for off-site disposal or sold to reprocessors for recovery of metals. Drying beds, lagoons, landfills, incineration, or a combination of these can be effectively used for on-site disposal.

33. Particulate matter from dry scrubbers may be burned, placed in a landfill or reprocessed for byproduct recovery.

BIBLIOGRAPHY

1. United Nations Industrial Development Organization. "Non-ferrous Metals - A Survey of Their Production and Potential in the Developing Countries." Vienna (1972)
2. Atkins, M.H. and J.F. Lowe, "The Economics of Pollution Control in the Non-Ferrous Metals Industry." Pergamon Press. Oxford (1979)
3. Boodson, K. "Non-Ferrous Metals - A Biographical Guide." Macdonald & Co. (Publishers) Ltd. London (1972)
4. Powers, P.W. "How to Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation. Park Ridge, NJ. and London (1976)
5. "Standard Methods for the Examination of Water and Wastewater." 15th Edition. American Public Health Association. New York (1980)
6. "Chemical Engineers Handbook." Ed. by Robert H. Perry and Cecil H. Chilton. Fifth Edition. McGraw-Hill Book Co. New York (1973)
7. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Point Source Category." Doc. EPA-440/1-79/019-a. (September 1979)

THE WORLD BANK

MARCH 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

NON-FERROUS METALS INDUSTRY
SILVER, TUNGSTEN, COLUMBIUM, AND
TANTALUM PRODUCTION
ENVIRONMENTAL GUIDELINES

1. The non-ferrous metals category includes a large number of metallic elements, but only a few are of concern to World Bank operations at this time. Those most frequently encountered in Bank projects are covered in four separate documents in this series, as follows: (a) aluminum; (b) lead and zinc; (c) copper and nickel; and (d) silver tungsten, columbium, and tantalum. This document will cover the production of (a) secondary silver from photographic and non-photographic wastes; (b) primary tungsten salts (ammonium paratungstate-APT) and metal; and (c) primary columbium and tantalum salts and metals.

MANUFACTURING PROCESSES
SECONDARY SILVER

2. The principal sources of raw materials are photographic wastes, plating and sterling ware wastes, electrical components, and miscellaneous sources. Photographic wastes are the largest single source. Typical production processes are shown in Figures 1 and 2.

3. In the recovery of silver from photographic materials, the film is chopped into small pieces, followed by separation of the silver from the films by nitric acid stripping. Then follows sedimentation, decantation and filtration. The plastic residue is disposed of as solid waste, while the liquid portion is mixed with chemicals to precipitate the silver. Spent photographic solutions may also be added at this point for recovery of the silver. The supernatant is decanted and sent to treatment. The sludge is thickened, filtered or centrifuged, dried, roasted, and cast into ingots (also known as Dore plates). The ingots may be further refined on site or shipped elsewhere. The roasting furnace slag is crushed and classified, the silver concentrate is returned as furnace feed, and the tailings go to landfill.

4. Cyanide solutions from the plating and sterlingware industries are treated with sodium hypochlorite to precipitate the silver and oxidize the cyanide. Following initial settling more sodium hypochlorite and lime are added, and the solution resettled. The resulting silver-chloride precipitate is washed and dried for further processing or sold as a final product.

PHOTOGRAPHIC FILM SCRAP

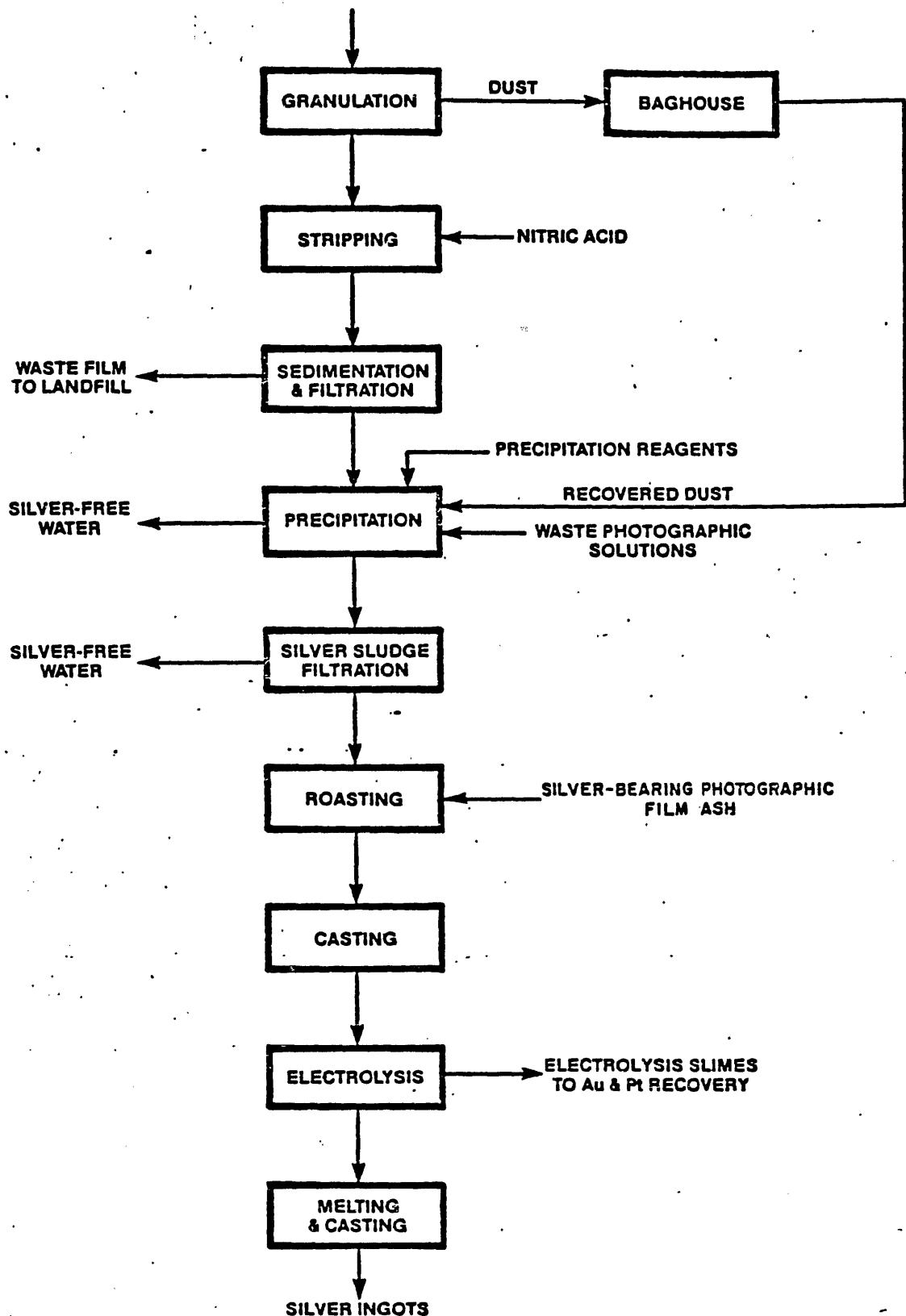


Figure 1. Silver Refining From Photographic Wastes
(from US EPA Document EPA 440/1-79/019a)

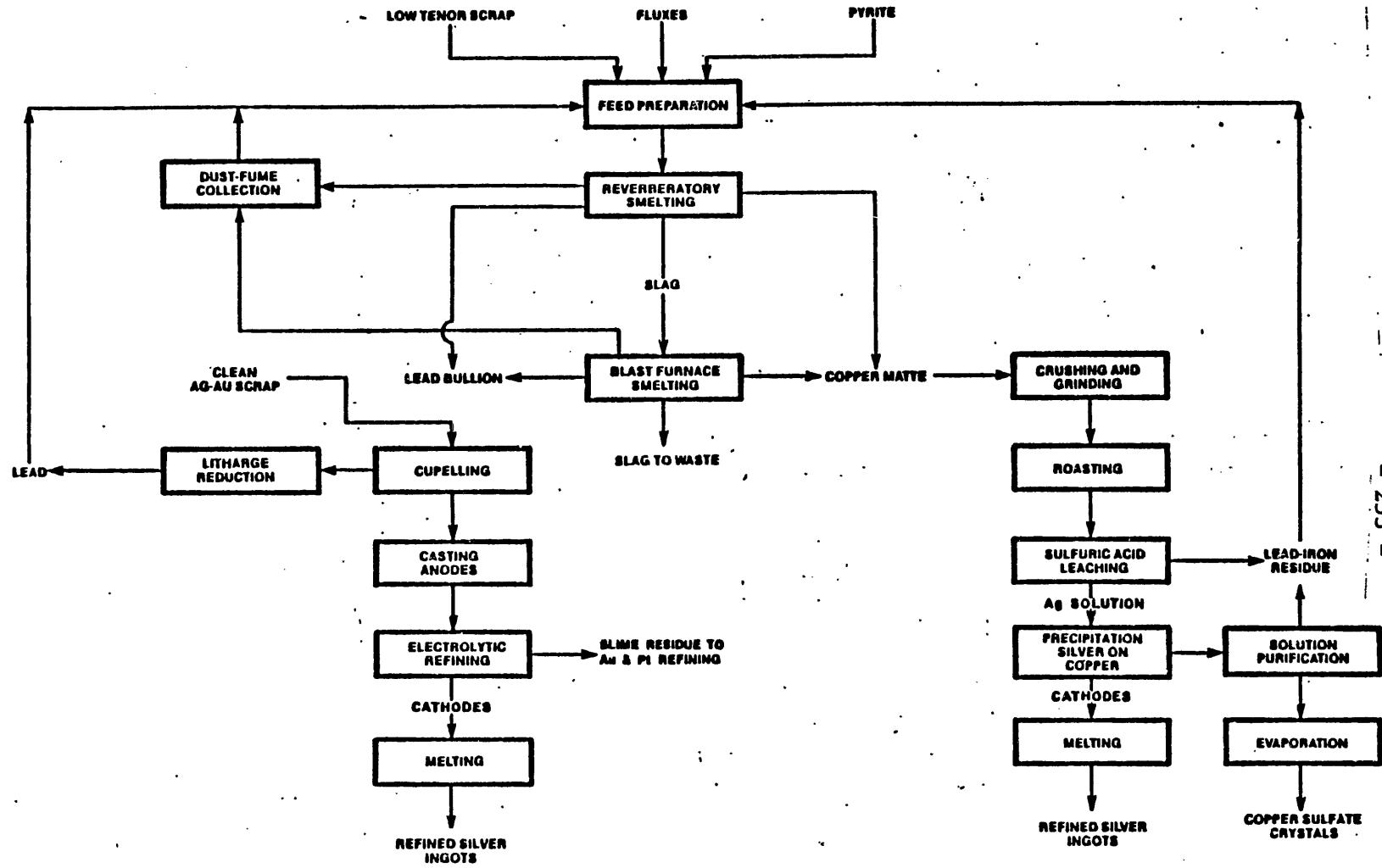


Figure 2. Secondary Silver Production Process from Non-Photographic Scrap.
 (From US EPA Document EPA 440/1-79/019a)

5. When electrical components scrap is not suitable for electrolytic refining, it must be further processed to recover the silver. The scrap is first melted in a reverberatory furnace to produce lead bullion, copper matte, and slag. The lead bullion is melted to produce litharge and precious metals layers. The litharge goes to a lead refinery and the precious metals layer is cast into anodes for electrolytic refining. The copper matte is processed to separate the silver, which is cast as ingots. The slag is smelted in a blast furnace to separate the lead and copper portions. Blast furnace slag is discarded as waste. This procedure is shown in Figure 2.

PRIMARY TUNGSTEN

6. A number of processes are available for producing tungsten salts and metal. Ferberite (FeWO_4) and scheelite (CaWO_4) are the two ores most widely used to produce ammonium paratungstate (APT) and tungsten metal powder. Typically, tungstate (WO_4) is purified from concentrates and converted to tungstic acid (H_2WO_4) through a series of filtration and precipitation reactions. Further processing produces the intermediate product designated as APT. The APT is dried, sifted, and converted to oxides which, in turn, are finally reduced to tungsten metal powder. The powder is eventually used to produce the metal, or combined with carbon or other metals to make carbides or metal alloys. The production process is shown in Figure 3.

PRIMARY COLUMBIUM AND TANTALUM

7. Columbium is the more popular name for niobium, which is element 41 in the periodic system. Tantalum (number 73 in the periodic system) and columbium generally occur together in nature as the minerals tantalite and columbite, respectively.

8. Raw materials for the production of primary columbium and tantalum salts are ore concentrates and slags. The slags used are generally those resulting from tin production. Three types of plants are encountered: producers of metals and salts from concentrate and slags; producers of purified salts only from concentrates and slags; and producers of metals from purified salts. The salts of these two elements are produced first in the process. The salts are then subjected to aluminothermic, sodium, or other reduction in order to produce the two individual metals. Production processes are illustrated in Figure 4.

WASTE SOURCES AND CHARACTERISTICS SECONDARY SILVER

Air Emissions

9. In the production of silver from photographic film, dusts and particulates originate in the film chopping operation. Particles are also released when the film is incinerated. The dusts are collected and returned to the process for recovery of the silver. Roasting furnaces also cause emissions but these are readily controlled by the use of wet scrubbers.

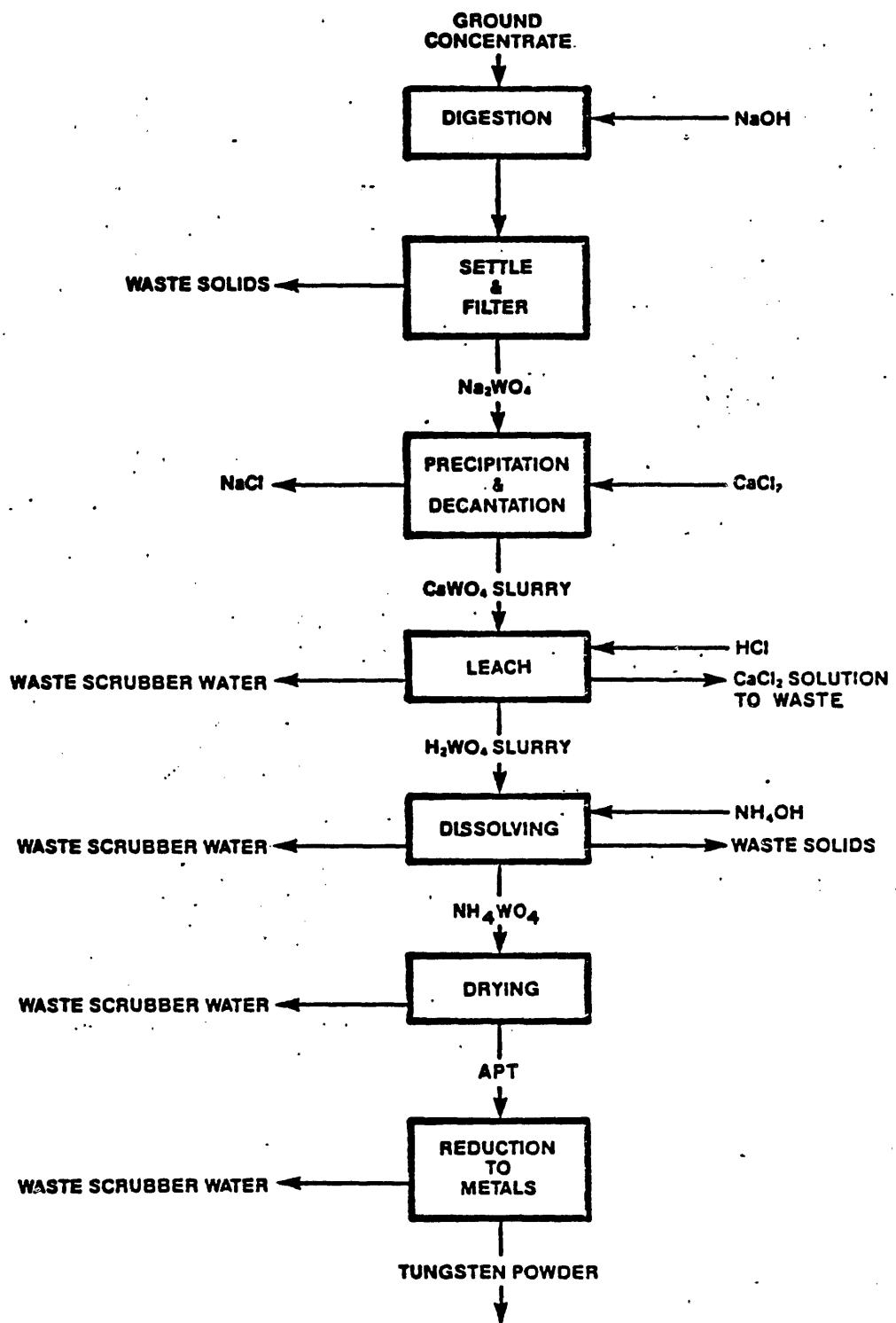


Figure 3. Primary Tungsten Production Process
(From US EPA Document 440/1-79/019a)

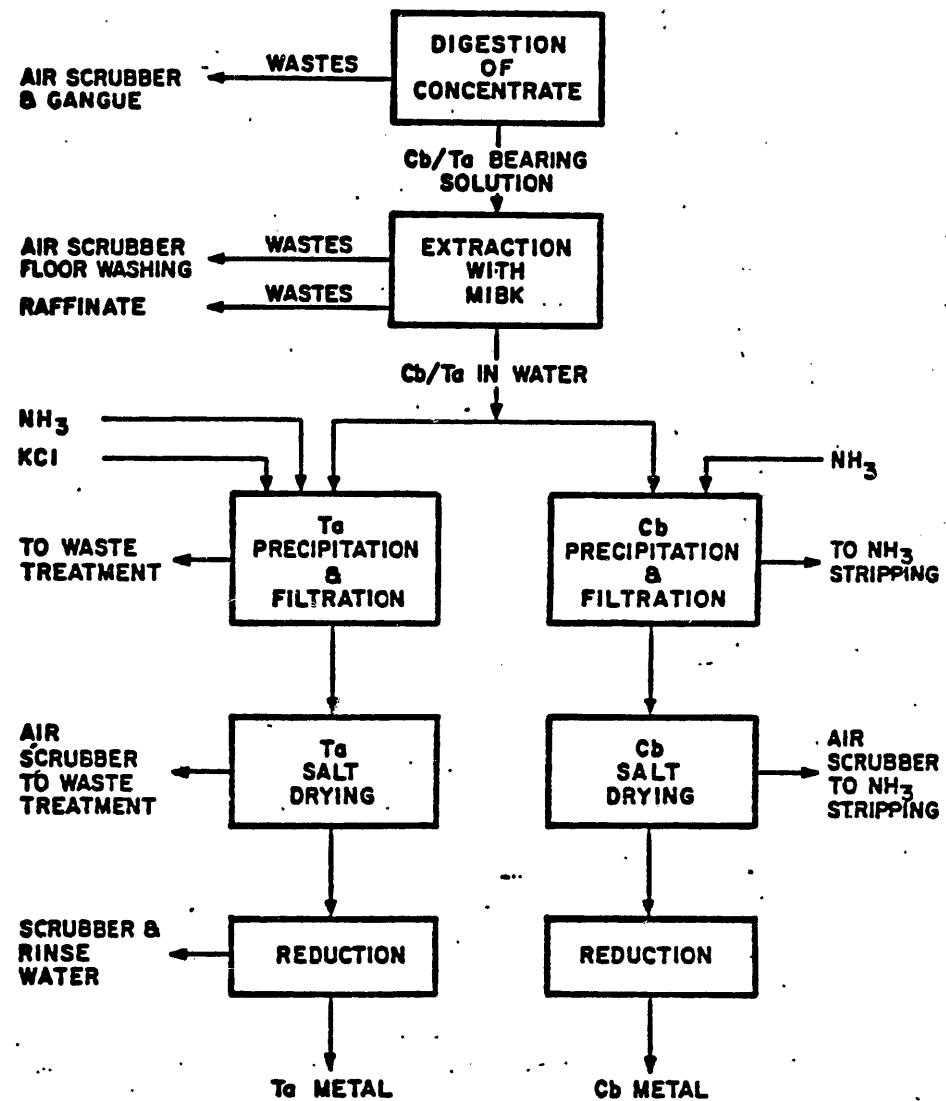


Figure 4. Primary Columbium and Tantalum Production Process
(From US EPA Document EPA 440/1-79/019a)

10. Secondary silver production from non-photographic materials results in emissions from the leaching and stripping of the scrap materials. These will contain significant levels of acids, cyanides (if used in the process), and metals. Smelting furnaces will also produce emissions of particulates and fumes. Wet or dry dust-fume collectors isolate the materials for return to the process or to waste.

Liquid Effluents

11. Liquid waste sources in the processing from photographic films and other photographic wastes include leaching and stripping, precipitation and filtration, roasting furnaces, electrolysis units (for recovery of other metals) and contact cooling. Wastewater from the leaching process will be strongly acidic or caustic, depending upon the leachate used. This effluent may also contain significant quantities of chromium, copper, lead, and zinc as well as some organic pollutants which are used in the manufacture of the film.

12. Waste effluents also result from the precipitation of silver from the leaching and stripping solution. These are similar to the leaching wastewaters, but will also reflect the composition of the chemical addition used. Iron, zinc, and soda ash are among the chemicals used for precipitating the silver. The precipitate is dried, roasted, cast, and cooled. Direct contact cooling water is discharged.

13. In silver production from non-photographic materials, a highly acidic wastewater results from the control of emissions in the stripping units. This effluent may also contain significant quantities of cyanides (if used in the stripping process) and other metals. The filtrate from the precipitation of the silver in the stripping solution is also discharged as wastewater. Wet scrubbers used to collect furnace emissions are another liquid effluent source. In those plants using electrolytic refining, the spent electrolyte, wastewater, and wet scrubber systems contribute to the final effluent. Contact cooling is a final source of waste flows in the plants.

Solid Wastes

14. Solid wastes generated in these processes include the plastic portion of the film remaining after stripping, solids from wet and dry scrubbers (when not recycled to the system) and sludge residues from which silver has been removed.

PRIMARY TUNGSTEN

Air Emissions

15. Principal emission sources in tungsten production are the leaching, dissolving, drying, and reduction units. Wet scrubbers are usually installed for this purpose, and discharges to the atmosphere are insignificant.

Liquid Effluents

16. Wastewaters originate from precipitation and filtration, leaching, and the wet scrubbers, in the conversion of ore concentrates to ammonium paratungstate (APT). The wastewater streams reflect the composition of the ore concentrate and the processing steps used prior to leaching. They are typically strongly acidic, very high in chlorides, and may contain significant levels of such metals as arsenic, lead, and zinc. Scrubber effluents from the drying may contain high concentrations of ammonia, and may be subjected to ammonia recovery before discharge.

17. The reduction units, which convert the salt into the metal, will produce wastewaters from the wet scrubbers. While this effluent may be high in ammonia, it usually is not treated for ammonia recovery.

Solid Wastes

18. A gangue, or residue, results from the fusion reaction in the formation of soluble sodium tungstate from the ore concentrates. These waste solids are usually transferred to landfills, but in some cases the residue is sold for molybdenum recovery.

PRIMARY COLUMBIUM AND TANTALUM

Air Emissions

19. Air emissions from the production of columbium and tantalum salts and metals originate from the treatment with methyl isobutyl ketone (MIBK) or other organic solvent, the salt drying units, and the reduction of salts to the pure metal.

Liquid Effluents

20. The most significant wastewater sources are the digestion, solvent extraction, and precipitation processes required for extraction of the salts from the concentrates and slags. The processing involves the use of acids, ammonia, and organic solvents. All of these are present in the final effluent. Production of the metals from the salts results in wastewater from the leaching operation (following reduction) and from wet air pollution control devices.

Solid Wastes

21. Treatment of the wastewaters and quench waters results in production of sludges, for which disposal must be provided.

EFFLUENT LIMITATIONS

Air Emissions

22. In general, particulates and gases emitted from the production of the metals covered by this document are readily controlled and eliminated

by the use of wet or dry scrubbers. Where any of the emissions are discharged to the atmosphere, then the following limitations are to be observed in all cases:

Sulfur Dioxide (SO₂)

Inside Plant Fence	Ann. Arith. Mean	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hour Peak	1000 $\mu\text{g}/\text{m}^3$
Outside Plant Fence	Ann. Arith. Mean	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hour Peak	500 $\mu\text{g}/\text{m}^3$
<u>Fluorides (as HF)</u>	Ann. Arith Mean	10 $\mu\text{g}/\text{m}^3$
	Max. 8-hour Peak	100 $\mu\text{g}/\text{m}^3$
<u>Particulates</u>	Ann. Geom. Mean	75 $\mu\text{g}/\text{m}^3$
	Max. 24-hour Peak	260 $\mu\text{g}/\text{m}^3$

Liquid Effluents

23. On the basis of best practicable technology currently available, liquid discharges are to be maintained within the following limitations:

Secondary Silver —

Photographic

Max 24-hour

Kg/MT Metal Prod.

TSS	0.60
Cr	1×10^{-3}
Cu	6×10^{-4}
Pb	2×10^{-4}
Zn	1×10^{-2}
Ag	4×10^{-4}
pH	6 to 9 units

Secondary Silver —

Non-photographic

TSS	0.30
Cu	3×10^{-2}
Zn	0.10
Ag	3×10^{-3}
pH	6 to 9 units

Max. 24-hour

Kg/MT APT Prod.

Primary Tungsten --
Ore to Salt

TSS	1
NH ₃ -N	1
Cr	2x10 ⁻³
Cu	6x10 ⁻³
Pb	4x10 ⁻³
Ag	4x10 ⁻³
pH	6 to 9 units

Primary Tungsten --
Salt to Metal

Max. 24-hour

Kg/MT Metal Prod.

TSS	9x10 ⁻²
NH ₃ -N	4x10 ⁻²
Cr	4x10 ⁻⁴
Cu	6x10 ⁻⁵
Pb	2x10 ⁻²
Ag	6x10 ⁻⁵
pH	6 to 9 units

Primary Columbium and Tantalum --
Ore to Salt

Max. 24-hour Consecutive
30-Day Aver.

Kg/MT of Purified Salt

Fluoride (total)	11.8	5.9
TSS	8.4	4.2
NH ₃ -N	10	20
pH	6 to 9 units	6 to 9 units

Primary Columbium and Tantalum --
Salt to Metal

Max. 24 hour Consecutive
30-day Aver.

Kg/MT of Metal

Fluoride (total)	8.4	4.2
TSS	6.0	3.0
pH	6 to 9 units	6 to 9 units

CONTROL AND TREATMENT OF WASTES

Air Emissions

24. The production facilities discussed in this document generally control and eliminate air emissions through the use of dry or liquid scrubbers. Gases are frequently utilized in the plant, either as a fuel or as a component of another product. Particulates are discharged with the wastewater streams, where wet collection methods are used, or else are utilized for other purposes within the plant. If dry collection systems are utilized then the particulates are dumped on land if they have no recovery value.

Liquid Effluents

25. Housekeeping practices should be critically examined and improved as a first step in the control of liquid effluents. Process changes, monitoring of water use, by-product recovery, and recycling are among the measures that can significantly reduce the volume of wastes requiring treatment and disposal.

26. Wastewaters from secondary silver processing from both photographic and non-photographic wastes can be treated by steam stripping of the high ammonia streams, and applying chemical precipitation and filtration to the combined stream. Treated effluents may be recycled or discharged.

27. In the production of primary tungsten metal, both in the ore to salt phase and in the salt to metal phase, high ammonia streams can be stripped to remove and possibly recover the ammonia. The residual can be combined with other streams and receive chemical precipitation and filtration. The resulting effluent may be recycled or discharged.

28. In the wastewaters from the production of the salt from the ore concentrate, steam stripping provides a high degree of ammonia removal and recovery. Lime precipitation is effective in removing the fluoride ions and results in the precipitation of metals dissolved in the waste streams. Suspended solids are removed by sedimentation.

29. Effluents from the production of the metal from the purified salt can be treated by lime precipitation to remove the fluoride ion and dissolved metals. Sedimentation removes the suspended solids.

Solid Wastes

30. Sludge disposal is a problem in these industries. These waste streams may contain large quantities of one or more heavy metals, and these are most commonly removed from liquid effluents by chemical precipitation. Consequently, the sludges contain large concentrations of the metals.

31. Sludges are disposed of by contractors or are sold to reprocessors. They may also be transferred to drying beds, lagoons, landfills, or incineration.

32. Other solid wastes, such as wet scrubber residuals, are added to the waste streams receive the same treatment and disposal and hence add to the sludge loads. Particulate matter from dry scrubbers is burned, dumped on land, or is recycled for by-product recovery.

BIBLIOGRAPHY

1. United Nations Industrial Development Organization. "Non-Ferrous Metals — A Survey of Their Production and Potential in the Developing Countries." Vienna (1972)
2. Atkins, M.H. and J.F. Lowe, "The Economics of Pollution Control in the Non-Ferrous Metals Industry." Pergamon Press. Oxford (1979).
3. Boodson, K. "Non-Ferrous Metals — A Biographical Guide." Macdonald & Co. (Publishers) Ltd. London (1972)
4. Powers, P.W. "How to Dispose of Toxic Substances and Industrial Wastes." Noyes Data Corporation, Park Ridge, N.J., and London (1976).
5. "Standard Methods for the Examination of Water and Wastewater." 15th Edition. American Public Health Association. New York (1980).
6. "Chemical Engineers Handbook." Ed. by Robert H. Parry and Cecil H. Chilton. Fifth Edition. McGraw Hill Book Co., New York (1973).
7. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and Standards for the Nonferrous Metals Manufacturing Paint Source Category." Doc. EPA-440/1-79/019a. Washington, (September 1979).

The World Bank
Office of Environmental Affairs

November, 1981

ENVIRONMENTAL RECONNAISSANCE OF OFFSHORE HYDROCARBON EXPLORATION
AND PRODUCTION PROJECTS

1. Background

The objective of an environmental reconnaissance to be carried out in connection with a proposed offshore energy project is to determine, in a general way, the possible impact of the project, its presence and operation, on the environment, worker health and safety and the social well-being of peoples to be affected by the project and to make recommendations to eliminate or mitigate adverse effects of the project.

The reconnaissance-type study should include; but not necessarily be limited to, the following considerations.

(a) Biota

The nature and extent of the biotic community resident in or transiting the area likely to come under the influence of the project; e.g., shellfish beds, benthic organisms, offshore fishery, spawning grounds, finfish nursery area, etc., during the exploration, construction, and operation phases. Especial attention should be paid to those members of the biota forming part of the food chain for economically important species, ecologically unique life forms or endangered species. The potential adverse impact on fishery, marine mammal, bird and other natural faunal/floral resources, including their presence, abundance, area dependence, and distribution should be carefully noted.

(b) Facility Integrity

The potential, and possibly dangerous, effects of environmental phenomena on the structural and operational integrity of the facility, including those related to unusual but recorded weather, wind, swell, seismic and related conditions.

(c) Waste Handling

The proposed plans for liquid, gaseous and solid wastes management, transportation and disposal, taking into consideration the likely dangers posed to the ecological systems, public health, environmental amenities and aesthetics.

(d) Contingency Plans for Blowouts, Spills and Fires

The appropriateness and adequacy of contingency plans, equipment, supplies, personnel, and response-time to cope with blowouts, major spills, fire, structural failure and/or other major emergencies. These should be noted with regard to the probable diseconomies and environmental damage.

(e) Occupational Health and Safety

The plans, regulations, codes, practices and their monitoring and enforcement relating to the protection, safety and health of the workers. Offshore facilities pose special problems of prevention, control, treatment, and evacuation.

(f) Scenic, Touristic and Aesthetic Considerations

The scenic and aesthetic qualities of the area likely to be affected by the project's presence and operation, including visual and acoustic considerations. Present and potential tourism values that may be prejudiced should receive consideration.

(g) Project-associated Environmental Impacts

Activities associated with the project, including transportation and shipping, may generate problems; e.g., ships' wastes, bilge discharges, spills during transfers, collisions, and touristic detraction.

(h) Onshore Facilities and Activities

The adequacy, relevance, timing and funding of plans and practices designed to cope with induced onshore development associated with the offshore scheme. Likely social and important environmental consequences should be identified, with particular reference to industrial and port-related developments.

(i) Existing Laws, Regulations and Codes Governing Offshore Projects

Identification of existing national and/or applicable local jurisdictional laws, regulations, codes, ordinances relating to offshore energy exploration and production operations.

(j) Future Expanded or Associated Offshore Development

If the project is one of several being planned or presently existent in the area or field being developed, a general assessment of the combined impact is important; i.e., aggregate impacts may have consequences differing in nature or magnitude from those identified with each incremental project. When a hydrocarbon field is expected to be exploited, the area of which may be large or configured in a manner to suggest an extended impact zone, a coastal zone management plan should be considered to ensure orderly and environmentally sound development.

(k) Report of Findings and Recommendations

A full report of the reconnaissance findings should be prepared to include appropriate detailed information on the anticipated environmental, worker health and safety, and social consequences of the proposed project; the nature, scope, and timing of any additional studies required; the nature, dimensions, timing, and severity of important problems should be highlighted, along with recommendations as to how they might be prevented or mitigated.

In preparing the report and detailing the measures to be taken, appropriate utilization should be made of the General Environmental Guidelines for Offshore Hydrocarbon Exploration and Production Projects which follow.

The World Bank
Office of Environmental Affairs

November, 1981

General Environmental Guidelines
for
Offshore Hydrocarbon Exploration and Production Projects

1. Background

In considering the environmental implications of offshore energy projects, the general policies of the Bank relating to the environment provide useful guidance (see Bibliography Nos. 1 and 2).

However, the unique nature of offshore energy development requires its own specific guidelines. In this endeavor the Bank has relied heavily on guidelines and regulations in force in the Commonwealth of Australia and Canada; and, practices recommended by the American Petroleum Institute, the Intergovernmental Maritime Consultative Organization, the Norwegian Petroleum Directorate, and others. These concern themselves with exploration, production, transportation, sensitive environments, special circumstances, environmental damages and legal liability, and related matters (see Bibliography Nos. 3-7). These materials have been included to address the spectrum of considerations and requirements seen as necessary to the Bank's financing of such type projects.

2. Procedure

Borrowers and/or their engineering consulting firm(s) serving them must satisfy the Bank that their approach to protecting the environment and its biota, accident prevention, blowout prevention, contingency preparedness, wastes management, worker health and safety, meet these, or equivalent, requirements and/or is adequate under anticipated prevailing and worst recorded offshore conditions.

3. Rigid standards, rules, regulations are not promulgated herein and are otherwise judged unwise and impractical given the varied project environments to be encountered world-wide. What is sought is a practical, eminently doable approach to the environmental dimensions of offshore energy activities tailored to the specifics of the total milieu; i.e., environmental, economic, political, and social.

4. It must be emphasized and highlighted, however, that blowout prevention (BOP) constitutes the highest priority in any setting. Detailed technical BOP recommendations are, therefore, included in the guidelines. Experience has shown that accidents will occur even when these precautions are practiced. It is realistic to expect a blowout frequency of roughly one in twenty-five even with the best prevention. In recognition of this, the Borrower must satisfy the Bank as to the adequacy of its contingency plans and preparedness for dealing with these situations.

5. The Bank recognizes that some of its member countries are poorly equipped to plan, oversee and enforce a program of coastal zone protection. It is prepared, therefore, to assist governments in this regard while assuming, inter alia, environmental oversight responsibility for projects it is financing in the coastal waters of such countries. In this regard, the Bank will, in cooperation with governments and in keeping with its project supervision activities, carry out a monitoring of those environmental, health and worker safety considerations incorporated into the project. Technical assistance will also be provided where appropriate.

6. Project Design Checklist and Related Bibliography

The brief design checklist and related bibliography* (which follow) include those major considerations to be addressed in Bank-financed offshore energy projects. The task is that of demonstrating to the Bank's satisfaction that offshore energy projects proposed for financing will not present unacceptable risks to the environment. The Borrower will be expected to recommend environmental protection and management measures that represent a balanced consideration of the benefits and risks entailed.

The checklist is intended to serve principally as a guide to the essential elements of the environmental provisions.

Environmental Checklist

Waste management program (at site, in transport, on shore);

- 1) Of solids
- 2) Liquids
- 3) Gases

The resources and environment at risk:

- 1) At site
- 2) In transport
- 3) On shore
- 4) In emergencies

Environmental threats to projects:

- 1) Weather-related
- 2) Fouling
- 3) Geological (drilling, completions)
- 4) Other

*NOTE: All documents listed in the bibliography are available in the Bank's Energy Department Library.

Emergency preparedness:

- 1) Available emergency equipment and finance (see para. 4)
- 2) Trained personnel
- 3) Response time
- 4) Worker safety
- 5) Medical facilities.

Other

- 1) Relevant national legislation and institutions
- 2) Monitoring and enforcement
- 3) Costs, benefits and social impact

BIBLIOGRAPHY

(All documents listed are available from World Bank Energy Library.)

1. a) Environment and Development, 1979. World Bank. 33 pages.
b) Environmental, Health and Human Ecologic Considerations in Economic Development Projects, 1974. World Bank. 142 pages.
c) Industry: Environmental Control, 1978. World Bank. 128 pages.
2. International Bank for Reconstruction and Development (IBRD), International Development Association (IDA), International Finance Corporation (IFC).
3. General Regulations (see Annex, page 1 for details)

Exploration:

- i) Marine Operations, Directions as to, -- Commonwealth of Australia, State of Victoria. Schedule 1. 23 pages.
- ii) Drilling Operations, Directions as to, -- Commonwealth of Australia, State of Victoria. Schedule 1. 16 pages.

Production:

- iii) Petroleum Production, Directions as to, -- Commonwealth of Australia, State of Victoria. Schedule 1. 8 pages.
(In arctic/antarctic environments use Canada Oil and Gas Production and Conservation Regulations, 1979. 359 pages.)

Transportation:

- iv) Recommended Practice for Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines. American Petroleum Institute (API), RP 1111. 22 pages.
- v) International Convention for the Prevention of Pollution from Ships, 1978. Inter-Governmental Maritime Consultative Organization (IMCO). 171 pages.

4. Supplementary Regulations (see Annex, pages 1 and 2 for details)

Exploration:

- vi) Recommended Practice for Blowout Prevention Systems. API, RP 53. 58 pages.

- vii) Testing of Drilling Fluids. API, RP 13B. 35 pages.
- viii) Oil, Gas, and S-Leases in the Outer Continental Shelf Area. US Geological Survey (USGS), OCS Order #2, Section 5. 10 pages.
- ix) Recommended Practice for Safe Drilling of Wells Containing H₂S API, RP 49. 11 pages.

Production:

- x) Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms. API, RP 2A. 86 pages.
- xi) Recommended Practice for Production Facilities on Offshore Structures. API, RP 2G. 15 pages.
- xii) Recommended Practice for Design, Installation, and Operation of Subsurface Safety Valve Systems. API, RP 14B. 27 pages.
- xiii) Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems Offshore Production Platforms. API, RP 14C. 85 pages.
- xiv) Outer Continental Shelf. US Geological Survey, Order No.11 (Sec. 10A-10D). 1 page. Order No. 7 (Sec. 4).

5. Sensitive Environments (see Annex, page 2 for details)

Exploration:

- xv) International Convention for the Prevention of Pollution from Ships, 1973. IMCO (Sec. 10-12). 5 pages.
- xvi) Oil and Gas Production and Conservation Regulations, 1979. Canada. 359 pages.

6. Special Circumstances (see Annex, page 2 for details)

- xvii) The Onshore Impacts of Offshore Oil and Natural Gas Development In the West African Region, 1981. UNEP. 50 pages.
- xviii) World Directory of National Parks and Other Protected Areas, 1977. IUCN. 2 volumes.

(Note: For working conditions and working environment in the petroleum industry - offshore - see Bibliography No.7, xxviii.)

7. Additional bibliographic information related to offshore energy development activities:

- xix) Provisional Regulations for Diving on the Norwegian Continental Shelf, 1978. Norwegian Petroleum Directorate (NPD). 39 pages.
- xx) Provisional Regulations Concerning Littering and Pollution Caused by Petroleum Activities on the Norwegian Continental Shelf, 1980. NPD. 8 pages.
- xxi) Guidelines for the Inspection of Primary and Secondary Structures of Production - and Shipment Installations and Underwater Pipeline Systems, 1978. NPD. 17 pages.
- xxii) Development Document for Interim Final Effluent Limitations Guidelines and Proposed New Source Performance Standards for the Oil and Gas Extraction Point Source Category, 1976. US Environmental Protection Agency.
- xxiii) Study of Offshore Mining and Drilling Carried Out Within the Limits of National Jurisdiction - Safety Measures to Prevent Pollution, 1980. UNEP Working Group of Experts on Environmental Law. 55 pages.
- xxiv) Guidelines for Preparing Outer Continental Shelf Environmental Reports, 1980. US Geological Survey.
- xxv) Guidelines for Preparation of an Environmental Impact Statement, 1980. Canada. 28 pages.
- xxvi) Drilling Mud Toxicity: Laboratory and Real-World Tests, 1978. Ocean Resources Engineering. 5 pages.
- xxvii) Programmatic Environmental Impact Statement: US Lake Erie Natural Gas Resource Development. US Army Corp of Engineers and EPA. 282 pages.
- xxviii) Working Conditions and Working Environment in the Petroleum Industry, Including Offshore Activities, 1980. ILO, Geneva. 116 pages.
- xxix) Guidelines on Means for Ensuring the Provision and Maintenance of Adequate Reception Facilities in Ports, 1976. IMCO. 16 pages.

- xxx) Reports from Working Groups I and II and III under the 1978 Hague Conference of Safety and Pollution Safeguards in the Development of N-W European Offshore Mineral Resources, 1980. IMCO. 40, 130, and 60 pages, respectively.
- xxxi) Study of Offshore Mining and Drilling Within the Limits of National Jurisdiction - Liability to Pay for - Compensation for Environmental Damage - Conclusions, 1980. UNEP Working Group of Experts on Environmental Law.

i. Marine Operations: These regulations concern issues relevant mainly to mobile platforms, anchoring, construction, certification, fixed equipment, general requirements, stairways, lighting conditions, life-jackets, evacuation facilities platform, population densities, fires, safety provisions, rescue crafts, helicopter landing decks. Schedule 1 is a regulatory document concerned with application for consent to "Designated Authority." For Bank purposes the authority in question will occasionally be the Bank itself.

ii. Drilling Operations: These regulations similarly consider consent requirements for equipment to comply with certain standards, (well casing, blowout preventers, etc.). They also consider abandonment of wells, inflammable and toxic gases, and production tests.

iii. Petroleum Production: These regulations consider requirements for production equipment and recovery of petroleum, pressure valves, control mechanisms, safety devices, flaring, accidents, toxic gases, pollution, (waste oil, oil sludge, emulsion disposal, petroleum effluent discharge limitations).

(Oil and Gas Production and Conservation Regulations. This very detailed document covers, inter alia, drilling program approvals, equipment standards, operator safety, medical facilities, firefighting, alarm systems blowout prevention, casing, operational manuals, contingency plans, inspections, safety zones, safety valves, monitoring, waste materials, personnel training, records, abandonment.)

iv. Recommended Practice for Design, Construction, Operation and Maintenance of Offshore Hydrocarbon Pipelines: A technical document covering design, safety systems, inspection and testing, operation and maintenance, corrosion control.

v. International Convention for the Prevention of Pollution from Ships: (70 countries). A regulatory, technical, and administrative protocol covering, inter alia, regulations for prevention of pollution by oil, by sewage, by garbage, by hazardous substances.

vi. Recommended Practice for Blowout Prevention Systems: A technical document of recommended practices for blowout prevention equipment systems. The document covers, inter alia, diverter systems, preventer stack arrangements, choke main folds, kill liner, closing units, auxilliary equipment, testing, sealing, blowout preventer modifications for hydrogen sulfide gas environments, pipe stripping. All of the above are considered for both surface and subsea installations.

vii - ix. These documents consider safe practices related to title texts.

xiii. Considers practices related to H₂S.

x. Recommended Practice for Planning, Designing and Constructing Fixed Offshore Platforms: A document covering planning, design criteria, welding, fabrication, installation, inspection, and surveys.

xi. Recommended Practice for Production Facilities on Offshore Structures: A document covering codes, rules, regulations, design considerations, production equipment arrangements, and fire protection.

xii. Recommended Practice for Design, Installation, and Operation of Subsurface Safety Valve Systems: A set of technical recommendations covering design, installation, operation, testing, and maintenance of subsurface safety valve systems.

xiii. Recommended Practice for Analysis, Design, Installation and Testing of Basic Surface Safety Systems on Offshore Production Platforms: A comprehensive, technical coverage of basic surface safety system on offshore production platforms.

xiv. US Geological Survey: No. 11 considers Flaring and Venting of Gas; No. 7, Spill Control and Removal. General and non-technical recommendations.

xv. International Convention for the Prevention of Pollution from Ships: (70 countries). A regulatory, technical, and administrative protocol covering, inter alia, regulations for prevention of pollution by oil, by sewage, by garbage, by hazardous substances.

xvi. Petroleum Production: These regulations consider requirements for production equipment and recovery of petroleum, pressure valves, control mechanisms, safety devices, flaring, accidents, toxic gases, pollution, (waste oil, oil sludge, emulsion disposal, petroleum effluent discharge limitations).

xvii. Onshore Impacts: Summary of Conference on Cooperation in the Production and Development of the Marine and Coastal Environment of the West African Region. Non-technical.

xviii. World Directory: Includes legislation and administration, country by country, as known by the IUCN, 1977.

THE WORLD BANK

JUNE 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

OIL PIPELINES

1. A wide variety of commodities and resources (gaseous, liquid, and solid) are presently transported by pipeline, over distances varying from a few meters to several hundred kilometers. This document will confine itself to pipelines designed for the bulk transportation of oil products over long distances, as opposed to piping necessary in the local handling, industrial processing, and marketing of crude oil and its by-products.
2. Pipelines are used for transport both between crude product and processing installations entirely on land, as well as between offshore wells and onshore transfer or processing facilities. In Europe, for example, transportation of crude oil has been mainly between ocean terminals and inland refineries, which are usually near the centers of consumption. In the United States pipelines have been used primarily to transport crude oil from production fields to refinery centers. Pipelines constitute an important element in the transfer of crude oils, both in terms of economics and time, as opposed to transfer by tankers. The development of supertankers has changed the economics of pipeline versus tanker transport.
3. Both crude oil and nearly all finished petroleum products can be transported by pipelines. Heavy fuel oils (residual fuel), used widely by industry and power stations, generally cannot be pipelined except at considerable extra cost and over limited distances. All the lighter products can be handled through a pipeline. A single line, by transferring batches in correct and properly scheduled sequences can be used to supply a large part of the variety of oil requirements of a specific area. Pipelines to date have the best safety record among the various methods used to transport crude oil.

PIPELINE CONSTRUCTION AND OPERATION

4. Pipelines do not have the flexibility of tankers. They are permanent fixtures and, once installed, cannot be rerouted even if conditions change or a different means of transport becomes more advantageous. Therefore, they are initially designed and constructed on the basis of the ultimate estimated capacity. The construction of a pipeline must be based on broad forecasts as to the flow of oil over a specific route for many years in the future.

5. Offshore pipelines, located in waters as deep as 350 to 450 meters, are frequently used to transfer oil from ocean production sites to onshore storage, handling, or processing facilities. Pipe sizes will range up to 90 cm or more in diameter, depending upon water depth as well as the flows to be carried.

6. Ocean pipelines are usually installed in one of three ways: (a) sections are assembled and joined onshore, and towed out to sea as assembly proceeds; (b) sections are joined at or near shore, towed out to sea as units, and sunk at the proper location. Sections are joined by divers after being put in place at the sea bottom; and (c) pipe sections 15 to 30 meters in length, depending upon diameter, are taken to sea on "derrick-lay" barges, welded together on the barge, section by section, floated out along the end of the barge, and then allowed to sink to the bottom. Regardless of the laying technique used, all pipe ends are joined together by welding at some stage of the installation.

7. Where depths permit the pipeline rests in previously prepared trenches on the sea bottom, and these are back-filled after the pipe is in place. In other situations, the line rests on the bottom but care must be taken to assure that it lies flat and avoids laying on large boulders or other obstructions. The pipe must be weighted to minimize or eliminate shifting after it is set in place. This can be accomplished by providing a heavy concrete outer coating on the pipe, some 10 cm. in thickness, before it is set in place; anchoring to cement filled bags; attached to the seabed by means of drill-in expandable rock anchors; or other similar techniques.

8. Laying pipes on land is considerably less complicated than in the case of marine installations. Once the route is established and rights-of-way cleared, the pipe is laid in trenches, specially prepared according to the soil conditions, topography and other factors. Sections of pipe are laid in the trench, and welded end-to-end at the site.

9. Pumping is required for transport of the petroleum over long distances. Centrifugal pumps, provided with variable speed drives, are most frequently used. Where only one product is to be moved at all times constant speed units are suitable. Pump design selections, and location are based on a number of factors such as viscosity of products to be transported, topography, distances, pressure gradients, and other characteristics. Power for pumping facilities is from diesel fuels and usually generated at the site, since locations are generally remote from population centers.

10. Once installed, pipelines can operate with relatively little attention. Constant inspection and maintenance must be provided, however. The major costs are those for installation, including construction, burial, materials and pumping equipment. Total operating costs, including direct operations and capital charges, will average about 10 percent of the total capital costs.

SOURCES OF POLLUTION

11. The principal source of pipeline pollution is from leaks which can result from a number of causes. Assuming a "zero percent loss" at time of installation leaks can arise from corrosion, damage from external forces or factors, and carelessness.

12. Pipe corrosion may occur both externally and internally. With modern techniques, this is no longer considered to be a significant problem. Cathodic protection enables advance detection of weak points.

13. Damage from external forces is considered potentially to be the most serious source; particularly when lines pass through or near large industrial or building sites. Lines in areas subject to operation of heavy agricultural equipment may also suffer damage. Ships anchors catching on lines laid in shallow waters are another potential source of damage. Leaking pumps and valves can also contribute pollution.

14. Carelessness is generally the result of human errors, and is the cause of spills in connecting to or delivery from the pipelines.

15. In the case of pipelines on land, soil erosion and discharge of sediment to surface waters can occur during the trenching required as part of the construction phase. The construction of necessary access roads and landing strips are also potential sources of sediment from runoff.

POLLUTION CONTROL MEASURES

16. Pipeline pollution can be prevented or minimized by various means, both before and after operations are started. During the construction phases (a) all materials should be carefully inspected for manufacturing defects; (b) all welded joints should receive careful inspection; (c) hydrostatic tests, at pressures above normal working pressures, should be made; (d) corrosion control technology should be applied; and (e) alarm systems, capable of providing advance or immediate warnings of failures or breakdowns, should be included. After the line is operating, an effective inspection and maintenance program will be required.

17. Hydrostatic tests are made on each pipe length to detect the presence of wall cracks, pinholes, or other defects which might cause leakage. Welding edges and pipe surfaces are inspected by visual and ultrasonic methods for material defects before welding. When completed, all welded joints should be inspected by X-ray techniques. Pressure relief valves are included in the system to provide for a rise in the internal pressure due to a temperature rise, or other occurrence which might cause a blockage.

18. Protection against external corrosion may be provided by coating with such materials as asphaltic mixtures, coal-tar enamels, or epoxy compounds. Pipelines should be electrically insulated from platforms and land structures. These measures protect against the loss of metal that could endanger the strength and safety of the lines. Internal corrosion may be controlled by addition of corrosion inhibitors to the materials passing through the lines.

19. Cathodic protection methods can also be used to minimize or eliminate external corrosion in land-based lines. The sacrificial-anode method, most often used, depends upon making the metal to be protected (the pipeline, in this case) the cathode in the electrolyte involved. The soil functions as the electrolyte. Zinc, magnesium, or aluminum are used as the metal anode and provide the extra (or sacrificial) metal which can be "sacrificed" in the corrosion process. The metal anode "bracelets" are attached to the steel pipe,

at distances of 100 to 200 or more meters, and are generally of sufficient size to last for the projected life of the pipeline.

20. Inspections along the length of pipelines, for land installations, are necessary to detect major leaks or losses. Helicopters are well suited for this purpose, particularly in marsh or sparsely populated areas. The inspection should cover not only possible leaks but also irregularities which might endanger the line such as places where the pipeline has been exposed, conditions of river banks intersected by the line, damages to communications lines adjacent to or part of the pipeline operation, and extraneous work underway near the pipeline.

21. In the case of pipelines running through the ocean and other waters, measures to control pollution should include:

- (a) Providing all pipelines leaving a structure and receiving production from the structure with a high-low pressure sensor to shut off the wells.
- (b) Providing all pipelines delivering products, to either offshore or onshore production facilities, with a shut-off valve at or near the receiving facility, connected to an automatic, or remote shut-off system.
- (c) Providing sensors and automatic shut-off valves or devices on all pipelines crossing a structure, to avoid uncontrolled flow at the structure.
- (d) Equipping all oil pumps with automatic high-low pressure shut-off devices.
- (e) Providing a metering system to give continuous comparison between input and output on all lines, and thus detect any line leaks.
- (f) Providing protective coatings, cathodic protection, or other measures to avoid loss of metal and weakening of the pipe.
- (g) Assuring that all pipelines are installed and maintained so as to be compatible with trawler operations.
- (h) Installing and maintaining pipelines to assure protection against water currents, storm scouring, soft bottoms, and other environmental influences.
- (i) Inspecting the ocean surface above the pipeline at least once per week for indications of leakage. Aircraft, floating craft, or similar means may be used for this purpose.

- (j) Conducting an external inspection of all lines by side scan sonar or other acceptable means, at least once per year, to identify exposed portions of the pipeline. Exposed sections are then inspected in detail by photographic or other means to determine if any hazards exist to the line or to other users of the area.
22. An acceptable, fully detailed system for operation, inspection and maintenance of the installation should be established before the start of operations. Once operations begin accurate records of all inspections, events, unusual incidents, actions taken, etc. should be maintained as part of the overall records system. Good operation and maintenance constitute the most effective method for controlling pollution from oil pipeline installations.

STANDARDS AND REGULATIONS

23. National standards and codes of practice exist or are under consideration in many countries throughout the world. Generally these cover minimum standards and requirements to assure design, construction, operation and maintenance of pipelines according to internationally accepted and proven engineering safety practices. While these standards may or may not have legal status, they are widely recognized and are sponsored by reputable engineering or standards organizations.
24. Standards promulgated by the United Kingdom Institute of Petroleum, the American Petroleum Institute, and the USA Standards Institute have received wide acceptance. The Economic Commission for Europe (ECE), Organization for Economic Cooperation and Development (OECD), and other international agencies have also promulgated codes and standards dealing with oil pipelines.

BIBLIOGRAPHY

1. Organization for Economic Cooperation and Development "Pipelines- The United States and Europe - Their Legal and Regulatory Aspects", Paris (1969).
2. Abrahamson, Bernhard J. and Joseph L. Stackler "Strategic Aspects of Seaborne Oil", International Studies Series No. 02-017, Vol. 2. Sage Publications, Beverly Hills/London (1973).
3. Hubbard, Michael. "The Economics of Transporting Oil to and within Europe". Maclaren & Sons Ltd. London (April 1967).
4. "Pipeline Design and Construction". Manual Compiled from 1976 issues of Oil and Gas Journal. Petroleum Publishing Co. Tulsa (1977).
5. Economic Commission for Europe "Proceedings of the Seminar on the Protection of Ground and Surface Waters Against Pollution by Crude Oil and Oil Products". Geneva, 1-5 December 1969. 2 Vol. United Nations. New York (1970).

6. U.S. Department of the Interior, Geological Survey. "OCS Orders 1 through 14 Governing Oil, Gas, and Sulphur Leases in the Outer Continental Shelf and the Gulf of Mexico Area". Washington (January 1977).
7. U.S. Department of the Interior, Geological Survey. "Notice to Lessees and Operators of Federal Oil and Gas Leases in the Outer Continental Shelf Pacific Area". Washington (June 1, 1971).

THE WORLD BANK

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ENVIRONMENTAL CONSIDERATIONS IN OIL SHALE PROJECTS

BACKGROUND INFORMATION

Introduction:

1. Shale oil production will combine a number of processing operations on one site: mining, ore preparation, retorting, gas treatment, refining, and solid waste management. The scale of operation will be massive. Consequently, the rates at which point source and fugitive pollutants are generated will require strict control. Potentially applicable control technologies employed in related industries--such as petroleum production, stone crushing, cement manufacture, and electric power operation--may not be directly transferable to shale oil production because of process mixes and integration.

General Overview of Environmental Problems

2. The environmentally problematic effluents and wastes from oil shale operations have not been thoroughly characterized. In some cases, adequate sampling and analysis methods have not been developed, validated, and standardized. In a commercial operation the byproducts of retorting will usually be processed in some further way before their characteristics as potential pollutants can be identified and control technology developed. Site and process-dependent pollutants, particularly trace organics and inorganics, may have the greatest potential impact on health and welfare. Finally, refining shale oil into end use products may result in increased emissions of toxic compounds.

3. Control technologies for treatment of off-gases are generally believed to be adequate, but they need to be demonstrated for key pollutants in off-gas streams. Additional studies are needed, however, to characterize off-gases from both in situ and surface retorting processes because of the potential for release of toxic trace elements.

4. It will be especially important to control particulates from mining and handling operations by use of suppression systems. Water sprays, along with wetting agents and organic binders, need to be evaluated for use at the points of emission as well as on haulways and ore piles. In-mine localized particulate removal by modular wet scrubbers, electrostatic precipitators, or baghouses needs to be evaluated. For example, whether electrostatic precipitators can be used to control particulates from mining and crushing operations will depend on characteristics of the dust. Raw oil shale dust resistivity has not been adequately investigated. Additional studies are needed, especially with respect to fine particulate control.

5. Because of the absence of a full scale oil shale industry, the adequacy of control technologies for handling oil shale wastewaters is still questionable. Some oil shale developers contemplate using retort water to moisten retorted shale for dust control and to aid compaction. If the retort wastewater is used in this manner, the hazardous and toxic constituents might migrate to local surface and ground water supplies.

6. Modified in situ oil shale processing will generate more wastewater than can be consumed by process reuse. Subsurface injection or surface discharge may be necessary. Wastewater constituents may include hazardous organics (polycyclic materials, phenolics, amines) and inorganics (arsenic, molybdenum, vanadium, boron, among others). Control techniques must be developed, therefore, to ensure effective removal of these constituents before wastewater disposal.

7. Little is known about the movement of ground water into and through abandoned chambers of modified in situ operations. To date, only speculations have been made about the leaching of such chambers by ground water. Consequently, laboratory studies should be conducted to determine probable leaching rates and concentrations of organic and inorganic constituents. These studies should be supplemented by field monitoring of existing and near-future in situ retorting operations.

8. The disposal of solid wastes resulting from oil shale mining and processing is a major environmental concern. Retorted shale could present problems of surface and ground water degradation if pile stability and impermeability are not maintained. All research and monitoring programs to date have dealt with relatively small quantities of retorted shale. Potential problems, such as mass stabilizations of shale piles and maintenance of an impervious layer below plant root zones, can likely be identified and solutions found only by creation of a large pile from commerical scale processing.

SPECIFIC ENVIRONMENTAL IMPACTS

Atmospheric Emissions

9. Atmospheric emissions will arise from several activities or operations during oil shale processing. The major source of SO_2 , oxides of nitrogen (NO_x), and carbon monoxide (CO) will be fuel combustion for process heat; SO_2 will also be emitted in the tail gases of sulfur recovery operations. The use of fuel oils in mobile equipment and explosives will result in emissions of CO and NO_x . Hydrocarbons will be present both in combustion emissions and in product storage tank vapors. Emissions of particulate matter will result from blasting, raw and spent shale handling and disposal, raw and spent shale dust in process gas streams, fuel combustion, and other site activities that generate fugitive dust.

10. Potentially hazardous substances may be emitted during the extraction and processing of oil shale. Silica (quartz) may be present in dust derived from oil shale and associated rocks and in fugitive dust. Particulate emissions from fuel combustion and fugitive dust from spent shale handling and disposal may contain polycyclic organic material (POM)

and certain trace metals. Gaseous ammonia (NH_3), hydrogen sulfide (H_2S), and volatile organics may be released during moisturizing and subsequent cooling of retorted shale. Catalyst materials may release particulate matter containing trace metals to the atmosphere during regeneration, handling, and final disposal.

11. Pyrolysis of essentially any type of organic material produces some POM, and oil shale is no exception. In general, POM compounds have low volatility and are associated with solids or high boiling liquids, or with particulates. Although POM is known to be present in carbonaceous retorted shales, its biological availability and potential hazard in this form are not well known. POM compounds could be released to the atmosphere during shale retorting, during handling and disposal of retorted shales, or during combustion of shale-derived oils.

12. Temperature and oxidation-reduction conditions during retorting are not severe enough to volatilize most metallic and heavy elements. With notable exceptions such as arsenic, mercury, and possibly antimony, most trace elements (for example, nickel, vanadium, and molybdenum) will probably remain with the spent shale or be found as components of raw and spent shale solids entrained in retort gases and in raw shale oil. Arsenic in raw shale apparently forms a range of volatile oil-soluble compounds (perhaps organic arsines) during retorting. It appears in raw shale oil and in all condensable oil fractions. If not removed during upgrading, arsenic will be present in shale oil combustion products. If nickel is present and process conditions favorable, nickel carbonyl, a highly toxic gaseous compound can be formed.

13. Actual emissions of nonvolatile trace elements will be in approximate proportion to raw and retorted shale particulate emissions from oil shale extraction and retorting. These emissions may not be different in nature or magnitude from those associated with the extraction and processing of other fuel and nonfuel minerals (coal, limestone, phosphate rock, and so forth). Further, the dolomitic or alkaline nature of some oil shale immobilizes many elements as relatively inert oxide, carbonate, or silicate salts. Trace element mass emission rates give no simple indication of bioavailability, chemical reactivity, or physical properties.

14. Metals (nickel, cobalt, molybdenum, chromium, iron, zinc) and their compounds are used as catalysts for hydrotreatment, dearsenation, sulfur recovery, and trace sulfur removal. Particulate matter containing catalyst metals could be emitted either during on-site regeneration or during handling and disposal. Catalyst use is, of course, not unique to shale oil processing, and most information and experience in preventing hazardous emissions can be borrowed from the petroleum and related industries.

15. The refining of crude shale oil will produce a number of potentially adverse environmental effects, primarily as a result of atmospheric emissions. Data have not been developed on the quality and quantity of these emissions.

Water Quality:

16. Water is necessary to the development of an oil shale industry. Water will be needed for dust control during mining and crushing, for gas cleaning and air pollution control, for cooling, and for moisturizing retorted shale. Upgrading crude shale oil, on-site power generation, and re-vegetating disturbed land and retorted shale disposal areas will also consume large quantities of raw water. The water needs per unit of net product will necessarily depend on the mining, retorting, and upgrading methods used. In general, in situ methods are expected to consume less water than conventional mining and retorting.

17. Most major developers in the United States have indicated that they intend to discharge no wastewaters directly to surface streams. Surface retorting process waters would be reused, and perhaps ultimately applied to retorted shale. Effects of extraction and processing activities on local hydrology and water quality are therefore likely to be indirect or incidental. The water pollution implications of mine dewatering, of creating large retorted shale disposal piles, and of abandoning in-ground retorts have not been determined; these actions could create major environmental impacts.

18. Because of the low concentration of compounds in discharge waters, no acute or chronic effects on aquatic biota in surface waters may result; however, compounds of low solubility may be bioaccumulated by some aquatic organisms and become toxic to other aquatic organisms, birds, and man. Oil shale process waters contain single-ring and polynuclear aromatics that contain suspected carcinogens. If process waters are discharged into the aquatic environment, sediments may accumulate these compounds and later release them slowly. More information is needed on the degradation of these compounds and on their potential for bioaccumulation in aquatic organisms. Effects of extraction and processing activities on existing water quality in the oil shale region will vary with the geography and the season.

19. Aqueous wastes from oil shale processing can be categorized broadly as originating from direct or indirect sources. Wastewaters from direct sources are those generated by unit operations or processes, including:

- Retorting
- Upgrading
- Some air emission control and gas cleaning processes
- Cooling and boiler water blowdowns
- Water Treatment
- Mine Dewatering
- Sanitary Disposal

20. Wastewaters from indirect sources include:

- Leachate from retorted shale disposal areas
- Runoff and erosion resulting from construction and site use
- Runoff resulting from mining and transport activities

21. Some water vapor will condense with crude shale oil during separation of the oil from retort gases. The condensate can partially separate from crude shale oil during storage, or it can appear in aqueous waste streams of shale oil upgrading operations. Water vapor remaining in retort gases after oil separation can be condensed during cooling or gas cleaning or it can appear in the flue gas stream for retort gas combustion. Water separated from crude shale oil will contain ammonia, carbonate and bicarbonate, sodium, sulfate, chloride, and dissolved or suspended organic compounds (phenolics, amines, organic acids, hydrocarbons, and mercaptans). Smaller quantities of calcium, magnesium, sulfides, and trace elements may also be present, along with suspended shale fines. Water condensed from retort gases will contain primarily ammonia and carbonates, with traces of organic substances and sulfur-containing compounds.

22. The quality of the wastewaters from upgrading operations will vary with the level of on-site upgrading or refining. In general, a full-scale refining operation may include any of the following wastewater streams: oily cooling water, process water, and wash water. These wastewaters will contain high concentrations of ammonia, bicarbonates, sulfides, phenols, total dissolved solids, oil, and grease.

23. Wastewaters from some air emissions control and gas-cleaning systems will contain shale dust particulate matter, hydrocarbons, hydrogen sulfide, ammonia, phenols, organic acids, and amines. Thiosulfate and thiocyanate may also be present in these wastewaters.

24. Because of evaporative losses, a constant buildup of dissolved solids in cooling water will necessitate discharge of part of this recirculated water as blowdown from cooling water systems. Similarly, part of the boiler water will have to be discharged as blowdown to minimize boiler scaling. Both the cooling water and the boiler blowdown water will contain high concentrations of dissolved solids and substances such as hexavalent chromium used for corrosion control.

25. Raw water treatment systems will have to supply water of good quality for processing operations, cooling towers, steam generation, and other miscellaneous uses. Water treatment wastes will usually consist of chemical sludges, backwash water from filtration systems, and blowdown from zeolite softening systems. Most of the waste will be lime sludge high in hardness and dissolved salts.

26. Aquifers encountered during mining must be dewatered. Unless ground water is prevented from entering the mine, however, dewatering could produce large quantities of low-quality water; quality and quantity will vary with location and processing technique. During full-scale surface retorting, most of this water will be used in wetting and compacting retorted shale. Major constituents of mine water are sodium, carbonate, bicarbonate, chlorides, fluorides, and boron. Reinjecting this water into the aquifer may increase ground water salinity.

27. Sanitary wastewaters from operational facilities will include domestic sewage from kitchens, bathrooms, and laundries. Because these wastewaters contain unstable organic matter and enteric micro-organisms, they will require treatment before disposal.

28. Perhaps 45 to 50 percent of the water needed for an oil shale plant will be used to moisturize retorted shale. Much of this water could possibly be supplied by mine water and process wastewaters. Because of the large quantities of water used and the exposure of retorted shale to rain and snowfall, indirect water pollution may result from leaching or runoff from retorted shale piles. Some of the water applied to retorted shale is expected to be bound to the shale in the form of simple hydrates. The suspended and dissolved constituents of wastewaters applied to retorted shale may affect the solubility of potential contaminants in the shale. Experiments in the laboratory and with small plots indicate that inorganic salts (sulfate and salts of sodium, magnesium, and chlorine) may be leached from retorted shales. Small quantities of organic substances and trace elements are also water soluble.

29. Construction, mining, and site use may increase sediment and dissolved solids loading in surface runoff and receiving streams. This indirect source of potential water pollution is not unique to oil shale extraction and processing, but may require careful control because of the magnitude of site activities. Collection and impoundment of runoff will likely be necessary.

Solid Waste

30. The solid wastes resulting from oil shale processing present one of the major environmental problems associated with commercial development. Shale-derived solid wastes will include fines from raw shale crushing and conveying, mined raw shale waste, and processed (or retorted) shale. Together these wastes constitute most of the process solids requiring disposal. Other solid wastes will depend primarily on the pollution controls employed and on the extent to which crude shale oil upgrading is carried out in conjunction with retorting. These wastes may include shale oil coke, treatment sludges, and spent catalysts.

31. Disposal of surface retorted shale will involve transport and surface emplacement of large quantities of solids on a scale only rarely attained to date in the mining industry. The spent shale will contain potentially leachable salts and, in some cases, a carbonaceous residue from retorting. If shale oil is upgraded in conjunction with retorting, a disposal pile might also contain spent catalysts, sludges, arsenic-laden solids, and other plant wastes.

32. In light of the foregoing, it would appear that potential hazards exist relating to:

- Pile stability
- Airborne particulates, odors, and organic vapors
- Leachates, organic and inorganic, caused by precipitation and ground water movement
- Transfer of possible hazardous organics or trace elements to the biosphere
- Translocations of toxic substances to vegetation

33. Mass movement of disposal piles could adversely affect water quality. Sediment and salts could be added to local surface waters, or to catchment structures. Changes in pile drainage systems caused by slumping, and so forth, may encourage infiltration.

34. Vegetation may be difficult to maintain on a destabilized pile surface; as a result, surface wind and water erosion may increase.

35. Because no large disposal piles have been constructed to date, little is known about pile stability in real situations. Further, most of the work to date has dealt with carbonaceous shales; decarbonized shales, from which the organic content has been burned off, are likely to differ significantly in stability and leaching properties.

36. To control fugitive dusts, and to provide moisture for compaction and stabilizing the disposal piles, retorted shale will be wetted before transport and disposal. It is not known whether wetting will be sufficient to minimize particulate emissions at the scale of operations contemplated at each site. The characteristics of the spent shale and the micrometeorology at a given site are among the pertinent variables.

37. Runoff from, and infiltration into, disposal piles may result in water pollution. It is planned to route natural drainage at each disposal site around the pile or through the pile in conduits. Provisions must be made to drain side gullies, if present, and to protect ground waters from leachate contamination. It is not clear whether the absorptive properties of the individual spent shales and the catchment basins planned by most developers are sufficient to ensure environmental protection against water quality degradation.

38. The surface of a disposal pile is subject to natural erosion by wind and water. In principle, it is possible to protect or stabilize pile surfaces by means other than vegetation; the large areas involved in commercial shale oil operations, however, may make vegetation the preferred or economic alternative. Moreover, successful vegetation can create a biotic habitat similar to or consistent with that of surrounding areas.

39. True and modified in situ retorting will leave the retorted shale below the ground. There, the retorted shale may create high potential for ground water pollution. Subsidence that may occur could fracture overlying aquifers and result in water movement between aquifers and reduction of ground water quality. Substantial quantities of raw mined oil shale brought to the surface by modified in situ mining may be permanently disposed of as raw shale or may be surface retorted. In either case, leachates may affect surface and ground water quality.

PUBLIC HEALTH

40. Waste streams associated with shale oil processing, crude shale oils, and upgraded or refined shale oil products may contain carcinogens or other hazardous trace substances from which industrial workers and the general population should be protected.

41. Various known and suspected carcinogens belonging to the POM class have been identified in crude shale oil and shale oil products, including benzo(a)pyrene (BaP). Other carcinogenic compounds in the POM class have been tentatively identified in shale products including 3-methylcholanthrene and an isomeric mixture of dimethylbenz(a)-anthracenes. In general, POM compounds have high boiling points, about 570°F (300°C), and are found in the higher boiling distillates or residues of shale oils, including shale oil coke and carbonaceous residues associated with processed shale.

42. Some of the controversy about the carcinogenicity of shale-derived materials arises from using BaP content as an indicator of activity. Levels of BaP in shale oils are usually in the same range as levels in petroleum oils having a similar boiling point, suggesting that shale oil presents no more hazard than petroleum. Experimental tests with crude shale oil and various distillate fractions have shown, however, that the carcinogenic potency of these oil shale products measured by nonhuman bioassay techniques cannot be attributed to BaP alone. Other carcinogenic or co-carcinogenic compounds may be present. Conversely, high measured levels of BaP in a material do not necessarily indicate biological availability.

43. In general, little is known about the hazards of shale-related waste streams; retorting and refining operations conducted to date have been limited in scope and size, and have been aimed primarily at demonstrating technology rather than determining effluent quantities and properties. Preliminary biological studies of the oil shale industry have not demonstrated unmanageable problems of toxicity. Studies now in progress will further delineate potential toxic profiles and possibly confirm provisional data now available. Continued research is needed to expand existing data and to develop data on various refinery cuts, including residual oil, emission products from retorting and refining, and emission products from combustion of fuels for power production. Data are also needed on the health hazards that may be associated with the contamination of stream estuaries or underground water by various leachates from shale oil technologies. Although results thus far are encouraging, it would be prudent to reserve judgment on the potential toxicity of oil shale development and shale oil production and use until the data base is extended to other parameters and until other investigators confirm the results.

ASSOCIATED EFFECTS

Radioactivity

44. Some radioactivity will be released to the atmosphere during oil shale mining and processing. Radioactive elements will be contained in dust emissions, fine particulate emissions, process water discharges, and leachate from spent shale disposal piles. Some radon gas will be released directly.

Noise

45. Noise will be created during oil shale development by processing plant construction and operation, community expansion, mining, and water reservoir operation, and by construction and operation of pipelines,

transmission lines, roads, and railways. Because oil shale development sites are, characteristically, a reasonable distance from population centers, the impacts of noise are expected to be negligible.

Social and Economic

46. Social and economic impacts of development are expected to be fairly severe because many oil shale sites are remote and sparsely populated. Population centers in the oil shale area are basically rural. The introduction of oil shale development will significantly increase the numbers of people who use the towns, creating higher demands on local municipal services such as fire and police protection, schools, hospitals and health care, and on local utilities such as electricity, water, and sewage treatment.

ARCHEOLOGICAL, HISTORIC, SCENIC AND OTHER VALUES POLLUTION CONTROL TECHNOLOGY

47. In planning for an oil shale operation, care should be taken in the initial stages to determine if the site contains any historical, archeologic, geologic, religious, paleontologic, biologic and/or cultural values that should be considered in the site preparation. Often a reconnaissance will serve to uncover evidences of such values resulting in a subsequent decision with the proper authorities regarding their disposition.

Air Emission Controls

48. Particulate matter and dust emission sources will include raw shale mining, blasting, conveying, crushing, and screening. Dust from spent shale will result from transfer, conveying, and disposal operations. Particulate and dust emissions will vary about threefold, depending on mining and processing techniques and the richness of the shale. Open-pit mines will generate large quantities of dust simply as a result of the large quantities of shale and overburden to be handled. In situ retort operations will release much less particulate matter; however, rubblizing from in situ operations may be a greater source of dust than conventional underground mining.

49. Water spray has potential for suppressing dust at open conveyors, crushers, or transfer points. Continuous sprays would be needed, but at properly adjusted rates so that no runoff would result. Without additives, water spray efficiency would be adequate (above 80 percent) for particles 5 micrometers and larger; however, efficiency drops to 43 percent for 3 micrometer particles and to 25 percent for 1 micrometer particles. Adding steam to the spray increases performance to 68 percent for 3-micrometer particles and to 40 percent for 1-micrometer particles. A more common method of increasing performance is addition of a wetting agent to reduce the surface tension of droplets on the particles. Overall mass efficiencies on the order of 95 percent can be achieved.

50. Water spray may be effective in controlling open-pit mining dusts. Chemical binders may also be applicable to these dusts, as well as to storage piles unprotected from wind erosion. Moisturizing techniques may be used to reduce dust emissions from spent shale handling.

51. A wide selection of control equipment is available for removal of fine particulate matter from gas streams and other closed operations. The performance efficiencies of baghouses, electrostatic precipitators, and scrubbers are all very high, even for fine particulate matter. The large quantities of particulate matter collected will probably be water slurred, then used to moisturize the spent shale.

52. Oil shale retorting will yield large quantities of low-Btu off-gas. Hydrogen sulfide and ammonia are the main constituents to be removed from gas streams before the gas is used as fuel. The presence of other sulfur contaminants, such as carbonyl sulfide or carbon disulfide is suspected but has not been confirmed by experimental work. The presence and concentrations of these constituents will affect the selection of desulfurization schemes.

53. Over 99 percent of the ammonia and a small percentage of the hydrogen sulfide will separate in the condensate from the vapor product cooling unit following the retort.

54. Sulfur emissions associated with oil shale operations will originate from retort off-gases (either burned for fuel or flared), tail gases from sulfur recovery operations, and the combustion of the produced shale oil. These emissions, primarily H_2S and SO_2 , must be removed before the gas streams are released to the atmosphere. As an alternative, combustion-generated sulfur emissions can be controlled by the use of clean (desulfurized) fuels.

55. Over the years, the petroleum, chemical, and gas industries have used various processes for concentrating and removing hydrogen sulfide from gas streams, and new processes are under development. The choice of an H_2S removal process depends on gas stream characteristics and economics. Retort off-gases and shale oil refinery gases contain sulfur dioxide, but in small quantities that may not need treatment; however, if a Claus unit is used for H_2S removal then the resultant tail gas will be rich in SO_2 and will need treatment. A number of SO_2 removal processes could conceivably be used.

56. If the retorting and refining gases are desulfurized, it is unlikely that further sulfur emissions control would be necessary to produce clean gases for use as fuel in process heaters and boilers. Trace amounts of ammonia in the gas would be converted to oxides of nitrogen on combustion; however, these quantities would be only a few parts per million compared to quantities of thermally generated NO_x . Thermally generated NO_x can best be controlled by demonstrated combustion modification techniques. If crude shale oil is used as process fuel, control of both SO_2 and NO_x emissions could be necessary. Full hydrotreating would be more cost effective than flue gas treating, if on-site refining is included in the shale oil facility.

57. Hydrocarbon emissions will result from direct preheating of raw shale, and will need control. Thermal incineration is probably the method of choice.

58. Hydrocarbons and carbon monoxide resulting from incomplete combustion will be emitted by the boilers, furnaces, heaters, and diesel equipment associated with oil shale development. With proper maintenance, emissions from these sources are not considered large; however, high background levels have been reported in some areas, and any additional contributions from process operations will be a cause for environmental concern. Hydrocarbon and carbon monoxide emissions can be held to a low level by proper design, operation, and maintenance of external and internal combustion equipment.

Wastewater Treatment

59. The quantity and quality of water available, methods of water use, and disposal criteria will dictate the pretreatment, internal conditioning, and wastewater treatment necessary at each oil shale processing site. Wastewaters from oil shale processing will contain dissolved and suspended solids, oil, trace elements and metals, trace organics, toxics (carcinogens), dissolved gases, and sanitary wastes.

60. Individual waste streams have not been characterized adequately to make firm treatment or control technology judgments regarding which unit processes should be applied to which waste streams. Nonetheless, some ideal processing schemes have been envisioned and discussed. The size of the treatment unit will depend on the wastewater volume to be treated at a specific site and on the concentrations of pollutants to be removed. The basic operating approach will be to concentrate the pollutants for ultimate disposal or containment so that clean water can be recycled or discharged.

61. Wastewaters that contain dissolved solids (more than 1,000 milligrams per liter) and suspended solids, and that are essentially free of oil and trace organics, can be collected and flow-equalized in large holding lagoons before treatment. Oily wastewaters (more than 10 milligrams of oil per liter) from all wastewater sources should be collected and processed by separators or similar equipment before receiving further treatment. Wastewaters contaminated with trace elements and metals should be essentially free of oil and dissolved solids to allow them to be treated separately. Trace organic wastewater volumes are not expected to be large, but these wastewaters will contain highly diverse types of organic pollutants. Toxic wastewater volumes are expected to be small, but advanced treatment and control will be needed for the concentrates collected. Specific controls and treatment will be necessary for wastewaters from scrubbers that absorb common oil shale process gases—such as hydrogen sulfide, ammonia, and carbon dioxide—before the water is reused or discharged. Sewage and water treatment plant releases should be considered for separate treatments and disposal.

62. The amounts and qualities of water to be expected from mine dewatering are not known, and they will depend on the site. In contrast to some earlier characterizations of surface retorting operations as large water consumers, true and modified in situ developments may produce a surplus of water that will have to be treated and discharged or reinjected into aquifers.

Solid Waste Controls

63. A commercial oil shale industry will produce tremendous quantities of spent oil shale, as well as smaller amounts of overburden, lean shales, raw shale fines, and chemical solids. Modified in situ operations may also produce large amounts of raw shale waste. For mining, handling, and disposal of overburden, techniques used in the surface mining of other minerals should usually be applicable to surface mining of oil shale. These techniques include disturbing the minimum area necessary, using water sprays and chemical binders to control dust, conserving soil, and using arid area vegetation methods.

64. Except in a true in situ oil shale operation, some raw or spent shale will have to be disposed of on the surface, either in disposal piles or as canyon fill. Any surface disposal of spent or raw oil shale will probably produce some leachate, which may adversely affect surface and ground water quality. It will likely be necessary to provide for collection, treatment, and reuse of this leachate.

65. Process-generated solid wastes—such as spent catalysts, lime sludges, coke, and other solids from water and wastewater treatment systems—may contain toxic substances. Disposal of these wastes by burying them in the spent shale pile would be likely to increase the levels of toxic pollutants in the spent shale leachate. It may be possible to dispose of some process wastes along with the spent shale if it is demonstrated that the wastes do not themselves produce a leachate or promote production of additional pollutants in the spent shale leachate. A preferred method of handling potentially toxic spent catalysts would be to return them to the manufacturer for regeneration and subsequent reuse.

66. It may be possible to dispose of surface-retorted spent shale by returning it to the mine, backfilling either with dry spent shale or with a spent shale slurry. Because of the potential for chronic leaching, it is recommended that spent shale not be returned to a wet mine; leachate problems would be more easily controlled on the surface than in a subsurface environment. Returning dry spent shale to a dry mine, however, would create support, decrease subsidence potential, and reduce surface spent shale storage by about 60 percent. In any case, mine disposal of spent shale should not be considered viable until it has been critically investigated to ensure that leachates will not degrade ground or surface waters.

67. Leachate will contain water-soluble organic and inorganic solids. Because of its expected poor quality, leachate from surface disposal piles will probably be collected behind dams constructed for the purpose and located slightly downstream of the toe of the pile. An impermeable base should underlie the pile, and drains should be included to pick up the leachate and discharge it at the collection point. For modified in situ oil shale operations, it will probably be necessary to minimize water flow through the retorts and collect and treat as necessary any leachate. Most of the ions present in leachate are also present in various flue gas desulfurization process liquids; therefore, it could be possible to use the leachate on site for removal of sulfur dioxide from flue gas streams of surface retorts. The leachate problem could also be reduced by leaching

the soluble minerals from the raw shale feed before retorting and passing the retorted shale through a spent shale burner to remove residual carbon and organics.

68. Modified in situ retorting, conventional underground mining, and possibly true in situ retorting may pose fracturing and subsidence problems unless subsidence control technology is provided. For conventional underground mining, some control technology exists that could probably be modified and applied to the specific hydrologic and geologic environment of a particular underground oil shale mine. Backfilling mine voids with spent shale could provide additional support though ground water pollution could be a concern. Special attention would be needed to avoid long-term problems from weakening of pillar strength by spalling and weathering. For modified and perhaps true in situ retorting, the key to controlling subsidence or fracturing of surrounding strata will probably lie in learning to control rubblization and in developing a technology that will provide pillars adequately sized and appropriately spaced to support overlying strata.

Other Controls

69. Other process controls include those necessary to reduce storage tank emissions, biological sludges, tank bottom sludges, and separator sludges. Floating-roof tanks and internal floating covers reduce both diurnal breathing losses and filling losses associated with fixed-roof tanks. The technology is well developed, having been used in the petroleum and chemical industries. Internal floating covers are preferable in sites having high wind, rainfall, or snowfall because they are protected from the weather.

70. Refineries limit or reduce sludges and other solid wastes primarily through source control techniques involve identifying and monitoring sources of oil, water, and other contaminants and then implementing inplant operating procedures to introduce less water into drains, to recover oil and water from solid wastes, to decrease the amount of contaminants in oily drainage, and to reduce the oil content of separator solid waste.

SAMPLING, ANALYSIS AND MONITORING

71. One problem facing developers is sampling and analysis of product and waste streams associated with producing oil from oil shale. The methods that have historically been used to analyze air and water samples have been applied to oil shale effluents, but without the straightforward results expected. Extraordinary interferences and matrix effects apparently make some methods ineffective. Many workers in the field are addressing the problem of standardization of methods for collecting, shipping, storing, and analyzing samples. Interlaboratory studies on many different types of environmental samples will be needed to validate those methods best suited for consistent analysis of oil shale pollutants.

72. Effective monitoring through sampling and analysis is expected to provide:

- A baseline evaluation of conditions before development
- A record of changes from baseline conditions
- A continuing check of compliance with environmental regulations and laws

--Predictive capability for timely notice of developing problems

--A check on the effectiveness of mitigating procedures

73. A monitoring program should include sampling of point source effluents at and around the facility, non-point source effluents resulting from activity at the mining, processing, and disposal sites, and accidental discharges. Monitoring should begin with a baseline survey.

74. An air-monitoring program should include on-site gas and particulate analyses and a network of meteorological and air quality measurement stations remote from the processing site.

75. Surface water monitoring should incorporate biological monitoring as well as physical and chemical analyses. Changes in aquatic biota may indicate subtle changes in water quality characteristics before they are detected by physical-chemical analyses for specific pollutants or by indicator parameters such as dissolved oxygen, pH, and hardness. Water monitoring should be done both upstream and downstream; wet and dry surface streams and springs and observation wells should be monitored to detect ground water changes.

76. In a water-monitoring program, non-point-sources will probably receive greater attention than point sources because of the difficulty of monitoring pollutants emanating from shale pile, construction sites, access roads, unlined catchments, and evaporation ponds. Adding to this problem will be the possible discharge of saline ground waters. Moreover, site activities may result in reduced water flows and, therefore, may affect already limited supplies of water for agriculture, livestock watering, and other beneficial uses.

77. In addition to spent shale, disposal sites will probably contain raw shale fines, spent catalysts, sludges, and process wastewaters. Surface erosion and leaching of soluble salts and organic compounds will necessitate extensive disposal site monitoring, particularly of revegetation trenches, of the alluvium, and at the toe of the pile where pollution is most likely. The spent shale monitoring program particularly should be designed to identify environmental problems in time for corrective measures to be taken.

NOTE: It is the intention of the Office of Environmental Affairs to make available two guidelines dealing with mining and retorting. These forthcoming guidelines will supplement those presently dealing with certain environmental problems also associated with oil shale; namely, Sulfur Dioxide, Dust, Noise, Effluent Disposal, Strip Mining, Underground Mining, Coke Oven Industry (retorting), and, Secondary Environmental Effects.

THE WORLD BANK

AUGUST 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

PALM OIL INDUSTRY

GUIDELINES

1. The oil palm is found in a wild, semi-wild, and cultivated state in several equatorial tropical areas, but principally in Southeast Asia, Africa, Central America, and the Caribbean. By 1976 Malaysia had increased its oil palm plantings to the point where it had become the world's leading producer of palm oil.
2. The fruit of the oil palm is a one-seeded fruit (drupe) whose outer pulp (mesocarp) provides the palm oil of Commerce. A hard-shelled nut within the mesocarp contains the palm kernel, from which are produced palm kernel oil (similar in composition to cocoanut oil) and palm kernel cake (useful as a protein source for livestock feed).
3. Both palm oil and palm kernel oil are used primarily in the manufacture of margarine, cooking fat, and soap. To a lesser extent they are also used for producing candles, glycerine, mayonnaise, bakery goods, and other edible and non-edible products.

INDUSTRIAL PROCESSES

4. The fruit of the oil palm grows in clusters, called fresh fruit bunches (F.F.B.), in which form it is harvested from the tree. Some loose fruit is trapped between the leaf and the stem, and is collected with the bunches. The bunches and loose fruit are transferred as quickly as possible to the factory for processing. Since maximum factory efficiency is achieved by maintaining a constant input of raw material, the fruit is sometimes placed in storage prior to processing.
5. In a typical operation the fruit is accurately weighted upon receipt and then either temporarily stored or transferred to processing. The fruit is processed as quickly as possible in order to minimize oil quality degradation. The initial processing step is sterilization, usually by steam injection, done to loosen the fruit in the bunches, and facilitate the stripping as well as other operations which follow.
6. After sterilization the fruit is fed to strippers to separate it from the leaves. The fruit falls through the slats of the strippers to a conveyor, and to the digesters. The empty fruit bunches are removed from the strippers for separate disposal. The bunches contain significant quantities of nutrients.

7. The purpose of digestion is to release oils from the pericarp cells, raise the temperature of the mass to facilitate subsequent pressing, and drain away free oil to reduce the volume of material to be pressed. The pericarp cells are the main oil-containing tissue in oil palm fruit. The digester is provided with rotating knives or beater arms, which serve to stir and pulp the fruit into a mash. The wet mash is then drawn off for the crude oil extraction.

8. Oil is extracted either by centrifuging or by squeezing the digested pulp. Centrifuging has been used mostly in factories having a low output. Ram presses (manually or hydraulically operated) and screw presses are most frequently used for the larger plants. Solvent extraction has been attempted, but to date its use has been limited to extraction of oils from palm kernels.

9. The liquid drained from the digesters and extractors is the crude oil product, and consists of a mixture of oil, water and cell debris. The mixture is passed through vibrating fine screens to remove particles of fiber and shell ends and, after heating, goes to the clarifiers. The screenings are returned to the digesters.

10. Static clarification is the method most frequently used to purify the oil. In this process, the oil and water mixtures go through a funnel to the bottom of a drum, one-fourth filled with hot water. Clean oil rises to the top and overflows, while the dirt tends to fall to the bottom. Centrifuging is used to remove oil from the settled dirt. The purified oil is then run through a high-speed centrifuge to remove the bulk of the remaining water and impurities. From the purification system the oil passes to storage tanks.

11. The residues from the extraction presses, containing the whole and broken nuts and shells, is dried and passed through an air stream to separate the lighter fibers. The nuts are further dried to shrink the kernel within the shell, allow easier separation after cracking, and reduce the amount of broken kernels. After drying, the nuts are passed through a nut cracker and then to a screen for separating the uncracked nuts from the kernels and shell fragments. The shell and kernel are then separated, by a hydrocyclone. The kernels are dried, bagged and stored for subsequent processing. The separated shell material may either be burned or used as fill material.

12. Generally, palm kernel oil is not produced at the site producing the crude palm oil. The conditions for release of kernel oils are different from those of palm oil but are similar to those of copra and hard oil-bearing seeds. The kernels must be crushed to a very fine meal before the oil can be extracted under pressure. Steam cooking releases the oil still further, and it is then extracted by hydraulic batch presses, continuous screw presses, or by solvents.

13. A typical system for the production palm oil and kernels is shown in Figure 1.

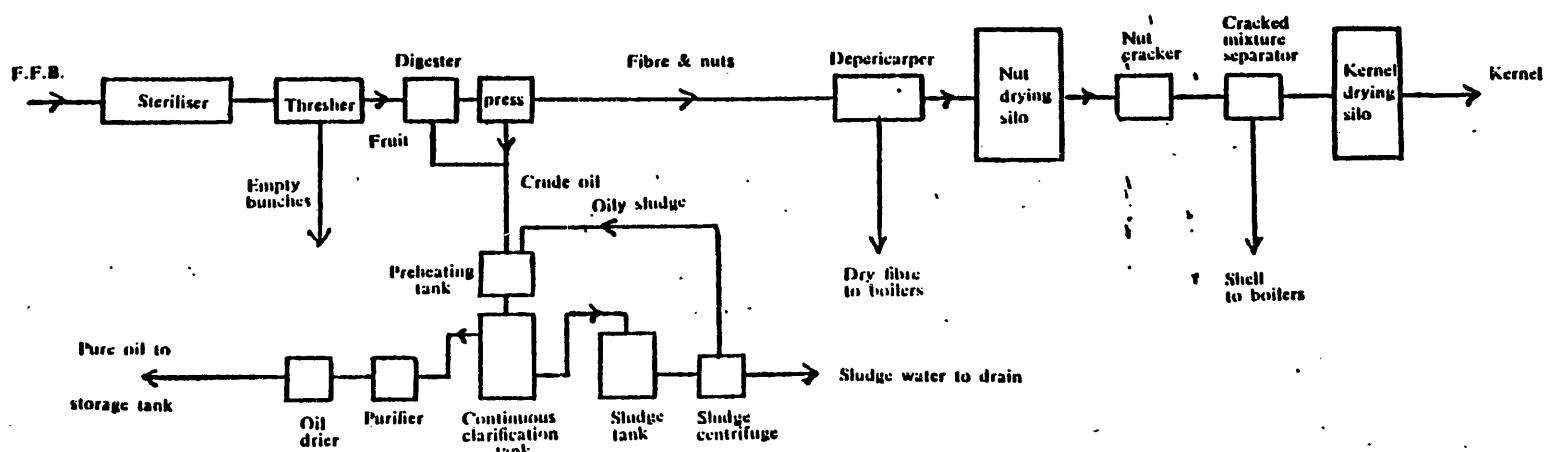


Figure 1. Typical System for the Production of Palm Oil and Kernels
(From Turner and Gillbanks).

WASTE SOURCES AND CHARACTERISTICS

14. Wastes originating from palm oil processing operations are generally limited to solids and liquids. The solid materials are readily amenable to separation and disposal.

15. The empty bunches, following the stripping operation, create a major disposal problem. They contain quantities of recoverable nutrients which are lost if the material is merely dumped. Dumping also creates conditions favorable for fly breeding, giving rise to nuisances. Use of the empty bunches for mulching has been found to be uneconomical. Separated shells are another solid waste for which provision must be made for disposal. Uncontrolled incineration of these residues, where utilized, could create air pollution problems.

16. Liquid wastes originate principally from (a) the sterilizers, where the fresh fruit bunches are heated under high pressure steam, and (b) the oil clarification step, in which the oil is separated from the sludge coming from the digester.

17. The most significant pollution parameters for palm oil processing wastes are 5-day biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), and hydrogen-ion concentration (pH). Other parameters may also be of significance at individual plants. Characteristics of a typical palm oil mill waste effluent are presented in Table 1.

EFFLUENT LIMITATIONS

18. The work done towards establishing effluent limitations for the wastes from this industry has been very limited, and much of it has been inconclusive. Considerable further development is needed on the chemistry and other characteristics of palm oil effluents under a variety of conditions.

19. It has been observed that waste effluents from palm oil processing are very similar in characteristics and behavior to effluents from the production of olive oil and by-product cake or meal from raw olives. The limitations and handling of wastes related to palm oil processing are based to some extent on accepted practices in the olive oil industry.

20. It is feasible to achieve 100 percent reduction of pollutant and waste effluent discharges to surface waters by one of the following methods:

Table 1. Typical Palm Oil Mill Waste Effluent ^{a/}.

Parameter	Average	Range
pH	3.7	3.5-4.5
BOD ₅ - mg/L*	25,000	20,000-35,000
COD - mg/L	45,000	30,000-60,000
NH ₃ N - mg/L	30	20-60
Org.N - mg/L	600	500-800
NO ₃ - mg/L	30	20-60
Tot. Sol. - mg/L	35,000	30,000-40,000
Susp. Sol. - mg/L	25,000	20,000-30,000
Ash - mg/L	4,500	4,000-5,000
Oil/Grease - mg/L	7,000	5,000-10,000
Starch - mg/L	2,000	---
Protein - mg/L	3,000	---
Tot. Sugar - mg/L	1,000	---
Flow - kg/kg FFB	0.6	---
Empty Bunches - kg per kg FFB Processed	0.25	

a/ From Sinnappa.

* mg/L = milligram per liter

- spray irrigation
- land application
- evaporation ponds
- discharge to municipal systems

21. Where the above methods cannot be applied, the wastes are amenable to biological treatment. However, because of the high strengths of the raw effluents, treatment efficiencies in the order of 99 percent or better will usually be required to avoid damages to the environment. Efficiencies of 95 to 97 percent are the levels generally economically achievable, and in many cases these may not be adequate.

CONTROL AND TREATMENT OF WASTES

22. As previously stated, the empty bunches present a disposal problem. Because they contain significant quantities of useful nutrients it is generally economical to institute by-product recovery measures. Currently, the most effective disposal method is slow burning by incineration, which reduces the bulk and produces an ash which can be used as a source of potash fertilizer.

23. The shells that have been separated from the kernels are collected and may be used either as fuel for steam generation or as road fill. When used alone, this residue is not satisfactory for boiler fuel since it contains silica which volatilizes and forms a glassy coating on the fire bars and refractory lining. Consideration has been given to the use of the shells as a filler for plastics, but no significant market exists at this time for this purpose.

24. The sludges originating in the sterilizer condensate and the clarification process have a high oil and solids content, and cause very strong and disagreeable odors. A common method of handling these is by means of a series of sludge pits. Water and dirt sink to the bottom of the pits, while the oil floats to the top. The oil is recovered by skimming, and used for soap manufacture in some countries. The sludge settling in the pits may be used as a fertilizer, or the water and sludge mixture disposed of by spray irrigation.

25. Where spray irrigation is applied to disposal of the effluent, pumping distances should be less than one kilometer. Land requirements will be about 200 square meters per cubic meter of effluent per day.

26. For land application the terrain should be terraced and graded to level. Waste effluents are then discharged to one terrace at a time, to a depth of about 8 cm. As a terrace dries it is plowed in preparation for the next application. Care should be taken to avoid contamination of fresh water aquifers.

27. Evaporation ponds are operated in series for maximum effectiveness, and should be lined to prevent percolation to ground waters. One pond at a time should be filled completely, to a depth of about 0.6 meter. The next pond in the series is then filled, while evaporation is taking place in the filled units. Enough ponds should be provided to permit handling the plant's total annual discharge. The number of ponds required will depend upon the annual waste volume, the annual net evaporation rate, and other local factors. The ponds are to be dredged periodically to remove the accumulated sludge.

28. The experience of several years in the Malaysian palm oil industry shows that liquid effluents are amenable to biological treatment. The anaerobic treatment is done in two steps: in the first, called the acidification phase where despite the name, the pH increases from 4.8 to 6.0 and the BOD drops to 6000 mg/L; in the methanogenic phase the pH goes first to 7.3 and then to 7.9. After this phase, the BOD falls below 200 mg/L.

29. This can be followed by aerobic oxidation where the BOD falls below 100 mg/L and the pH reaches 8.5. If ponds are used, the total retention time for the effluent is between 55 and 60 days.

30. To prevent deposition of hard sludge on the bottom of the methanogenic ponds, the liquor is desludged on sand beds and the cake used as fertilizer on the estate.

31. Ponds can be replaced by agitated tanks consuming more energy but allowing for the recovery of methane gas. Odors are not a nuisance if foam is kept on top of the methanogenic ponds.

Effluent Limitations

32. Limitations for liquid effluent from palm oil pressing plants are shown below:

pH	6 to 9
BOD	below 100 mg/L
COD	below 1000 mg/L
TSS	below 500 mg/L

BIBLIOGRAPHY

1. United Nations Industrial Development Organization "Technical and Economic Aspects of the Oil Palm Fruit Processing Industry," Sales No. E74.II-B.10. United Nations, New York (1974).
2. "The Oil Palm". Papers presented at Conference held in London, May 3-6, 1965. Ministry of Overseas Development-Tropical Products Institute, London (1965).

3. Turner, P.D., and R.A. Gillbanks, "Oil Palm Cultivation and Management." The Incorporated Society of Planters, Malaysia (1974).
4. Hartley, C.S.W., "The Oil Palm." Longmans, Gram and Company, Ltd. London, (1967).
5. Ahmad, A.A.B., and F.L.C. Ming, "Palm Oil Processing Effluent Treatment — Foreseeable Technological Problems." Malaysia Factories and Machinery Department, Doc. 628-54/634-614, Kuala Lumpur (1975).
6. Sinnappa, S. "Treatment Studies of Palm Oil Mill Waste Effluent." Department of Chemistry, Malaysia (1977).
7. U. S. Environmental Protection Agency. "Draft Development Document Effluent Limitation Guidelines and New Source Performance Standards for the Miscellaneous Foods and Beverages Point Source Categories". Prepared by Environmental Science and Engineering, Inc., Gainesville, Florida (February 1975).
8. BUKIT Kraiong Palm Oil Mill, Highlands and Lowlands BHD, the Engineering Department, Barlow Boustead Estates Agency SDN, BHD, Malaysia Biological treatment of palm oil mill effluent by ponding, using a 2 phase anaerobic digestion and facultative oxidation.
9. Division of Environment, Ministry of Science, Technology and Environment, Kuala Lumpur, Malaysia. Effluent standards for palm oil industry (1982).

THE WORLD BANK

OCTOBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

SAFETY AND OCCUPATIONAL HEALTH

PESTICIDE MANUFACTURE

1. This guideline will address safety of personnel working in the plant as well as health hazards inside the plant.

Plant Safety:

2. Toxic organic chemicals and highly volatile solvents are used in the manufacture of pesticides. Danger of fire and explosion is always present; accidents can happen if process conditions change, leaks develop or static electricity builds up on equipment, or storage vessels.

3. Major explosions followed by fire can occur at the plant as the following examples show. A control thermometer not in the liquid phase of a distillation vessel recorded erroneously low temperatures and thus caused overheating. The reaction reached explosive speed, and the vessel blew up. No injuries were reported and the equipment damage was around US\$300,000. The instrumentation equipment was then changed and the problem disappeared.

4. Process conditions were changed in a distillation vessel to increase capacity. The reaction reached explosive velocity and the distillation reactor blew up. This time, one operator was killed and damages amounted to US\$500,000. Sweeping changes were made and the process conditions were brought back into a safer zone. The vessel was put in a concrete bunker and provided with a high pressure diaphragm which will rupture before the vessel does. Alarms and trips were also added to forewarn the operators of changes and to shut off the process, if necessary, before the danger point is reached.

5. A company was producing Malathion at a higher temperature than is normally accepted. At this high temperature, some of the reagents were unstable, and an explosion resulted. Seven operators were wounded and burned—three died later on. The equipment damage amounted to US\$800,000. Malathion production was then discontinued.

6. Toxic or dangerous materials in the form of gases, solids and liquids, are handled by employees. Included are raw materials, in-process materials, finished products and effluents. Among the most toxic gases are sulfur dioxide, chlorine and phosgene. The most dangerous liquid (and to a certain extent vapor) is mercury. Every finished product, whether solid or liquid, is toxic to a certain degree.

7. In order to decrease minor accidents and avoid a serious one, standing orders for safety should be issued, and the Safety Officer should make sure these regulations are implemented. The Safety Department's main duties should be:

Fire protection and maintenance of fire-fighting equipment.

Accident prevention.

Evaluation of hazardous, toxic and flammable materials.

8. Materials should be segregated in three classes, according to their flammability:

Class A - Flash point */ below 6.67°C.

Class B - Flash point between 6.67 and 21.1°C.

Class C - Flash point above 21.1°C.

9. Toxic substances should also be divided into three classes according to their LD 50 **/

Class A - LD 50 less than 100

Class B - LD 50 between 100 and 800

Class C - LD 50 over 800

10. According to their class, materials should be stored in three areas;

- a) in the open-non-flammable or low flammable products or low toxicity,
- b) in closed warehouses—products of medium toxicity or flammability.
- c) in trenches or in buried storage tanks—products of high toxicity or flammability.

11. Every employee should receive instructions in safety and accident prevention and be aware of the dangers involved in handling toxic products. Prevention measures should be backed up by fire-fighting and toxicity fighting measures and equipment. The water fire loop should have a sufficient number of hydrants and should deliver a flow of at least 150 m³/h at a pressure of four to six kilos from a tank containing at least 500 m³. In case of power failure, a generator connected to an emergency electrical pump should make the fire loop independent from the outside power supply. Every operator should be trained in fire-fighting and first aid. Special teams should receive additional fire-fighting training. The company fire-fighting brigade should train with the town fire-fighting brigade on a regular basis. Besides the water fire loop, there should be portable fire extinguishers (chemical powder or CO₂) distributed in the plant and inspected regularly.

*/ The flash point is the minimum temperature at which the vapor of a liquid will ignite under certain test conditions.

**/ LD 50 represents the lethal dose for 50% of the test animals. Measured as 100 mg/kg of animal body weight will cause 50% of the test animals to die. The smaller the value for LD 50 the more toxic the material (less material will cause 50% of the animals to die).

12. Each employee should receive a gas mask. Air packs (portable breathing equipment with a reserve of air or oxygen) should be available in each unit. A doctor should be on duty and all cases of allergy or poisoning reported to him. Special measures should be taken for mercury pollution or any other toxicant. In some units every employee should have urine and blood tests taken every six months to detect and cure any poisoning.

13. A record of lost time by accident should be kept. The record should also include frequency and severity indexes for each accident.

14. The safety engineer should be well experienced and enthusiastic. Every piece of safety equipment should be in excellent condition. The safety engineer should supervise the fire chief and be assisted in his work by one or more safety technicians.

Plant Surroundings:

15. Plant wastes can be classified as liquid effluents or gas pollutants. Liquid effluents contain raw materials and intermediate or finished products which, if toxic, can create serious safety and pollution problems. Most important are toxicant losses. The company should avoid discharging in the environment any toxic waste effluent, regardless of its biodegradability.

16. Several gas pollutants are released by the different processes. Among the most important in a pesticide plant are sulfur dioxide, chlorine, hydrochloric acid and mercaptans. These pollutants should be scrubbed before being discharged into the atmosphere.

BIBLIOGRAPHY

1. United Nations Development Programme. "Environmental Operations Guidelines", with Attachments 1101 through 1106. Document G3300-1/TL., New York (28 May 1981).

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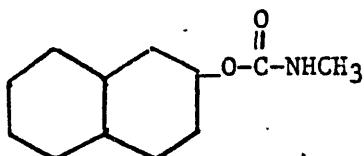
FEBRUARY 1983

OFFICE OF ENVIRONMENTAL AFFAIRS

PESTICIDES

GUIDELINES FOR USE

1. A pesticides component is now very often incorporated in Bank agricultural projects. As a consequence, this Office has received several requests for advice on the toxicity and the use of certain pesticides.
2. In some cases, the answer given was not complete because the name mentioned was a trade name unknown in the US. To prevent this, sponsors should be asked to supply the chemical name and the common name generally used in the pesticides trade. For instance, if the sponsor decides to use RAVYON, there is no way here to identify the material. The sponsor should give the generally accepted common name CARBARYL, the chemical name 1-naphthyl methyl carbamate, and if possible the chemical formula.



or even the US trade name. In this case SEVIN.

Choice of Pesticide

3. The criteria for choosing pesticides should be based on the following factors:

Biodegradability
Toxicity to Mammals and Fish
Risks of Application
Price

4. Biodegradability should be the most important criteria as stable chemicals will accumulate, and this accumulation can be magnified into the food chain. This is why chlorinated hydrocarbons which are very stable, chemically speaking, should be avoided and why the US Environmental Protection Agency banned the following products: DDT, Aldrin Chlordane and Heptachlor.

5. Using these products in Bank projects should be avoided if at all possible. If they are absolutely required, the detailed reason should be given; price differential is not a sufficient reason.

6. Depending on when the chemical is used and where it will end up, toxicity for mammals and/or fish should then be taken into account.

7. Toxicity figures show the relative toxicity of the product to laboratory animals (white rats unless otherwise specified). LD₅₀ is the dose that kills half of the experimental animals in any test expressed in milligrams of the chemical per kilogram of animal weight. The higher the LD₅₀ value, the lower the toxicity. Toxicity can be oral (mouth ingestion), dermal (skin absorption), or inhalation dusts. Special measures should be taken when handling products with high dermal toxicity.

8. Risks of application depend in part on the toxicity but also on the physical properties of the material and the way it is applied. The product can be sold as a concentrate, a solution, an emulsifiable concentrate, a wettable powder, or a dust. It is for instance safer to apply a solution on the ground than a dust, but it may not be always possible to do so. Aerial spraying is potentially the most damaging.

9. Price as an element of choice between two pesticides should only be considered after the other criteria have been decided.

Application of Pesticides

10. Even the safest among pesticides will probably involve some health risks. To avoid any serious accident, the appraisal mission should make sure that the people going to handle or be in contact with the product (dealers - formulators - applicators - farmers) have been properly trained in its use and known about the hazards of handling it. The product should be shipped in adequate containers with labels, clearly identifiable, showing how to use it, how to avoid any problems, and how to give first aid in case of an emergency.

11. The use of casual (migrant) workers for applying pesticides is widespread but should be avoided for the following reasons: These workers do not have the knowledge or the experience necessary for safe application and they will have a tendency to disregard the safety rules.

12. If these workers must be employed, they must be educated and trained, keeping in mind that their schooling is most of the time inadequate or nonexistent. Secondly, they must work under experienced supervisors doing nothing but supervising the pesticide application.

13. Disposal of containers should not be overlooked. In 1967, 16 people died in Mexico from eating flour and sugar stored in Parathion drums.

14. Common transportation of pesticides and food in the same vehicle should be forbidden. In Colombia 63 people died and 165 became seriously ill from eating flour contaminated with Parathion during transport by truck.

INSECTICIDES

SUBSTITUTE FOR

<u>PRODUCT</u>	<u>DDT</u>	<u>Aldrin</u>	<u>Dieldrin</u>	<u>Chlordane</u>	<u>Heptachlor</u>
Phorate	o	o		o	o
Demeton	o				
Methyl parathion	o				
Parathion	o	o		o	o
Guthion	o				
Aldicarb	o				
Azodrin	o				
Diazionon	o	o		o	o
Dimethoate	o				
Fenthion	o				
Methomyl	o				
Crotoxyphos	o				
Chlorpyrifos	o	o		o	o
Bux		o		o	o
Carbofuran	o	o		o	o
Counter		o		o	o
Dasanit	o	o		o	o
Disulfoton	o	o		o	o
Dyfonate	o	o		o	o
Landrin		o		o	o
Trichlorfon	o	o		o	o
Dacthal				o	
Aspon	o	o	o	o	
Siduron				o	
Ethion	o	o	o	o	
Propoxur	o	o	o	o	
Acephate	o		o	o	
Methoxychlor	o		o	o	
Endosulfan	o	o	o	o	o

May 1976

<u>HERBICIDES AND FUNGICIDES</u>		
<u>SUBSTITUTE FOR</u>		
	<u>2, 4, 5-T</u>	<u>EBDC</u>
<u>HERBICIDES</u>		
Bromacil	○	
MSCA/DSMA	○	
Cacodylic acid	○	
Dinoseb (DNBP)	○	
Dicamba	○	
Monuron	○	
Simazine	○	
Trifluralin	○	
<u>FUNGICIDES</u>		
Captan		○
PCNB		○
Folpet		○

May 1976

15. For additional details see UNIDO's book "Industrial Production and Formulation of Pesticides in Developing Countries" - 2 volumes - UN - New York, 1972.

16. Annex 1 contains the EPA tables which show equivalent acceptable substitutes for banned pesticides.

17. The following pesticides should not be used: DDT, Aldrin, Diel-drin, Chlordane, Heptachlor, 2,4,5T (2,4,5 Trichlorophenoxyacetic Acid), EBDC (Ethylenebisdithiocarbamate), all mercury compounds, all arsenic compounds, MIREX (Dechlorane), and DBCP (Dibromochloro Propane).

18. The product Phosvel (leptophos) an organo phosphate made, but not sold in the United States should also be banned for its long range effects. Chronic neurological disorders, paralysis, and sometimes death are associated with this chemical believed to eat away myelin, the sheathing around the nerves. The pesticide EDB (Ethylene Dibromide) is a proven carcinogen.

19. The following pesticides are suspect of long-range chronic effects and should be avoided: endrin, toxaphene, strobane, 1080, strychnine, kepone, lindane, cadmium, DECP, BHC, dimethoate, diallates, triallates, chlorobenzilate, ethylene oxide, EPN, carbaryl, aramite, PCP, creosote, chloranil, monourea, benomyl, DDVP, chloroform, (SST) DFF, piperonyl butoxide, rotenone, perthane, safrole, promide and merphos.

20. The use of DBCP and EDB should be restricted to cases where no substitutes exist for the considered application. The use of MIREX should be restricted to compounds where it is mixed with products enhancing its photodegradability.

21. In view of the added potential damages to the environment and of the Bank's official policy favoring "Intermediate Technologies", aerial spraying of pesticides should be discouraged whenever it can be replaced by ground spraying.

22. Ultra low volume application (ULV). ULV techniques with quantities habitually below 5 liters per hectare are now well proven and should be promoted in Bank projects either for aerial or ground spraying. To be effective this technique requires proven equipment, strict control of the spray droplets diameter (usually in the order of 30 um), and experienced supervision to take into account the weather conditions. The main pesticides manufacturers will supply technical bulletins on ULV and also trained supervisors.

ADDENDUM

1. The pesticide MIREX (Dechlorane) has been forbidden by the EPA and the same Organization has suspended the use of the pesticide DBCP (Dibromochloro Propane).

2. The pesticide EDB (Ethylene Dibromide) is a proven carcinogen and it is actually being examined by the EPA.
3. The use of DBCP and EDB should be restricted to cases where no substitutes exist for the considered application.

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

PETROLEUM REFINING

1. The petroleum industry is a complex combination of inter-dependent operations, which can be divided into three major divisions: production, refining, and marketing. This document will be concerned only with refining, and thus cover only those operations necessary to convert the crude oil into consumer products, prior to marketing.

REFINERY PROCESSING

2. The production of consumer products from crude oil involves several separate processes which are fundamental to refinery operations. Each of these produces wastes that are identifiable and must be disposed of under controlled conditions to avoid environmental damages. The principal processes are discussed below.

3. Crude and product storage. Crude oil is stored in order to provide constant supplies of feedstocks for primary fractionation runs of economical duration. Intermediate products are stored to equalize flows within the refinery. Finished products are stored to await shipment, for mixing and blending on or off the premises, and to lessen the effects of changes in product demands. Storage is provided in steel tanks, permitting sufficient detention for settling of water and suspended solids. The settled water layers are drawn off periodically.

4. Crude desalting. This removes inorganic salts and some of the suspended solids from the crude oil, in order to minimize mechanical plugging and corrosion in process equipment. Salts are separated by water washing in the presence of chemicals specific to the type of salts present and the characteristics of the crude oil.

5. Crude oil fractionation. This is the basic refining process, by which crude petroleum is separated into intermediate fractions of specified boiling point ranges. Topping (sometimes called prefractionation or skimming) is the first step in the process, and serves to separate the economical quantities of the very light distillates from the crude oil.

6. Cracking. Thermal cracking breaks down heavy oil fractions into lower molecular weight fractions, such as heating oils. Catalytic cracking also breaks down heavy fractions into lower molecular weight fractions but utilizes a catalyst and runs at lower temperatures and pressures than in thermal cracking. Hydrocracking converts hydrocarbon feedstocks (including distillates, gas oils, and residues) into gasoline, high-quality middle distillates, LPG, or low-sulfur residual fuel. Hydrocracking consists basically of catalytic cracking in the presence of hydrogen.

7. Hydrocarbon processing. Several operations are included in this category. Polymerization converts olefin feedstocks into higher-octane polymer gasoline, propane and butane. Alkylation converts normally gaseous hydrocarbons into high octane alkylates for use as gasoline blending components. Isomerization is also used for converting light gasoline stocks into higher-octane isomers to produce higher octane motor fuel, as well as to convert isobutane from normal butane for use as fuel-stock in the alkylation process. Reforming converts low octane naphtha, heavy gasoline, and naphthene-rich stocks to high octane gasoline blending stock.

8. Solvent refining. Used primarily to obtain lube oil fractions or aromatics from feedstocks containing mixtures of hydrocarbons and undesirable materials such as unstable acidic, sulfur, organometallic, napthenic, and/or nitrogen compounds. Refined oils, high-octane blending components, and high-purity aromatics are produced. Dewaxing which is also a solvent process, is used to remove wax from lube oil stocks to produce lubricants with low pour points and to recover wax for further processing.

9. Hydrotreating. Saturates olefins and removes sulfur, nitrogen, and oxygen compounds and other contaminants from either straight run or cracked petroleum fractions to produce materials having low sulfur, nitrogen, and olefin contents and improved stability. The process occurs in the presence of hydrogen.

10. Grease manufacture. Blends various alkali earth metal hydroxides and fatty acids for soap manufacture with lube oils, waxes and other materials to produce lubricating greases.

11. Deasphalting. Separates asphalts or resins from viscous hydrocarbon fractions, segregates heavy or medium neutral fractions by propane extraction, and/or removes paraffinic catalytic cracking stock from distillation residues. The resulting products are deasphalted or decarbonized oil, asphalt, and heavy fuel blending stocks.

12. Wax manufacture. Takes high-oil-content wax fractions directly from crude fractionation and/or waxes from dewaxing of lube oils and converts them to paraffin and microcrystalline waxes of low-oil-content, high melting point, and other characteristics required for high-quality waxes.

13. Product finishing. Drying and sweetening are used to remove sulfur compounds, including hydrogen sulfide and mercaptans, and to improve color, odor, oxidation stability, and inhibitor response to produce materials suitable for blending, shipping or further processing. Lubricating oil finishing takes petroleum fractions that have been solvent extracted and dewaxed, and converts them to finished lube oils ready for blending and compounding. Blending and packaging are the final steps in preparation of the petroleum products which must meet those specifications required by industries, retailers, and consumers.

14. Hydrogen production. Produces the hydrogen needed for refining operations, such as hydrotreating and hydrocracking, and for petrochemical feedstocks. The primary raw materials are natural gas; refinery gas, propane, butanes and others.

15. General Utilities. Certain utility facilities, such as supplies of steam and cooling water, generally serve several processes. Boiler feed water is prepared and steam generated at a single location. Non-contact steam, used for surface heating, is circulated through a closed loop, from which needed quantities are made available for specific process purposes. The condensate is recycled to the boiler house, with a certain portion being discharged as blowdown. Steam is used principally for: non-contact process heating; power generation in turbines, compressors, and process pumps; and as a diluent, stripping medium, or vacuum source with steam jet ejectors.

16. A petroleum refinery consists of a complex combination of inter-dependent operations concerned with separation of crude molecular constituents, molecular cracking, molecular rebuilding, and solvent finishing. Only the major processes have been identified above, since the intermediate and finished products are too numerous and too variable in composition to cover in this document. Not all of these operations are necessarily carried out at one refinery. The products of one or more of these operations are frequently transferred to other plants for further processing into marketable commodities.

SOURCES AND CHARACTERISTICS OF WASTES

17. The principal environmental problems in oil refinery operations are due to both emissions and effluents.

Gaseous Emissions

18. The air pollutants emitted by refineries are affected by crude oil capacity, air pollution control measures being utilized, general level of maintenance and housekeeping, and the specific processes being carried out. Table 1 presents the principal potential sources of various contaminants.

19. Sulfur oxides, nitrogen oxides, hydrocarbons, carbon monoxide, and odor are the emissions of greatest concern. Particulates, aldehydes, ammonia, and organic acids may also be present but are usually of lesser importance.

Liquid Wastes

20. Refineries vary in complexity from small installations employing perhaps single atmospheric fractionation, to the very large integrated facilities producing a broad spectrum of petroleum and petrochemical commodities from a wide variety of feedstocks. Basic refinery operations may be grouped into five categories on the basis of the effects on raw waste water loadings.

Table 1. Potential Sources of Oil Refinery Emissions a/

Emission	Principal Potential Sources
Sulfur Oxides	Boilers, process heaters, catalytic cracking unit regenerators, H ₂ S flares, decoking operations.
Hydrocarbons	Storage tanks, wastewater separators, catalyst regenerators, pumps and valves, cooling towers, volatile hydrocarbon handling equipment, process heaters, compressor engines.
Nitrogen Oxides	Process heaters, compressor engines, catalyst regenerators, flares.
Particulate Matter	Regenerators, boilers, decoking, incinerators.
Aldehydes	Catalyst regenerators
Ammonia	Catalyst regenerators
Odors	Treating units, drains, tank vents, wastewater separators
Carbon Monoxide	Catalyst regenerators, decoking, compressor engines, incinerators

a/ See Ref. 1.

21. The categories used are patterned after the American Petroleum Institute (API) classification system. These categories and the refinery operations included in each are as follows:

— Topping: Topping, catalytic reforming, asphalt production, or lube oil manufacturing, but no cracking or thermal operations.

- Cracking: Topping and cracking
- Petrochemicals: Topping, cracking and petrochemicals operations (first generation and isomerization products or second generation products).
- Lube: Topping, cracking and lube oil manufacturing processes.
- Integrated: Topping, cracking, lube oil manufacturing processes, and petrochemicals operations.

22. The pollution parameters of major significance in this industry are as follows:

- 5-day Biochemical Oxygen Demand (BOD_5)
- Chemical Oxygen Demand (COD)
- Total Organic Carbon (TOC)
- Total Suspended Solids (TSS)
- Oils and Greases (O/G)
- Phenolic Compounds
- Ammonia Nitrogen (NH_3-N)
- Sulfides
- Total Chromium (Tot.Cr.)
- Hexavalent Chromium (Cr^{+6})
- Hydrogen Ion Concentration (pH)

23. The waste water flows and characteristics of refinery effluents can vary considerably according to the type of operations. Table 2 lists the median (50% of occurrences less than or equal to the values shown) raw waste flows and loadings, representing the oil separator effluents for each of the processing categories cited above. In general, all wastewaters from processing units discharge to large basins or ponds (API separators) which function as oil and water separators. The oil is usually recovered as a valuable by-product. Hexavalent chromium is present in refinery effluents, due to the addition of chromates to cooling waters in order to inhibit corrosion.

Table 2. Median Waste Flows and Loadings for Petroleum Refinery Operations, Following Oil/Water Separation. a/

Parameter	Process Category				
	Topping	Cracking	Petro-Chem.	Lube	Inte-grated
	Net Kg per 1000 m ³ of Feedstock <u>b/</u>				
BOD ₅	3.4	73	172	217	197
COD	37.	217	463	543	329
TOC	8.0	41	149	109	139
TSS	12.	18	49	72	58
O/G	8.3	31	53	120	75
Phenols	0.03	4.0	7.7	8.3	3.8
NH ₃ - N	1.2	28	34	24	20
Sulfides	0.05	0.94	0.86	0.01	2.0
Tot. CR	0.01	0.25	0.23	0.05	0.49
Cr ⁺⁶	0.007	0.15	0.13	0.02	0.30
Flow <u>c/</u>	67	93	109	117	235

a/ From EPA Doc. 440/1-74-014a.

b/ Feedstock = Crude oil and/or natural gas liquids throughput.

c/ As m³ per 1000 m³ of feedstock.

EFFLUENT LIMITATIONS

Gaseous Emissions

24. Limitations for gaseous emissions from specific refinery processing

operations are given in Table 3. For processing operations not covered in these limitations, acceptable ambient air quality standards applicable to the specific pollutant are to be applied.

Table 3. Performance Limitations for Petroleum Refinery Emissions

Parameter	Source	Limitations
Sulfur Oxides	Fuel gas combustion devices	Shall not burn any gas containing over 230 mg H ₂ S per dry m ³ at standard conditions
Sulfur Oxides	Sulfur recovery plant	Not over 0.025% SO ₂ by volume at zero oxygen on a dry basis, with reduction control system and incineration
		Not over 0.030% sulfur compounds and 0.0010% H ₂ S by volume at zero oxygen on a dry basis, with reduction control system but no incineration
Hydrocarbons	Storage vessels with capacity of over 150 Mg (40,000 Gallons)*	No discharge to atmosphere. Equip with floating roof and vapor recovery system if true vapor pressure is 10.4 to 76. kPa
		Equip with vapor recovery system if true vapor pressure is over 76 kPa
Particulate Matter	Catalyst regenerator	Not over 1 kg/1000 Kg coke burnoff
Carbon Monoxide	Catalyst regenerator	Not over 0.050% by volume
Opacity ^{a/}	All emissions	Not over 30% except for 3 minutes in any 1 hour

^{a/}. "Opacity" is the degree to which emissions reduce the transmission of light and obscure the view of an object in the background.

* 1 megagram = 1 metric ton, 1 mm Hg = 133.3 Pa
Mg = ,egagram, 1'a = kilo Pascal

Liquid Effluents

25. Table 4 presents the permissible maximum daily discharge of various pollutants in petroleum refinery effluents. These limitations are based on the application of best demonstrated end-of-pipe technology currently available, the use of API (or equivalent) oil and water separators in the plant, segregation of non-contact waste waters from process waste waters, and effective in-plant process control and housekeeping measures.

CONTROL AND TREATMENT OF WASTES

26. The gaseous emissions and the liquid effluents are of equal importance in the refinery operations and the discharges must be controlled in order to avoid environmental damage. A combination of process control, in-plant housekeeping, and treatment technology can usually be effective in achieving reduction of these discharges to acceptable levels.

Gaseous Effluents

27. It is difficult to categorize emission sources on the basis of refinery operations, since many of them are common throughout the plant. For purposes of emissions control the refinery should be considered as an integrated systems of storage facilities, process heaters, cooling equipment, pumps, valves and other units and operations.

28. Hydrocarbon emissions originate principally from storage facilities, valves, pumps, compressors, waste water separators, and loading facilities. These emissions can, in most instances be collected by vapor recovery systems or ventilating systems and eliminated by burning. Disposal is most frequently through elevated flares, using steam ejection. Flares must be so located as to avoid proximity to combustible materials, tanks and processing equipment.

29. Other measures for reducing emission discharges include high efficiency dust removal equipment on catalytic cracking units, waste heat boilers on catalyst regenerators, smokeless flares, and sulfur recovery systems. Improved housekeeping, coupled with maintenance and employee education can also contribute significantly.

Liquid Effluents

30. Technology for control and reduction of effluent loadings falls into three categories: in-plant control, at source pretreatment, and end-of-pipe technology.

31. Two types of in-plant measures can greatly reduce the volume of final effluents. The first of these utilizes the reuse of water from one process to another, such as using blowdowns from higher pressure boilers as feed to low pressure boilers or using treated effluent as makeup water whenever possible. The second approach is to utilize recycle systems that use water more than once for the same purpose, such as using steam condensate as boiler feed water or using cooling towers.

Table 4. Liquid Effluent Limitations for Petroleum Refinery Wastes.

Process Category	Maximum Daily Discharge - Kg per 1000 m ³ of Feedstock <u>a/</u> <u>b/</u>									
	BOD ₅	COD	TOC	TSS	O/G	PHEN.	NH ₃ -N	SUL-FIDES	TOTAL CR	CR ⁺⁶
Topping	6.3	32	8.2	4.0	1.9	0.04	1.3	0.04	0.10	0.002
Cracking	8.7	61	11.	5.8	2.6	0.06	8.6	0.05	0.14	0.002
Petrochemicals	12	69	15.	7.7	3.5	0.08	11	0.06	0.19	0.003
Lube	18	126	24.	12.	5.6	0.12	11	0.10	0.31	0.005
Integrated	22	152	29.	14.	6.7	0.14	11	0.12	0.37	0.006
Runoff <u>c/</u>	0.03	0.19	0.03	0.02	0.01	--	--	--	--	--
Ballast <u>d/</u>	0.03	0.24	0.03	0.02	0.01	--	--	--	--	--

a/ Feedstock - Crude oil and/or natural gas liquids throughput.

b/ For all effluents pH = 6 to 9.

c/ Applies only to process area runoff treated in main treatment system. All runoff from tank fields and non-process areas shall not exceed 35 mg/l of TOC or 15 mg/l of O/G when discharged.

d/ Applies only to ballast waters treated at refinery.

32. Good housekeeping will further reduce waste flows. Examples are minimizing waste when sampling product lines, using vacuum trucks or dry cleaning methods to clean up oil spills, applying effective maintenance and inspection in order to keep the refinery equipment as leakproof as possible, and providing individual disposal for waste streams (such as spent cleaning solutions) having special characteristics.

33. Process modification, in most cases applicable to both existing and new installations, could include:

- Substitution of improved catalysts having longer life and requiring less regeneration.
- Replacement of barometric condensers with surface condensers or air fan coolers to reduce a major oil-water emulsion source.
- Substitution of air fan coolers for water cooling to reduce blowdown discharges.
- Installation of hydrocracking and hydrotreating processes designed to generate the lowest possible waste loadings.
- Provision of automatic monitoring equipment, such as for TOC, to assure early detection of process upsets and avoiding excessive discharges to sewers.
- Maximum use of improved drying, sweetening, and finishing procedures to minimize volumes of spent caustics, filter solids and other materials requiring disposal.

34. Major at-source pretreatment measures include stripping of sour waters, neutralization and oxidation of spent caustics, ballast water separation, and slop oil recovery. Gravity separators remove the major portion of the free oil found in refinery waste waters. Most of these oils can be re-processed, and hence the separator is considered an integral part of the refinery operation.

35. End-of-pipe control technology relies most heavily on a combination of flow equalization and biological treatment methods. Equalization, which eliminates surges in flows and loadings, is particularly important for a biological treatment system since, for example, sudden discharges containing high concentrations of certain materials can upset or completely kill the organisms in the system.

36. Among the biological techniques most commonly applied are dissolved air flotation, oxidation ponds, aerated lagoons, trickling filters, activated sludge, physical-chemical methods, granular media filters, and activated carbon. These may be applied singly or in combination, depending upon the volume and characteristics of the wastes to be treated, availability of land areas and other factors.

37. The most frequently used methods for disposal of chromium bearing wastes are by reduction of the hexavalent to the trivalent form (with sulfur dioxide, sulfites, ferrous sulfate, or other reducing agents), followed by neutralization and precipitation of the reduced chromium with alkali.

38. Sludges produced from biological treatment may be disposed of by land-filling, land farming or incineration.

BIBLIOGRAPHY

1. Jones, Harold R. "Pollution Control in the Petroleum Industry". Noyes Data Corporation. Park Ridge, N. J. and London (1973).
2. Powers, Philip W. "How to Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation. Park Ridge, N. J. and London (1976).
3. U. S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Petroleum Refining Point Source Category". Doc. EPA-440/l-74-014-a (April 1974).
4. UN Environment Programme "Seminar on Environmental Conservation in the Petroleum Industry - 29 March to 1 April, 1977". Doc. UNEP/lss.5/10 (Final). United Nations. New York (June 10, 1977).
5. U. S. Federal Register, US Government Printing Office, Washington, as follows:
 - (a) Vol. 39 (39FR9308), March 8, 1974
 - (b) Vol. 40 (40FR46250), October 6, 1975
 - (c) Vol. 41 (41FR36600), August 30, 1976
 - (d) Vol. 41 (41FR43866), October 4, 1976
 - (e) Vol. 43 (43FR10866), March 15, 1978
 - (f) Vol. 43 (43FR21616), May 18, 1978

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

PLATING AND ELECTROPLATING

EFFLUENT GUIDELINES

Process Description

1. Electroplating applies a surface coating by electrodeposition on a metal surface. Copper, nickel, chromium, zinc, tin, lead, cadmium, iron aluminum or combinations thereof can be used as coating. Precious metals as gold, silver, palladium, platinum, rhodium or combinations can also be used as coating. Chemical plating on metals or plastics can also be done and generally a plant applies both processes.
2. A plating line is a sequence of tanks in which one or more coatings are applied. It may be broken down in 3 steps; preparation of the surface for coating, application of the coating and finally post treatment.
3. The pretreatment involves cleaning, descaling and degreasing. Cleaning removes oil, grease and dirt; it can be done by solvents, alkalis, emulsions, ultrasounds or acids. Salt bath descaling is used to get rid of hard to remove oxides from stainless steels or other alloys. A typical electroplating pretreatment is shown in Annex 1 and a typical chemical plating pretreatment in Annex 2.

Wastes Characteristics

4. Annex 3 shows the pollutants occurrence in the U. S. plating industry in general and per section (common metals - precious metals - chemical plating - anodizing - coating - milling and etching - printed circuit boards).
5. All the pollutants mentioned in Annex 3 are commonly present in significant amounts and require some control in the effluent discharge. This control can be achieved by currently available technology.

Waste Removal

Reduction of Hexavalent Chromium

6. Because of its high toxicity hexavalent chromium has to be reduced to the trivalent state. This is done with any reducing agent but SO_2 is most commonly used at a pH between 2 and 3. The reaction will take two to three hours and sulfuric acid may have to be added to keep the right pH.

Oxidation of Cyanides

7. Any oxidation agent will do the job. Chlorine, hypochlorites and hydrogen peroxide are the most commonly used but oxygen in air is also effective if there is room for an aerated pond. Cyanates being much less toxic than

cyanides, there is no need to go to complete oxidation to nitrogen as long as all the cyanides have disappeared.

Metals Removal

8. This is done by pH adjustment. Lime addition to the waste water will increase the pH and promote precipitation of metal hydroxides. The maximum precipitation corresponds to a well defined pH changing for each metal. The maximum solubility for Cr is 0.012 mg/L at pH 8.5. Below and above this pH the solubility increases. At pH 10.5, nickel solubility is 0.001 mg/L but at the same 10.5 chromium solubility is back up to 1 mg/L. The precipitation of metal hydroxides may consequently have to be done in several stages.

9. The solubility figures given above are for pure solutions of the metal. Other factors can increase or decrease the solubility, among them, temperature, other salts concentration, common ions, etc.

10. In industrial practice, the precipitation of metal hydroxides is promoted by adding inorganic coagulants or polyelectrolytes flocculants in a clarification tank or pond or both.

11. The sludge collected from clarification is first dewatered and then either buried in a landfill, incinerated or hauled away.

Results of Treatment

12. Although there are more sophisticated treatments that can replace or be added to the operations described, these can achieve the following results for the main pollutants:

<u>Pollutant</u>	<u>Residual (mg/L)*</u>
Copper	0.5
Nickel	0.03
Cr Total	0.1
Cr Hexavalent	0.01
Zinc	1.2
Cyanide	0.01
Cadmium	0.02
Lead	0.03

13. These figures should be considered as World Bank guidelines for the plating industry not forgetting that effluent pH should always be between 6 and 9.

Costs of Treatment

14. Annex 4, 5 and 6 taken from the EPA publication Electroplating (see bibliography) gives the investment and operating costs for clarification, chromium reduction, and cyanide oxidation.

* mg/L = milligram per liter

BIBLIOGRAPHY

For more information consult EPA 440/1-78/085 - Electroplating.
Point source category. Publisher: United States Environmental Protection
Agency - February, 1978.

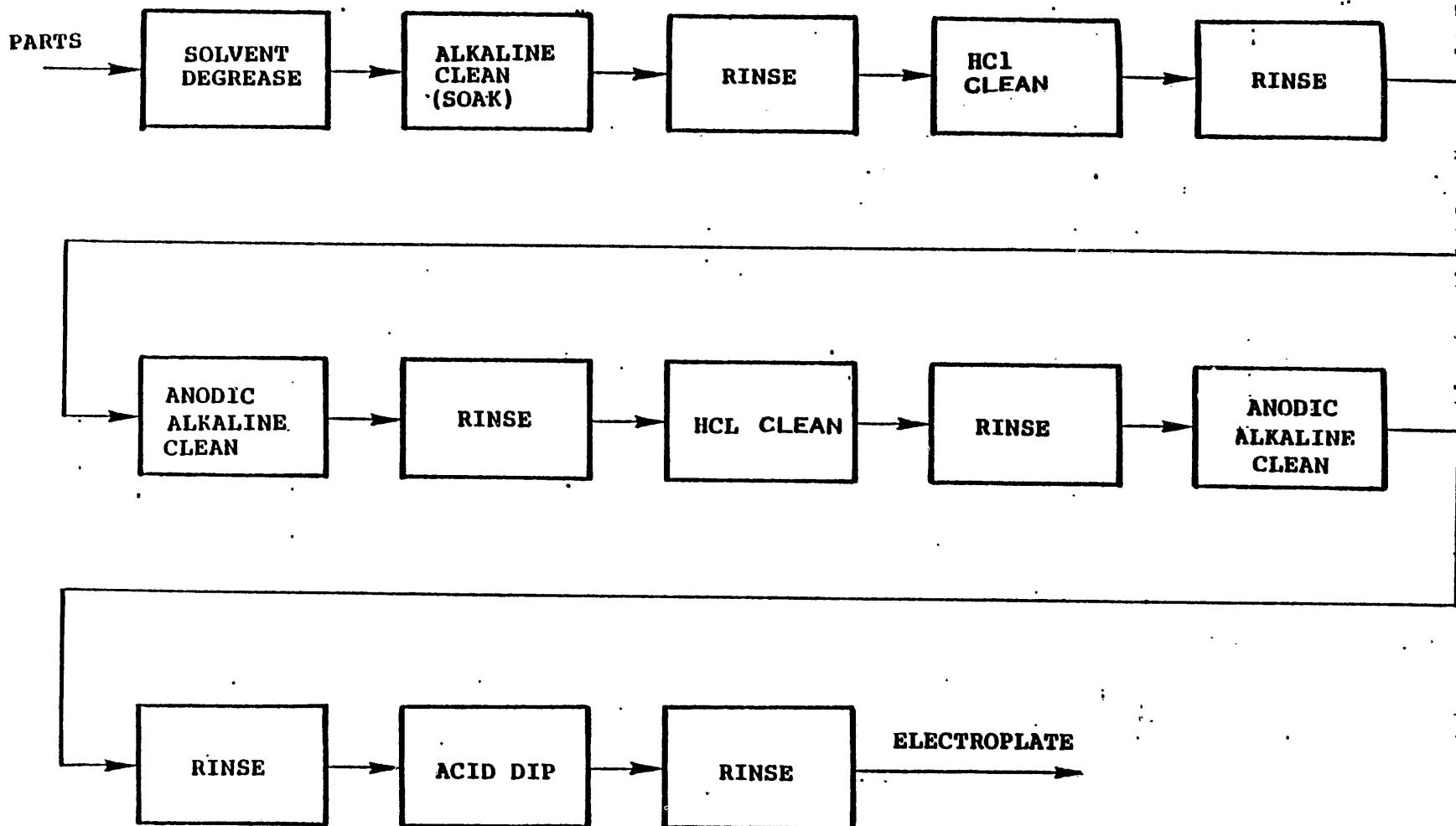


FIGURE 3-7 TYPICAL ELECTROPLATING PRETREATMENT
SEQUENCE

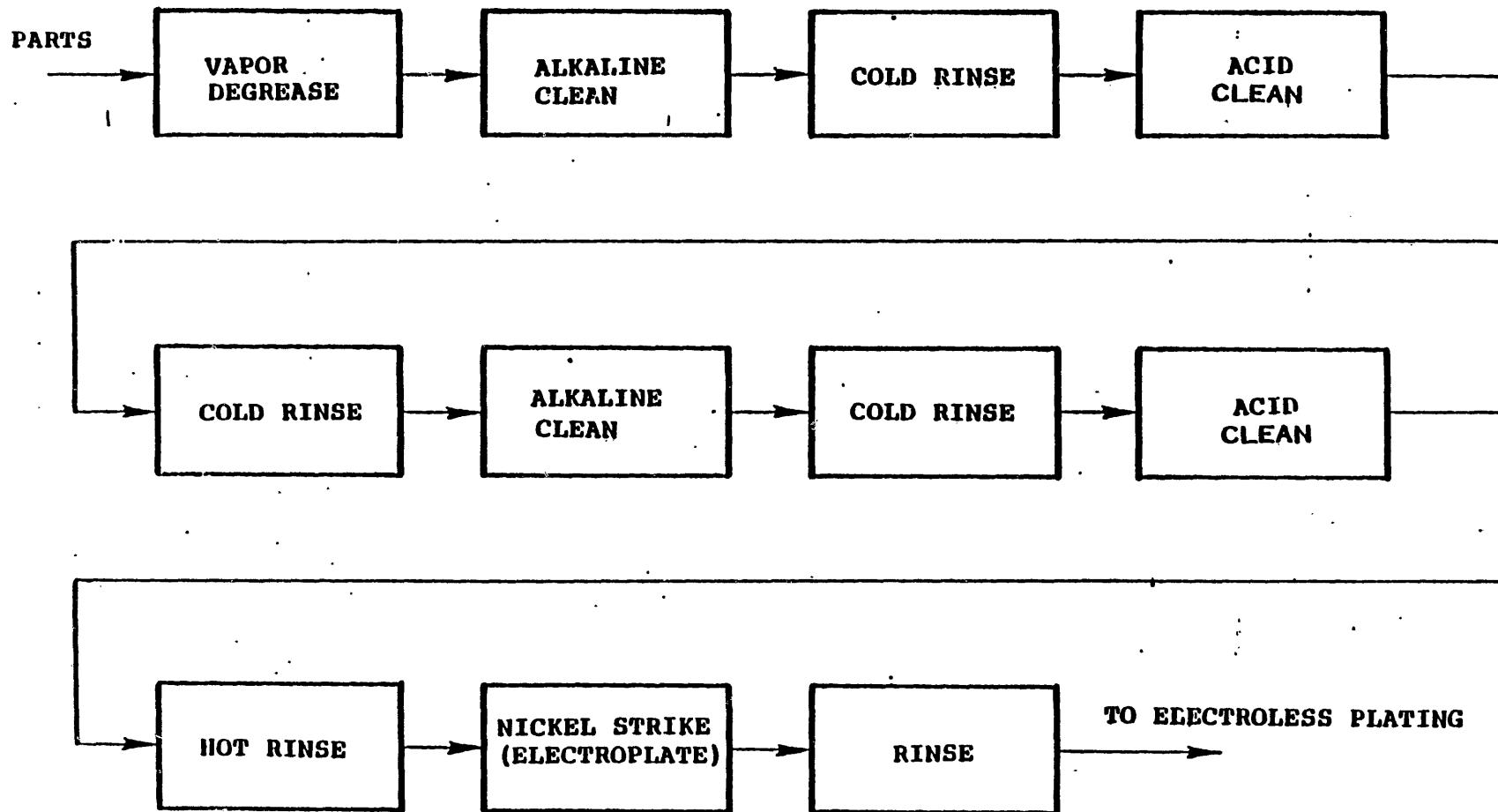


FIGURE 3-9 TYPICAL ELECTROLESS PLATING ON METALS-PRETREATMENT SEQUENCE

POLLUTANT PARAMETER OCCURENCE

Pollutant Parameter	SUBPART						
	Common Metals Plating	Precious Metals Plating	Electroless Plating	Anodizing	Coatings	Chemical Milling & Etching	Printed Circuit Boards
Copper	0.032-272.5		0.002-47.90			0.206-272.5	1.582-535.7
Nickel	0.019-2954		0.028-46.80				0.027-8.440
Chromium, Total	0.088-525.9			0.268-79.20	0.190-79.20	0.088-525.9	0.005-38.52
Chromium, Hexavalent	0.005-334.5			0.005-5.000	0.005-5.000	0.005-334.5	0.004-3.543
Zinc	0.112-252.0				0.138-200.0	0.112-200.0	
Cyanide, Total	0.005-150.0	0.005-9.970	0.005-12.00	0.005-78.00	0.005-126.0	0.005-126.0	0.002-5.333
Cyanide, Amenable	0.003-130.0	0.003-8.420	0.005-1.00	0.004-67.56	0.004-67.56	0.005-101.3	0.005-4.645
Fluoride	0.022-141.7		0.110-18.00			0.022-141.7	0.648-680.0
Cadmium	0.007-21.60						
Lead	0.663-25.39						0.044-9.701
Iron	0.410-1482				0.410-168.0	0.075-263.0	
Tin	0.060-103.4				0.102-6.569	0.068-103.4	
Phosphorus	0.020-144.0	0.020-144.0	0.030-109.0	0.176-33.00	0.060-53.30	0.060-144.0	0.075-33.80
Total Suspended Solids	.1-9970	.1-9970	.1-39.00	36.1-924.0	19.1-5275	.1-4340	1.0-408.7
Silver		0.050-176.4					0.036-0.202
Gold		0.013-24.89					0.007-0.190
Palladium		0.038-2.207					0.008-0.097
Platinum		0.112-6.457					
Rhodium*		0.034					

*Only 1 plant had a measurable level of this pollutant

CLARIFICATION-CONTINUOUS TREATMENT SETTLING TANK

Flow Rate (Liters/Hr)	37,850	75,700	157,708
Investment	\$71,363	\$91,575	\$130,102
Annual Costs:			
Capital Costs	4,552	5,842	8,301
Depreciation	14,273	18,315	26,020
Operation & Maintenance Costs (Excluding Energy & Power Costs)	2,506	2,565	3,851
Energy & Power Costs	36	72	150
Total Annual Cost	\$21,367	\$26,794	\$ 38,322

TABLE 8-7

CLARIFICATION-BATCH TREATMENT SETTLING TANK

Flow Rate (Liters/Hr)	1,893	3,785	18,925
Investment	\$25,551	\$28,529	\$38,032
Annual Costs:			
Capital Costs	1,630	1,820	2,427
Depreciation	5,110	5,706	7,606
Operation & Maintenance Costs (Excluding Energy & Power Costs)	2,334	2,341	2,394
Energy & Power Costs	41	81	811
Total Annual Cost	\$ 9,155	\$ 9,948	\$13,238

CHROMIUM REDUCTION - CONTINUOUS TREATMENT

Flow Rate (Liters/Hr)	3,785	7,570	18,925
Investment	\$20,416	\$21,538	\$24,003
Annual Costs:			
Capital Costs	1,303	1,374	1,531
Depreciation	4,083	4,308	4,801
Operation & Maintenance Costs (Excluding Energy & Power Costs)	1,086	1,375	2,089
Energy & Power Costs	256	256	256
Total Annual Cost	\$ 6,728	\$ 7,313	\$ 8,677

TABLE 8-9

CHROMIUM REDUCTION - BATCH TREATMENT

Flow Rate (liters/Hr)	189	379	1,893
Investment	\$8,493	\$9,535	\$14,405
Annual Costs:			
Capital Costs	541	608	919
Depreciation	1,699	1,907	2,881
Operation & Maintenance Costs (Excluding Energy & Power Costs)	155	295	1,415
Energy & Power Costs	256	256	256
Total Annual Cost	\$2,651	\$3,066	\$ 5,471

CYANIDE OXIDATION - CONTINUOUS TREATMENT

Flow Rate (Liters/Hr)	3,785	5,678	7,570
Investment	\$47,808	\$51,875	\$55,556
Annual Costs:			
Capital Costs	3,050	3,310	3,544
Depreciation	9,561	10,395	11,111
Operation & Maintenance Costs (Excluding Energy & Power Costs)	2,218	2,750	3,563
Energy & Power Costs	90	135	180
Total Annual Cost	\$14,920	\$16,570	\$18,098

TABLE 8-11

CYANIDE OXIDATION - BATCH TREATMENT

Flow Rate (Liters/Hr)	189	757	1,893
Investment	\$10,325	\$13,258	\$17,069
Annual Costs:			
Capital Costs	659	846	1,089
Depreciation	2,065	2,652	3,414
Operation & Maintenance Costs (Excluding Energy & Power Costs)	464	1,854	4,636
Energy & Power Costs	5	18	45
Total Annual Cost	\$ 3,192	\$ 5,370	\$ 9,184

THE WORLD BANK
OFFICE OF ENVIRONMENTAL AFFAIRS

FEBRUARY 1982

PLYWOOD MANUFACTURING

ENVIRONMENTAL GUIDELINES

1. Plywood consists of several layers of wood (or veneer) joined together by means of an adhesive. The material has many uses. It can be designed and engineered for both construction and decorative purposes, and in various shapes (flat, curved, or bent). Hardwood plywood is generally used for decorative purposes and has a facing layer of wood from deciduous or broad leaf trees. Softwood plywood is generally used for construction and structural purposes, with the facing layers being from coniferous or needle-bearing trees.

MANUFACTURING PROCESS

2. The operations required for converting logs into veneer and then into plywood are mainly mechanical. The process flow diagram for a typical veneer and plywood mill is presented in Figure 1.

3. Logs are delivered to the plant either with or without the bark, and cut to proper lengths. Where barking is required the bark is removed by any one of several wet or dry processes. The machines most commonly used include drum, ring, bag, hydraulic, and cutterhead barkers.

4. The most important operation in the process is the cutting of the veneer, since the appearance of a plywood panel is greatly dependent upon the manner in which the wood layers are prepared. Prior to cutting, the log is heated or "conditioned" to improve the cutting properties, particularly in the case of hardwoods. When conditioning occurs prior to debarking then bark removal is greatly facilitated. With the increasing use of ring and cutterhead barkers, whose operations are not aided by prior heating, the conditioning more commonly occurs between the barking and veneering operations.

5. Two basic methods are used to heat the logs: (a) directing steam onto the logs in a steam vat (or steam tunnel) or (b) heating the logs in a vat full of hot water, in turn heated either directly by live steam or indirectly by steam coils.

6. The cutting of veneers may be accomplished by (a) rotary cutting, (b) slicing, (c) stay log cutting, or (d) sawn veneering. Rotary cutting is the most widely used method at the present time. In this method a log or ("bolt") of wood is centered and turned on a lathe against a knife extending across the length of the unit. A thin sheet of veneer is peeled from the log as it turns. Log lengths will vary from about 0.6 to 2.4 m, although lengths of up to nearly 5 m are not uncommon. Rotary cut veneers generally vary from 1.3 to 3.6 mm in thickness.

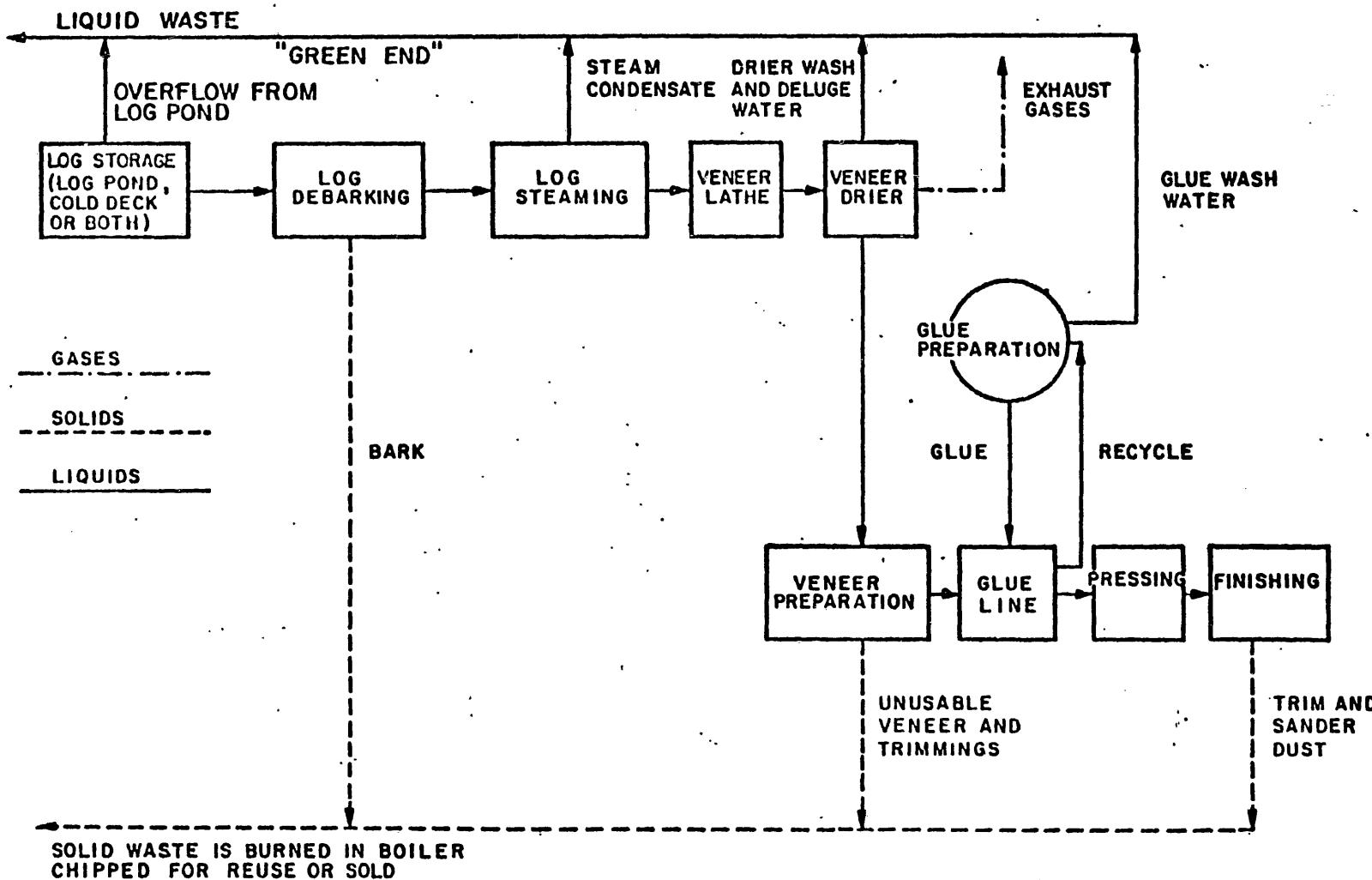


Figure 1 - Process Flow Diagram for Veneer and Plywood Production.
(From EPA Publication EPA-440/1-74-023-a)

7. Freshly cut veneers are usually dried to a moisture content of less than 10 percent since, if not dried, they would be unsuitable for glueing. In addition, the undried materials are also susceptible to attack by molds, bluestain and wood-destroying fungi. Several drying methods are in use, the most common being a long chamber, equipped with fans and heating coils, through which the sheets are transported under controlled temperatures and humidity conditions.

8. Following the drying operation the stock is prepared for glueing. Preparation includes grading and matching, redrying, dry-clipping, jointing, taping and slicing, and inspection. Except for jointing and splicing, which generally requires an adhesive, these steps are completely mechanical.

9. Adhesives may be divided into three principal categories:

- (a) Protein-contains various combinations of water, dried blood, soya flour, lime, sodium silicate, caustic soda, and formaldehyde.
- (b) Urea-formaldehyde resin-contains various combinations of water, defoamer, wheat flour, and
- (c) Phenol-formaldehyde-contains various combinations of water, furafil, wheat flour, phonolic formaldehyde resin, caustic soda, and soda ash.

10. The phenol-formaldehyde mixture is used almost exclusively for exterior applications, while the other two are used chiefly for interior applications. Current information indicates that urea-base glues are the most widely used.

11. Most plants mix their own glues. Application to the veneers is usually by means of power driven rollers which spread the adhesive on the sheets. More recently sprays and curtain-coaters have been coming into wider usage. After glueing, the sheets are subjected to pressure of up to 17 or 18 atmospheres, to insure proper alignment and full contact between the glue and wood layers.

12. Following the pressing, a series of finishing steps are applied, depending upon the plant and the final product desired. Such steps include (a) redrying, (b) trimming, (c) sanding, (d) coating, (e) sorting, (f) molding, and (g) storing.

WASTE SOURCES AND CHARACTERISTICS

13. Veneer and plywood production operations will produce wastes of a gaseous, liquid, and solid nature.

Gaseous Emissions

14. Formaldehyde is the principal component of concern in the glues which are most widely used today. There is little free formaldehyde in the resin mixtures. The high cure temperatures used will generally volatilize any residual free formaldehyde.

15. Volatile organic compounds may be emitted by evaporation of organic solvents used in conventional coatings currently applied. Coatings are used primarily at hardwood plywood plants but, in most cases, only a small percentage of the total production is coated.

Liquid Effluents

16. The parameters of major significance in the production of veneers and plywood are 5-day biochemical oxygen demand (BOD_5) and total suspended solids (TSS). Other pollutants may be present but are considered to be of minor significance. The processing method, raw materials used, and the chemicals added are the principal considerations in identifying the important parameters.

17. In the log barking operation BOD_5 and TSS are both of concern. The TSS concentrations from drum barkers are slightly higher than for hydraulic barkers, but the BOD_5 values are significantly higher in the drum barker. The higher values are due to the longer contact time between the bark and the water, as well as because of the grinding action which occurs in the water. BOD_5 values are also affected by the species of wood barked and by the time of the year in which the log is cut. Drum barking waters are often recycled. The ranges of BOD_5 and TSS values in log barking waters are as follows:

	<u>BOD_5 (mg/l)</u>	<u>TSS (mg/l)</u>
Hydraulic	56-250	520-2360
Drum	48-990	2020-2880

18. As previously stated, log conditioning is accomplished either by steam vats (or tunnel systems) or by hot water vats. The only waste water from the steam vats is the steam condensate, which carries with it leachates from the logs and wood particles. The magnitude of flows will vary with the number and size of the vats. Typical values for wastewaters from steam vats are as follows:

Waste Volume:	1.6-3.1 L/sec. 1/
BOD_5 :	470-3100 mg/L
TSS:	74-2940 mg/L
pH:	4-6 Units

1/ For a plant with annual production of 9.31 million Sq. M. Plywood, 9.53 mm thick.

19. Hot water vats, because of the method of heating (steam, heating coils, etc) do not have a constant discharge, and are generally emptied only periodically. The water and solids that build up in the closed system are replaced with clean water. In many cases the wastewater is settled and then recycled back into the vats. The characteristics of these waters vary widely, as indicated by the following typical analysis:

BOD ₅ :	330-4700mg/L
TSS :	70-2500 mg/L
pH :	4.4-6.9 Units

20. Veneer dryers accumulate wood particles, which are removed either by flushing with water or blowing out with air. Volatile hydrocarbons will also condense on the surface of the dryers to form an organic deposit called "pitch". It is necessary to remove these deposits periodically, in order to avoid excessive buildup. A high pH detergent is applied to dissolve most of the pitch, followed by a water rinse. The nature and volume of the dryer wash waters depend upon the amount of water used, the amount of any scraping prior to application of the detergent and the rinse, condition and operating patterns of the dryer, and the species of wood being dried.

21. The water released by the veneer in the drying process is converted to steam and vented to the atmosphere. The liquid discharge from the dryer includes spent wash water and the water from the deluge system when that system is used to extinguish fires that sometimes start inside the unit. Some plants take advantage of fires to clean the dryers. Water is also used occasionally to flood the bottom of the units in order (according to some claims) to lessen the incidence of fires and reduce air pollution problems. For veneer dryer washing purposes a typical plant will discharge about 17.5 liters per metric ton of production. Dryers are generally washed once in every 80 hours of operation.

22. Many plants recycle all wash, fire, and flood waters from the dryers because the operation causes substantial evaporation of water. Thus, fresh water can be used to clean the dryers and still operate as a closed system.

23. Waste water in the glue operation originates from washing of the mixers, glue hold tanks and the glue spreaders. Discharge from the glue washing operations averages about 45 liters per metric ton of product.

24. A typical combined veneer and plywood mill requires a certain amount of cooling water to dissipate heat from the air compressors, as well as the lathes and presses. This is normally "pass-through" water and does not require any special handling before discharge to the environment. The discharge should be monitored, however, to assure that temperatures do not reach unacceptable levels.

Solid Wastes

25. Solid wastes generated in the production process include (a) bark, (b) wood particles from the veneer dryers, (c) organic "pitch" from cleaning of the veneer driers, (d) wood trimmings from cutting veneers and plywood sheets to size and (e) wood dust from the sanding and finishing operations. It is difficult to quantify these materials since they are dependent on the practices and products at each particular plant.

EFFLUENT LIMITATIONS

Gaseous Emissions

26. Gaseous emissions are not considered significant in plywood plants, except where coatings are applied as part of the production process. Volatile organic compounds are discharged from the coating lines. The nature of these emissions depends upon the organic solvent used. These are normally multicomponent mixtures which may contain various combinations of methyl ethyl ketone, methyl isobutyl ketone, toluene, xylene, butyle acetates, propanol, and others.

27. Emissions levels of volatile organic compounds (VOC) should be kept at or below the following concentrations:

Printed interior wall panels of hardwood plywood	2.9 kg VOC per 100 m ² coated surface
Natural finish hardwood plywood panels	5.8 kg VOC per 100 m ² coated surface

Liquid Effluents

28. Liquid effluent limitations are presented in Table 1. These limits are considered achievable on the basis of best practicable technology currently available.

CONTROL AND TREATMENT OF WASTES

Gaseous Emissions

29. Measures for reduction of volatile organic compounds from coating operations includes the use of low solvent, ultra-violet curable coatings; use of waterborne coatings; and incineration.

Table 1. Effluent Limitations for Plywood Manufacturing Plants.

Waste Source	BOD ₅ - kg/m ³ ^{1/}		TSS - kg/m ³ ^{1/}	
	30-day Av.	Max. Daily	30-day Av.	Max. Daily
Barking Except Hydraulic	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>
Barking - Hydraulic	0.5	1.5	2.3	6.9
Log Conditioning - Except Direct Steam	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>
Log Conditioning - Direct Steam				
Softwood	0.24	0.72	0	0
Hardwood	0.54	1.62	0	0
Glueing Operations	<u>2/</u>	<u>2/</u>	<u>2/</u>	<u>2/</u>

1/ Kg/m³ = Kilograms per cubic meter of wood barked or of veneer produced from conditioned logs.

2/ Zero discharge.

30. Ultraviolet curable coatings, where applicable, effect a nearly complete reduction of VOC emissions. In the flat wood industry, UV coatings have found use as clear to semitransparent fillers and top coatings for interior printed panelling and cabinet-making products. The advantages of UV coatings include reduced power requirements, space savings through reduced storage and oven size, very little VOC emission, and essentially 100 percent utilization of the coating mixture. Safety precautions must be taken to minimize personnel exposure to UV radiation and to avoid contact with the coating, since some of the raw materials can cause chemical burns.

31. The use of waterborne coatings can achieve anywhere from 70 to 90 percent reduction of emissions. This is currently the principal measure being followed by the flat-wood industry. The primary use of these coatings is in the filler and base coat applied to printed interior panelling. Waterborne coatings can reduce fire hazards, fire insurance costs, and air pollution. Problems with these coatings include possible grain raining, wood swelling, poor quality finish, and longer cure times.

32. The use of control devices such as direct-flame and catalytic incinerators is very limited in this industry. Few data are available on control efficiency or fuel requirements.

Liquid Effluents

33. Where debarking is by a dry process, the bark chips are shredded and burned as fuel. For wet drum and bag barkers, the chips are pressed to remove the water and sent to the boiler for use as fuel. The water can be recycled.

34. Bark from the hydraulic type of unit is separated, pressed to remove the water, and used as boiler fuel. The amount of water resulting from the process is more than can be used in other plant unit operations, and hence must be otherwise handled. Treatment follows the practices widely utilized in the pulp industry, i.e. the use of circular heavy-duty type clarifiers or thickeners. The clarifier effluent is dewatered, by vacuum filters or other means, and then subjected to biological treatment which is normally 85 to 95 percent effective. The filter cake, containing up to 30 percent moisture, is disposed of on land or sold for use as a mulch.

35. The major effort in the veneer production segment of this industry has been directed towards reducing waste water volumes by reuse and conservation, and by containment of those waste waters that cannot be reused. Waste water from log conditioning is probably the largest and most difficult source to handle in a veneer mill.

36. Hot water vats, when heated indirectly through coils, will not have a continuous discharge. Any discharge results from spillage when logs are placed into or taken out of the units. The wastewater from these operations can be clarified by settling in tanks or ponds and then reused for makeup. The resulting sludge is transferred to a landfill. Some decreased pH in the vats may occur over time. If this happens, lime or sodium hydroxide should be added for corrosion control.

37. Wastewater from steam vats must be discharged because of the difficulty of reusing the contaminated condensate. In some instances modification can be made to allow conversion of steam vats to hot water spray tunnels which then function in a manner similar to hot water vats.

38. Either the use of hot water sprays or the use of modified steaming would allow mills that use steam vats to operate in a manner similar to those that use hot water vats (in which there is no steam impingement). All of these are closed systems, requiring only solids removal and periodic "flush-outs". The relatively small volume of water produced from the "flush-outs" can be contained in evaporation ponds or used for irrigation.

39. In cases where effluents from either hot water or steam vats must be treated then biological methods, such as ordinary or aerated lagoons, have been both practicable and effective. It has been reported that BOD₅ reductions of 85 to 90 percent are readily achievable.

40. Waste discharges from cleaning of veneer dryers can be reduced through various modifications in the procedure. One mill reports a significant reduction by manually scraping the dryer and blowing it out with air prior to the application of water. Installation of water meters or valved hoses promotes water conservation and results in significant reductions. The volume of wastes from this source is small enough to be handled by containment or by use for irrigation or similar purposes.

41. Technology is currently available to eliminate the discharge of all wastes from the glueing operations. Recycling systems are accepted technology in the industry, and are applicable for protein, urea, and phenol types of glues. However, mills that use several types of glues must have individual recycle systems to separate the different wash waters, since attempts at mixing the wastewater from different types of glues have not been successful. Various inplant operational and equipment modifications can reduce the volume of glue wash water.

42. In addition to recycling the plant may also contain and/or evaporate the glue washwater, spray the liquid on the bark that goes into the boiler as fuel, or use a combination of these techniques.

Solid Wastes

43. Along with the bark chips previously mentioned, solid wastes also include veneer dryer scrapings, unusable veneer and trimmings, and trim and sander dusts from the finishing operations. These wastes may be burned for fuel, dumped on land, or sold for other uses elsewhere.

BIBLIOGRAPHY

1. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Plywood, Hardwood, and Wood Preserving Segment of the Timber Products Point Source Category". Doc. EPA-440/1-74-023-a. Washington, (April 1974).
2. U.S. Environmental Protection Agency. "Guidance for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds". Doc. EPA-450/3-79-024. Washington (April 1979).
3. Nestler, F.H. and Max Nestler. "The Formaldehyde Problem in Wood-Based Products-An Annotated Bibliography". U.S. Forest Service General Technical Report FPL-8. Washington (1977).
4. Blomquist, R.F., "Formaldehyde Emissions Are No Problem With Wood Products Bonded With Phenolic Resins". American Plywood Association, Tacoma, Washington 98411. (August 6, 1981).
5. Baker, William A., Ed. "Technical Literature Index". American Plywood Association, Tacoma, Washington 98411. (September 1980).

OFFICE OF ENVIRONMENTAL AFFAIRSPOULTRY PROCESSING PLANTSINDUSTRIAL WASTE DISPOSAL

1. Poultry processing operations cover young and mature chickens, turkeys, ducks, geese, various other birds, and small game such as rabbits. The final product may consist of whole carcasses, parts, cooked or canned meats, and specialties such as rolls and patties. Plants may produce one or a combination of several of these items.

INDUSTRIAL PROCESSES

2. Live birds are taken to processing plants in coops, which are first transferred to the hanging area. The birds are removed from the coops and suspended by the feet from an overhead conveyor line. This is followed by slaughtering, most commonly done by severing the jugular vein or by debraining. The dead bird then travels through an enclosed area, known as the "blood tunnel", for draining and recovery of free-flowing blood. Recovery may be either from the floor of the tunnel or from troughs installed for the purpose.

3. After the blood tunnel the birds are scalded and mechanically defeathered. Remaining pin feathers are next removed, either by hand or by wax stripping. The defeathered carcass goes to the evisceration room, where the feet are cut off, the peritoneal cavity opened, and the viscera removed. The visceral parts are separated into edible and non-edible portions. The non-edible portions are added to the offal disposal system. Next, the head and neck are removed, the carcass thoroughly washed and then inspected. The final step is chilling or freezing, and packing either for marketing or for further processing.

4. Additional processing can involve thawing, cutting and boning, dicing, grinding and chopping, batter and breading, mixing and blending, stuffing, canning, final product preparation, packaging and shipping in various combinations.

5. Product flows for basic and further processing plants are shown in Figures 1 and 2, respectively.

SOURCES AND CHARACTER OF WASTES

6. Liquid wastes carrying varying amounts of solids are the major concern in this industry. Solid wastes, resulting mainly from housekeeping and screening of effluents may also be of concern but this will depend upon in-plant practices and degree of solids separation. Gaseous wastes are generally of no significance. The purely hazardous types of waste components, such as heavy metals and pesticides are not normally found in the effluents.

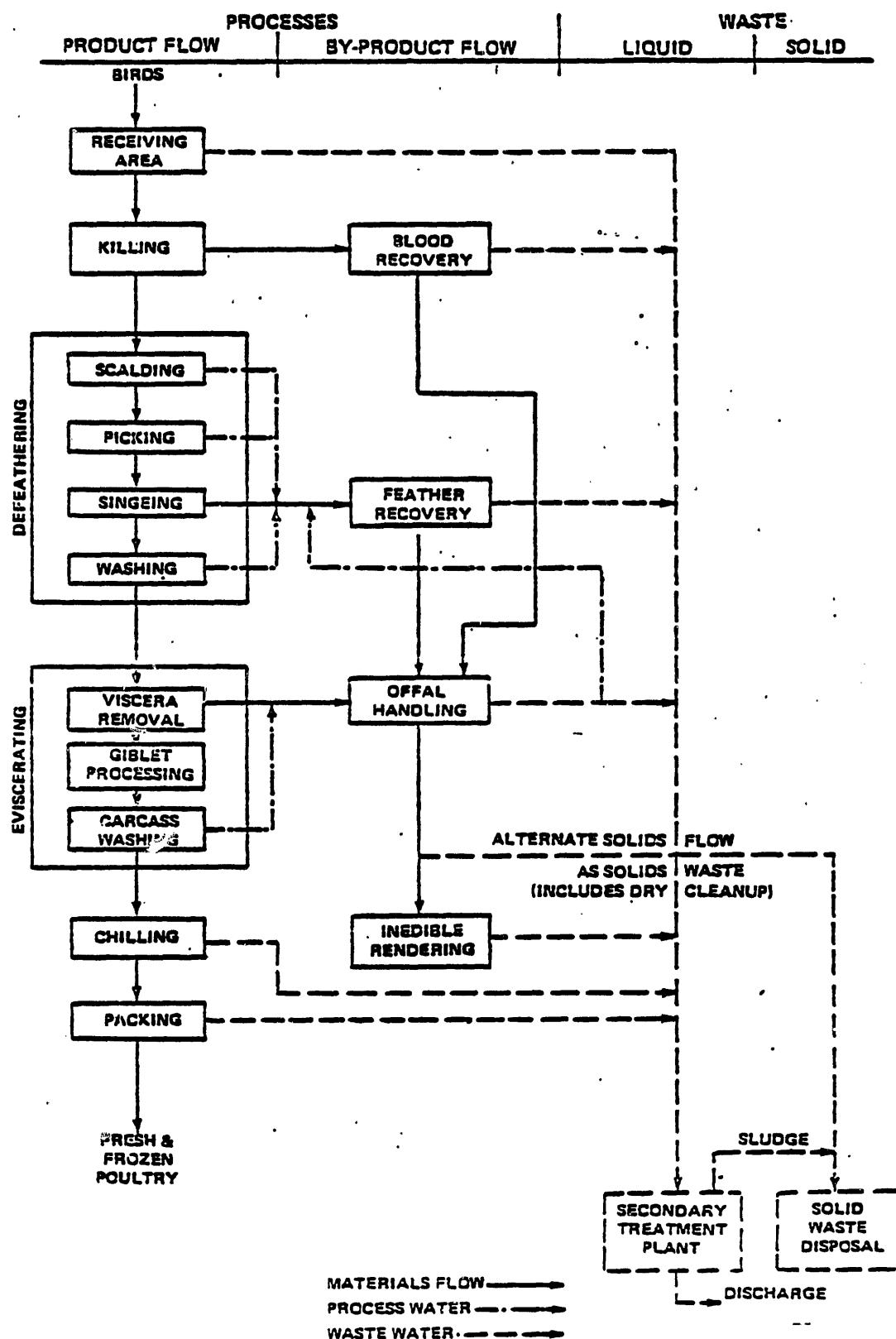


Figure 1 - Typical Process Flow and Waste Sources for Poultry Processing Plants.
(From Ref. 2)

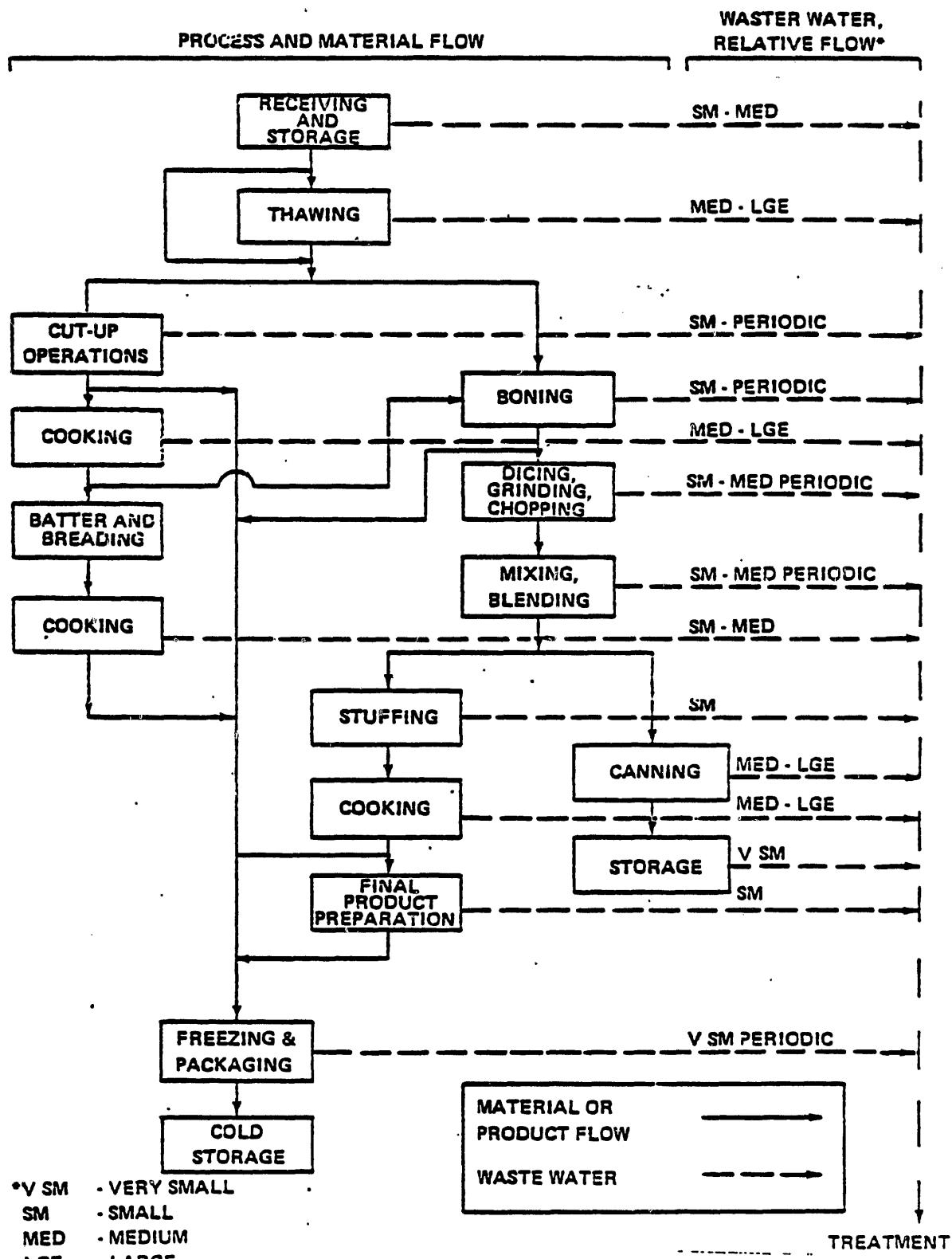


Figure 2. Typical Process Flow and Waste Sources for Further Processing Poultry Plant. (From Ref. 2)

7. The most significant parameters applicable to the liquid effluents are the 5-day biochemical oxygen demand (BOD_5), total suspend solids (TSS), oils and greases (O + G), hydrogen-ion concentration (pH), and fecal coliform organisms. Ammonia levels may occasionally be of concern.

8. All of the steps in the poultry plant processing contribute to the waste loadings. These contributions include blood, offal, feathers, meat and fatty tissues, materials lost in processing, preservatives and caustic or alkaline detergents. In most plants, raw wastes are subjected to "primary" treatment by discharge through catch basins, skimming tanks, air flotation systems, or other devices. The basic purpose of this procedure is not waste treatment per se, but the recovery of by-products which can be profitably separated and marketed.

9. The strongest single pollutant is blood, generated in the killing area. Feathers, dirt and manure will also be added at this point. Those materials not removed by drains or dry scraping are flushed to the sewer during cleaning. Overflows from the scalding and defeathering operations will also contribute these same materials.

10. The evisceration process and subsequent washing generate a large volume of waste water. The carcass and giblet washing, worker hand washers, side-pan washers and viscera flow-away water, and clean up operations, all contribute to this flow. Waste waters from the evisceration procedures will contain tissue and fat solids, gut, grease, blood and intestinal bacteria.

11. Another waste source is the carcass and gizzard chilling operation. This is made up of chiller overflows, dumping of chiller water at the end of each day, and equipment clean-up. The chiller wastes contain greases, meat and fat particles and blood.

12. Feathers and offal are discharged to flumes and recovered by screening. The flume water and the water retained by these materials and draining through the equipment eventually become a part of the total plant effluent.

13. The operations designated as "further" processing use waters to thaw frozen materials, to cook the poultry and finished products, to cool the freshly cooked products, and to clean the equipment. The birds and products come into direct contact in some of these processes and thus contribute waste components.

14. Some plants have on-site rendering facilities to produce feed grade materials from the feathers, offal, blood and other by-products. Generally, however, these by-products are taken off-site for rendering purposes. Rendering operations are discussed in greater detail in the guideline titled "Meat Processing and Rendering Industry".

15. Waste water effluent streams for typical poultry processing plants are shown in Figures 1 and 2. Typical raw waste flows and characteristics are shown in Table 1. These data are for effluents following the application of in-plant "primary" treatment for by-product recovery.

Table 1. Typical Raw Waste Flows and Characteristics for Poultry Industry Plants a/

Type of Plant	Av. Live Weight (kg)	Flow (Liters)	BOD ₅ (kg)	TSS (kg)	O + G <u>b/</u> (kg)
Per Bird			Per Mg Live Weight Killed		
Chickens	1.74	34	9.9	6.9	4.2
Turkeys	8.3	118	4.9	3.2	0.89
Fowl	2.3	49	15.	10.	2.3
Ducks	2.9	75	7.1	4.4	1.9
Per megagram Final Product*					
Further Processing <u>c/</u>	-	12,500	19	9.1	6.4

a/ Following application of in-plant "primary" treatment.

b/ O + G = Oils and Greases

c/ No slaughtering

* 1 megagram = 1 metric ton, Mg = megagram

EFFLUENT LIMITATIONS

16. Effluent limitations for plants which slaughter and process poultry products are presented in Table 2. The limitations are based on the best practicable control technology currently available. Where further processing or on-site rendering is carried out, it is necessary to add an adjustment, according to the factors shown in paragraph 17.

17. Adjustments to these limitations are to be made in cases where further processing or rendering (or both) may be carried out in conjunction with other operations. These adjustments are to be added to the limits shown and are as follows:

Further Processing:

BOD₅: 0.30 X $\frac{\text{MgFP}}{\text{MgLWK}}$

TSS: 0.35 X $\frac{\text{MgFP}}{\text{MgLWK}}$

O + G: 0.10 X $\frac{\text{MgFP}}{\text{MgLWK}}$

By-Product Rendering:

BOD₅ 0.15 X $\frac{\text{MgRM}}{\text{MgLWK}}$

TSS: 0.17 X $\frac{\text{MgRM}}{\text{MgLWK}}$

O + G 0.10 X $\frac{\text{MgRM}}{\text{MgLWK}}$

In computing the above adjustments, terms denote:
 Mg = Megagram
 FP = Final Product
 LWK = Live Weight Killed.
 RM = Raw Materials Rendered

Table 2. Maximum Daily Effluent Limitations - Poultry Industry Wastes.

Type of Plant <u>a/</u> & <u>b/</u>	BOD ₅ (kg)	TSS (kg)	Oils & Greases (kg)
Per Mg Live Weight Killed			
Chickens	0.46	0.62	0.20
Turkeys	0.39	0.57	0.14
Fowl	0.61	0.72	0.15
Ducks	0.77	0.90	0.26
Per megagram Final Product			
Further Processing <u>b/</u>	0.30	0.35	0.10

a/ For all plants: Fecal coliform MPN not over 400/100ml and pH = 6 to 9.

b/ For off-site processing. See above for adjustments when further processing and rendering are carried out at the same site as other operations.

CONTROL AND TREATMENT OF WASTES

18. Waste loads discharged by the poultry industry may be reduced to acceptable levels through a combination of techniques including efficient water management, in-plant waste controls, process control, and varying degrees of biological treatment. Wastes may also be released to municipal systems provided that pretreatment measures are applied.

19. In-plant measures include (a) monitoring flows and waste strengths in all major water use areas; (b) control and reduction of water flows at major outlets through use of properly sized nozzles and pressure regulation; (c) confining bleeding procedures and recovering all possible collectable blood for rendering; (d) shutting off unnecessary water flows during work breaks; (e) reusing water for makeup purposes whenever possible; (f) applying dry offal handling in place of fluming; (g) close monitoring of screening and handling systems for offal and feathers to prevent discharge of these materials; (h) using dry cleanup prior to washdown of all floors and tables; and (i) training all employees in applying good water management practices.

20. By-product recovery of offal and feathers, when fluming is utilized, is accomplished by the use of screens. These may be rotary, vibrating or static types. Vibrating and rotary screens are most frequently used in the poultry industry. They can be useful not only for materials recovery but also for providing at least primary treatment for all plant wastes when screening openings are sufficiently fine. Grease and solids may also be removed by the use of catch basins or air flotation systems.

21. Several biological systems may be used for treatment of these wastes, following the application of in-plant primary treatment. Anaerobic processes, aerobic lagoons, and activated sludge systems are commonly used. The system used must be adapted to the individual plant on the basis of waste water volume, waste loads, equipment used, required waste load reduction, sludge disposal, odor problems and other factors.

22. Where a maximum degree of treatment is required, chemical precipitation, sand filters, and microstrainers have been effective. A no discharge condition can be achieved through the use of spray or flood irrigation where sufficient areas of relatively flat land are available.

BIBLIOGRAPHY

1. Jones, Harold R. "Pollution Control in Meat, Poultry, and Seafood Processing". Noyes Data Corporation. Park Ridge, N.J. and London (1974).
2. U.S. Environmental Protection Agency "Development Document for Proposed Effluent Limitations Guidelines and New Source Performance Standards for the Poultry Segment of the Meat Product and Rendering Process Point Source Category". Doc. EPA-440/l-75/031-6, Group I, Phase II. Washington (April 1975).
3. U.S. Environmental Protection Agency "Upgrading Poultry Processing Facilities to Reduce Pollution". EPA Technology Transfer Seminar Publications. 3 Vols. Washington (July 1973).

THE WORLD BANK

JANUARY 1981

OFFICE OF ENVIRONMENTAL AFFAIRS

PULP AND PAPER INDUSTRY

EFFLUENT GUIDELINES

1. Paper is produced from raw materials containing cellulose fibers, which is the basic required component. While the greatest portion of the fibers are produced from wood, some are produced from recycled paper and from non-wood sources.
2. Several methods are used for pulping wood. In some processes it is cooked with chemicals under controlled conditions of temperature, pressure, time and liquor composition, with different chemicals and combinations of chemicals being utilized. In other methods wood is reduced to a fibrous state by mechanical or by a combination of mechanical and chemical means.
3. To prepare the paper stock the pulp is resuspended in water, followed by refiners to refine the individual fibers into the state required to produce the strength needed in the paper product. The degree of fiber refining is governed by the type of pulp and the end paper product desired.

MANUFACTURING PROCESSES

4. Wood may be received at the pulp mill in any one of several different forms, including logs, chips, sawdust and other sawmill residues.

Wood Preparation

5. In the case of logs the bark is first removed, and this may be done either by friction with other logs (in barking drums), by mechanical tools, or by water jets (hydraulic debarking). The barking drums may be operated either with or without water, but better debarking is achieved and wood losses are lower when water is used. The clean logs are then chipped to produce wood fragments of suitable size (about 30 x 30 x 4 mm). The chips are screened to separate those which are either too small or too large, and transferred to storage bins or chip piles for later use.

6. Fibers constitute the basic raw material in the manufacture of paper. These are composed mainly of cellulose, and may be derived from either wood or non-wood sources. The fibers represent some 50 percent of the dry weight of the fiber source, with the other major components consisting of hemi-celluloses and lignins. The last two substances serve to cement the fibers together. Fibers are separated from the wood by means of the pulping operations, using mechanical pulping, chemical pulping, or a combination of both. On a world-wide basis, approximately one-third of the paper production is from mechanical pulps and two-thirds is from chemical pulps.

7. World-wide it is estimated that 5 percent of new pulp comes from non-wood fibrous materials. Non-wood materials used for pulp, papers and paper board production include agricultural residues (bagasse, cereals), natural plants (such as bamboo and esparto grass) and cultivated fiber crops (such as jute, flax, sisal and cotton fibers). The most widely used of these are wheat straw, rice straw, bamboo and bagasse. The processes used for producing non-wood materials are generally similar to those used in the wood-based segments of the industry.

Pulp Preparation

8. Mechanical pulp is also known as groundwood pulp, since mechanical action, in the form of large rotating grindstones, is used to process the whole logs. The type of wood most readily or economically available usually determines the groundwood process to be applied. Softwood generally does not require pretreatment and has therefore been the usual raw material for the stone groundwood process, as well as for some of the other processes. The high energy requirements for grinding untreated hardwood may be offset by using processes which incorporate pretreatment. Sawmill residues are also a source of raw materials for processes which utilize wood chips.

9. The principal mechanical pulping processes include stone groundwood, refiner groundwood, thermo-mechanical, cold soda, and chemical groundwood. The process selected is based on the raw material supplied, type of fiber desired, and strength of paper needed for specific uses.

10. In chemical pulping wood, the raw material is cooked in batch or continuous digesters (large pressure vessels) with solutions of various chemicals. Digestion (or cooking) proceeds to the point at which non-cellulosic constituents are dissolved and the fibers can be liberated by "blowing" (i.e. ejecting the chips) from the digester.

11. The principal chemical methods include acid sulfite, kraft and soda. Softwoods are the primary raw materials of the sulfite process, while both soft and hardwoods are used in kraft and soda pulping.

12. While the mechanical pulps have many desirable qualities for the manufacture of low cost paper (where opacity is important), they normally do not have sufficient brightness for the better grades. Brightness will also vary with the characteristics of the wood raw material. Bleaching is therefore necessary to satisfy the demands of better end paper products where mechanical pulps are used for their production.

Pulp Bleaching

13. The most common bleaching agents for stone and refiner groundwoods are hydro-sulfites and peroxides, used either individually or in sequence. Zinc hydrosulfite, sodium and potassium borohydride, hydrogen peroxide and sodium peroxide are the specific chemicals particularly used. The same chemicals may also be used for cold soda and chemi-groundwood pulps.

14. For chemical pulps the most frequently employed bleaching chemicals are chlorine, calcium or sodium hypochlorite, and chlorine dioxide. Alkalies such as caustic soda and calcium hydroxide are used to extract chlorinated reaction products.

15. Oxygen bleaching of chemical pulps is a new process developed in recent years, and is currently used in a limited number of mills world-wide. It is said to achieve a brightness and strength equivalent to that obtained by more costly methods. It has also been reported as being less susceptible to brightness reversion.

16. Displacement bleaching, barely beyond the pilot plant stage, has recently been installed in two U.S. plants. In this process, chemicals are displaced through a pulp mat rather than being conventionally mixed into the pulp. Very rapid bleaching occurs, due to high reaction rates.

17. A variety of waste papers are deinked to produce a variety of pulps. Before waste paper can be used for this purpose it must be carefully classified into different groups, only some of which can be deinked, since (a) not all waste papers are suitable for deinking and (b) specific types of waste papers are suitable only for specific types of reclaimed pulps.

18. Where the pulp is to be used away from the production site it is dried for market purposes. The pulp is reduced to a thick mat, on either a Fourdrinier machine or a cylinder mold, subjected to mechanical pressure in a series of presses, and then dried to air-dry consistency (about 10% moisture content). Wet market pulp, with a moisture content of 50 percent is also produced in some cases. The process is the same as that for the dry pulp, except that the final drying step is omitted.

19. Unbleached kraft and neutral sulfite semi-chemical (NSSC) pulps are also produced in some plants. The unbleached pulps are mainly used for liner-board (used as the smooth-surface facing in corrugated board), wrapping paper, grocery bags, and shipping sacks. Semi-chemical pulps are used mostly as the corrugating medium in corrugated board.

20. The paper mill may be close to or at a distance from the pulp mill. An integrated paper mill is one that is located near a pulp mill, and the pulp is transferred as a slurry directly to the paper-making process. The non-integrated mill is usually located at some distance from the pulp mill and receives the pulp in a dry or semi-dry form. The paper stock is prepared by resuspending the dry or semi-dry pulp in water to a consistency of 4 to 6 percent.

Stock Preparation

21. The stock is mechanically treated in the refiners to "brush" or cut the individual fibers. This step produces the properties needed to give the required strength to the paper. In cases where good formation is desired,

such as for fine papers, the stock is also pumped through a jordan, which further cuts the fibers to the necessary length with a minimum of brushing. The amount of cutting and brushing varies with the type of pulp used and the requirements of the end paper product.

22. Chemical additives may be used for various purposes, either before or after stock preparation. For example, resin is used for sizing, which prevents blotting of ink. Clay, calcium carbonate, and titanium oxide are some of the substances added as fillers where opacity and brightness of the papers are important. A wide variety of other additives such as wet strength resins, dyestuffs, and starches may be used, depending on end-use requirements.

Paper Production

23. The final paper or board product is formed on either a Fourdrinier, a cylinder machine, or a twin-wire machine. The Fourdrinier has a flat sheet-forming surface while the cylinder machine utilizes a cylindrical-shaped mold. The Fourdrinier is most widely used at the present time.

24. In the Fourdrinier operation the dilute pulp flows onto a wire screen, on which the water drains off and the sheet is formed. A suction pick-up roll transfers the sheet from the wire to presses, which enhances the density and smoothness and removes additional water. It then passes through a series of heated hollow metal cylinders for final drying.

25. In the cylinder operation, revolving wire-mesh cylinders rotate in one or more vats of dilute pulp, picking up fibers and depositing them on a moving belt. The pressing and drying procedures are the same as for the Fourdrinier operation. The cylinder machine has the capability of producing heavier multi-layered sheets, and therefore its principal use is in the manufacture of paperboard.

26. In the twin-wire operation the paper stock passes between two wire webs. Water drains simultaneously from each side of the stock, resulting in formation of the sheet.

WASTE SOURCES AND CHARACTERISTICS

27. Pulp and paper production affects the environment in several ways, since gaseous, liquid, and solid wastes are produced from various parts of the operations. The greatest environmental impact comes from the bleaching and pulping of chemical pulp. Mechanical pulping operations usually have less impact on the environment. The environmental impacts can be greatly reduced by recycling and reusing most of the process waters and many of the chemicals back into the process.

Air Emissions

28. The principal emissions of concern at kraft pulp mills are sulfur dioxide, total reduced sulfur (TRS) compounds and particulate matter. Hydrogen

sulfide, methyl mercaptans, dimethyl sulfide, and dimethyl disulfide as a group constitute the TRS compounds. The most noticeable characteristics of the TRS group is its highly odorous nature.

29. The TRS group originates mainly in the sulfate cooking process -- generally in the digester systems, the brown stock washers, the multiple effect evaporators, the black liquor oxidation systems, the recovery furnace, the smelt-dissolving tank, the lime kiln, and the condensate stripper systems. Sulfur dioxide originates from the sulfite process as well as from the neutral sulfite and bisulfite processes. Some sulfur dioxide is formed in the recovery boiler of the sulfate process, as well as from burning coal or fuel oil in the power plant. Principal sources are the recovery furnace, lime kiln, smelt dissolving tanks, and the power plant. Principal sources of the particulate matter are the recovery furnaces, the smelt dissolving tank, and the lime kiln. Fly ash particles consist mainly of carbonates and sulfates.

30. Chlorine emissions can occur, but are mostly of the "diffuse" type. This means that they are not located at any particular point source, but originate as fumes from tank vents, wash filters, sewers, and other similar sources. The gases are mainly chlorine or chlorine dioxide. Generally concentrations are not significant, but provisions should be made for detecting and handling lethal concentrations, should they develop. Hydrogen sulfide can collect in the stock chests. Good ventilation should be provided; work operations at that location should be carried out by at least two persons together in case of emergency.

Liquid Effluents

31. Water is a principal raw material in the manufacture of pulp and paper, and is used extensively in each of the subprocesses. As it flows through the various process steps it is in contact with other raw materials and absorbs many of the substances.

32. The parameters of principal importance for describing the degree of contamination in liquid effluents from pulp and paper mill operations include 5-day biochemical oxygen demand (BOD_5); total suspended solids (TSS); color (not including groundwood, deinked, and non-integrated sub-categories); ammonia nitrogen (for ammonia base sulfite and ammonia base dissolving subcategories only). In European practice chemical oxygen demand (COD) is also frequently used as a parameter. Typical flows, BOD_5 , and TSS for untreated wastes (the parameters of most importance in the Bank's activities) are shown in Table 1.

33. In the various chemical pulping procedures lignin and lignin derivatives enter into solutions from the wood during the cooking process. The spent cooking liquors containing these highly colored compounds are removed from the pulp in a washing sequence following the cooking process. The wash water is highly colored. In spite of recovery procedures many mills continue to discharge wastes having a high degree of color.

Table 1. Typical Untreated Liquid Effluents from Pulp and Paper Mills (See EPA Doc. 880/1-75 /047).

Waste Source	Flow	BOD ₅	TSS
	M ³ /MT Prod. ^{a/}	Kg/MT Prod. ^{a/}	
<u>Bleached Kraft Pulp Mills</u> ^{b/}			
Dissolving Pulp	242	55	150
Market Pulp	177	41	70
Fine Paper Pulp	108	30	84
BCT ^{c/} Pulp	152	34	52
<u>Sulfite Pulp Mills (Bleached)</u> ^{b/}			
Papergrade Pulp	208	116	82
Dissolving Pulp	272	132	92
<u>Soda Pulp Mills</u> ^{b/}	123	42	105
<u>Groundwood Pulp Mills</u> ^{b/}			
Chemi-Mech. Pulp	83	50	28
Thermo-Mech. Pulp	62	28	25
Fine Paper Pulp	91	17	52
CMN ^{d/} Pulp	99	18	70
<u>Deink Paper Mills</u> ^{b/}	94	68	204
<u>Non-Integrated Paper Mills</u> ^{b/}			
Fine Paper	62	11	31
Tissue Paper	96	12	34
Tissue Paper (FWP) ^{e/}	96	14	40

a/ MT Prod. = Metric Ton produced daily.

b/ See Appendix A for descriptions of waste sources.

c/ BCT = Pulp used to manufacture paperboard, coarse papers, and tissue.

d/ CMN = Pulp used to manufacture coarse, molded fiber, and newsprint papers.

e/ FWP = From waste paper.

34. Pulp and papermaking liquid wastes normally contain minor concentrations of ammonia nitrogen, and nitrogen compounds are often added to provide necessary biological treatment efficiencies in the plant waste treatment systems. In the same way, zinc compounds also normally occur in sub-lethal concentrations and hence are of minor concern in pulp mill waste discharges. Zinc concentrations in excess of 5 mg/L in waters used for public supply can cause undesirable tastes which persist through conventional water treatment systems.

Solid Wastes

35. The characteristics of solid wastes from pulp and paper mill operations will vary considerably from one mill to another. For the average mill the distribution of total solid wastes will be as follows:

Wastewater sludges	45 percent
Ash	25 percent
Bark, wood waste	15 percent
Paper, trash	10 percent
Miscellaneous	5 percent

Approximately 75 percent of the solid wastes will be organic in nature. Total solid waste generation for a typical kraft mill producing 200 tons of pulp per day, and typical paper mill producing 100 tons/day, are presented in Table 2.

Table 2 - Solid Wastes Generated in Typical Pulp and Paper Mill Operations a/

Waste Source	Principal Constituents	Bleached Kraft Pulp Mill	Newsprint Paper Mill
Log pond, wood room	Stones, mud, bark	500	-
Boiler ash	Ash, sand	1200	-
Knots, screen rejects	Wood slivers, pulping chem.	300	-
Recausticizing rejects	Lime, metals, carbon	1300	-
Wastewater sludges	Fiber, sand, fine clays	1400	1200
Paper, trash	Varied	100	50

a/ From Reference No. 4

b/ Producing 200 tons/day

c/ Producing 100 tons/day

EFFLUENT LIMITATIONS

36. Limitations for air emissions discharged from pulp and paper mill operations are shown in Table 3.

Table 3 - Gaseous Emission Limitations - Pulp and Paper Mills

Source	TRS ^{a/} g/kg ADP ^{b/}	Particulate Matter μg/Nm ³ (Ambient)	Sulfur Dioxide μg/Nm ³ (Ambient)
Recovery Furnace System	0.075	-	-
Lime Kiln	0.0125	-	-
Smelt Tank	0.0125	-	-
Brown Stock Washer	0.005	-	-
Black Liquor Oxid.	0.005	-	-
Condensate Stripper	0.005	-	-
Digestor System	0.005	-	-
Mult. Eff. Evaporator	0.005	-	-
All Sources	-	100 <u>c/</u>	100 <u>d/</u>

a/ TRS = Total Reduced Sulfur Compounds, measured as H₂S

b/ ADP = Air Dried Pulp

c/ Annual Arith. Mean, max. 24-hours = 1000 μg/Nm³

d/ Annual Geom. Mean, Max. 24-hours = 500 μg/Nm³

37. Liquid effluent guidelines for bleached kraft, groundwood sulfite, soda, deink and non-integrated paper mills, unbleached kraft and semichemical pulp mills are presented in Table 4. In all cases, the limitations are based on the best practicable control technology considered to be widely available.

Table 4 - Liquid Effluent Limitations - Pulp and Paper Mills
 (See Appendix A for descriptions of Waste Sources)

Waste Source ^{a/}	<u>BOD₅</u>	TSS	ZINC ^{b/}
	Kg/MT produced/Day		
<u>Bleached Kraft Pulp Mills</u>			
Dissolving Pulp	13.0	15.6	-
Market Pulp	7.1	10.3	-
Fine Paper Pulp	4.7	7.4	-
BCT ^{c/} Pulp	6.4	10.3	-
<u>Sulfite Pulp Mills</u>			
Papergrade Pulp	15.2	21.2	-
Dissolving Pulp	22.7	26.2	-
<u>Soda Pulp Mills</u>			
	5.8	8.3	-
<u>Groundwood Pulp Mills</u>			
Chemi-Mech. Pulp	3.5	5.9	0.13
Thermo-Mech. Pulp	2.6	4.4	0.10
Fine Paper Pulp	3.8	6.4	0.14
CMN ^{d/} Pulp	4.2	7.0	0.15
<u>Deink Paper Mills</u>			
	7.0	12.6	-
<u>Non-Integrated Paper Mills</u>			
Fine Paper	4.2	4.2	-
Tissue Paper	4.7	4.7	-
Tissue Paper (FWP) ^{e/}	4.7	4.7	-
<u>Unbleached Kraft Pulp Mills</u>			
NSSC - Ammonia Pulps ^{f/}	2.8	6.0	-
NSSC - Sodium Pulps	4.0	5.0	-
Unbleached Kraft - NSSC Pulps	4.4	5.5	-
	4.0	6.2	-

a/ In all cases pH = 6.0 to 9.0

b/ Maximum of average daily values in any 30-day period. Maximum daily value not to exceed 2 times 30-day average.

c/ BCT = Pulp used to manufacture paperboard, coarse papers, and tissue papers.

- d/ CMN = Pulp used to manufacture, coarse, molded fiber and newsprint papers.
- e/ FWP = From waste paper.
- f/ NSSC = Neutral sulfite semi-chemical process.

CONTROL AND TREATMENT OF WASTES

38. Although there are variations in equipment and technology between individual mills manufacturing the same types of products, such differences do not significantly change the characteristics of the wastes produced in each situation. Currently available control technology will not usually require major changes in production processes. Changes in piping, modification of existing equipment, and other relatively minor changes will generally permit application of existing control technology.

Gaseous Wastes

39. Except in an occasional situation (such as unfavorable topography or adverse climatological conditions) sulfur dioxide is not a problem for kraft mills. Adequate control is possible by proper operations, especially of the liquor recovery furnace. Appropriate selection of auxiliary fuels will also be a major factor in resolving discharges of the pollutant. Where discharge concentrations are too high fuel desulfurization, flue gas removal, process modification, or some combination of these may be required.

40. The TRS gases (can cause unpleasant odors from kraft mill operations. These gases (also referred to as non-condensable) originate in various parts of the mill, especially from the digester evaporators and the foul condensate stripping. These are commonly collected in headers, scrubbed with an alkali solution to remove a portion of the sulfur, and then burned. Incineration most frequently takes place in the lime kiln, where the TRS is converted to sulfur dioxide which, in turn, is largely recovered by adsorption on the lime dust and in the liquid in the kiln exhaust scrubber.

41. Particulates originate in various elements of the mill operation, such as the recovery furnace, power boilers, lime kiln, exhaust, and others. Control and removal is best achieved by the use of scrubbers, electrostatic precipitation and other similar means.

Liquid Wastes

42. Liquid wastes can be reduced in both volume and concentrations by a combination of in-plant control measures and end-of-the-pipe treatment.

43. In-plant measures include effective pulp washing, chemical and fiber recovery, treatment and reuse of selected waste streams, collection of spills, and prevention of accidental discharges. Continuous monitoring of mill sewers should be conducted, including the outfall, in order to receive rapid warning

of accidental spills. Storage basins, prior to treatment, will serve to absorb shock discharges and provide a more constant loading on the treatment facilities. Wastes loadings from wet barking can be materially reduced by recycling the barking water. These and other similar operating and housekeeping measures are very effective.

44. External effluent treatment includes neutralization, primary treatment to remove the settleable solids, and biological (or secondary) treatment to reduce the effluent BOD_5 .

45. Large pieces of assorted materials, such as knots and rocks, are discharged into the sewers from process operations. Large items such as tools and hard hats may also occasionally be discharged to the sewers by accident. Screens are required at strategic locations within the mill to remove these materials. Screens may utilize mechanical or manual cleaning, depending upon the loadings expected.

46. Bleached kraft pulp mill effluents are highly acidic, while effluents from mechanical pulp mills and most paper mills are mildly acidic. Where the pH in the effluent requires only a small adjustment then a liquid alkali such as caustic soda, or an acid, such as hydrochloric, can be used for neutralization. Where wastes are highly acidic some form of lime is used for this purpose.

47. Settleable solids are removed in a clarifier, usually a circular tank in which the particles are allowed to settle to the bottom. In some cases slow stirring is used to cause an agglomeration of particles. Conditioning chemicals are sometimes added to enhance flocculation. At some mills settling basins, either following or in place of clarifiers, are used. These function entirely by gravity, and have a detention time of up to 8 hours. The sludges collected at the bottom of these units is withdrawn at regular intervals and handled by various disposal methods.

48. Biological treatment is now required for effluents from new mills in many industrialized countries. Such treatment facilities are also being installed at many older mills. This type of treatment accomplishes several purposes: it reduces the acute toxicity of the effluent and usually renders it non-toxic to fish; it reduces the potential of the wastes to cause taste, foaming, odors, and tainting of fish flesh; and generally creates an effluent suitable for discharge to most surface waters.

49. Where sufficient land is available for the purpose, aerated lagoons are most often used to provide extended detention of pulp and paper mill effluents. This system will consist of one or more lagoons equipped with aerating devices and providing a detention period of several days. As a rough guide, one cubic meter of lagoon capacity will be required for each 30 grams of BOD_5 in the influent. As an average, the system will provide a 90% reduction in BOD_5 , with a total detention period of about 10 days. The activated sludge process is also effective but because of the higher capital and operating costs, its use is usually limited to situations where sufficient land is not available. The activated sludge process also requires a high degree of operator attention and skills. Other methods, such as oxidation ditches and trickling filters, have also been effective.

Solid Wastes

50. The largest volume of solid wastes is generated by the wastewater treatment process. Land disposal, by lagooning or dumping, has been used extensively in the past. This method is being used less and less because of odors from decomposition of the materials, potential pollution of both surface and ground waters, and the elimination of affected lands from future use. However, with the application of proper sanitary landfill measures this method should create few or no environmental problems.

51. Dewatering and incineration of sludges are now receiving wider usage. Vacuum filtration produces a filter cake containing 20 to 30 percent solids. Chemical conditioning with ferric chloride, alum, or polyelectrolytes will greatly aid poorly filterable sludges. Although costs are high, three types of incineration are being practiced: burning in a specially designed incinerator, burning in the bark boiler, and burning in a power boiler utilizing fossil fuels.

52. Many of the solid wastes can be utilized for useful purposes. Because they are organic in nature they can be used as a fuel, for agricultural, or other purposes. Fibrous sludges and barks are suitable for manufacturing wallboard and roofing papers. It has been demonstrated that crop yields have significantly improved when fibrous sludges have been applied as a mulch. Ash from bark burning boilers is rich in plant nutrients, particularly potash. It can be used as a soil conditioner, particularly for acid soils. There are several other ways in which solid wastes can serve a useful purpose. It is often advantageous to enlist the cooperation of various government agencies, local industries, and others in developing by-product recovery and utilization measures.

BIBLIOGRAPHY

1. United Nations Environmental Program. "Effluent and Emission Control in the Pulp and Paper Industry". 2 Parts. Paris (1979)
2. U.S. Environmental Protection Agency. "Development Document for Advanced Notice of Proposed or Promulgated Rule Making for Effluent Limitations Guidelines and New Source Performance Standards for the Bleached Kraft, Groundwood, Sulfite, Soda, Deink, and Non-Integrated Paper Mills Segments of the Pulp, Paper, and Paperboard Mills Point Source Category". Doc. EPA 440/1-75/047, Group I, Phase II. Washington (August 1975).
3. U.S. Environmental Protection Agency. "Standards Support and Environmental Impact Statement - Vol. I: Proposed Standards of Performance for Kraft Pulp Mills". Doc. EPA 450/2-76-014-a. Washington (September 1976).
4. U.S. Environmental Protection Agency. "Standards Support and Environmental Impact Statement - Vol. II: Promulgated Standards of Performance for Kraft Pulp Mills". Doc. EPA 450/2-76-014-6. Washington (December 1977).

5. Beak Consultants Limited "Environmental Considerations for the Pulp and Paper Industry". File K4386 (Draft). Vancouver, B.C. (September 1979).
6. U.S. Environmental Protection Agency. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Unbleached Kraft and Semicontaminated Pulp Segment of the Pulp, Paper, and Paper Board Mills Point Source Category". Doc. EPA-440/1-74-025-a. Washington (May 1974).
7. APHA, AWWA, WPCF "Standard Methods for the Examination of Water and Waste-water". 14th Edition. American Public Health Association. New York (1975).
8. U.S. Environmental Protection Agency. "Guidelines for Lowest Achievable Emission Rates from 18 Major Stationary Sources of Particulate, Nitrogen Oxides, Sulfur Dioxide, or Volatile Organic Compounds". Doc. EPA 450/3-79-024. Washington (April 1979).
9. U.S. Environmental Protection Agency. "Water Quality Criteria". Doc. EPA 23-73-033. Washington (March 1973).
10. Powers, Philip W. "How to Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation. Park Ridge, N.J. and London (1976).
11. Wasser, Abwasser, Abwasserreinigung in der Papierindustrie, em. Prof. Dr.-Ing. W. Bracht und Dr.-Ing. H. L. Dalpke, Guntter-Staib Verlag, Postfach 180, D-7950 Biberach/RiB 1, West Germany. (December 1980).

PRINCIPAL GRADES OF PULP AND PAPER PRODUCTION

FROM WOOD CELLULOSE FIBERS (*)

1. BLEACHED KRAFT: DISSOLVING PULP means the production of a highly bleached pulp by a process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. Included in the manufacturing process is a "pre-cook" operation termed prehydrolysis. The highly bleached and purified dissolving pulp is used principally for the manufacture of rayon and other products requiring the virtual absence of lignin and a very high alpha cellulose content.
2. BLEACHED KRAFT: MARKET PULP means the production of bleached pulp by a "full-cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. Included in this subcategory are mills producing papergrade market pulp as the only product.
3. BLEACHED KRAFT: FINE PAPERS means the production of bleached pulp by a "full-cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. This pulp is used to manufacture fine papers.
4. BLEACHED KRAFT: B.C.T. PAPERS means the production of bleached pulp by a "full-cook" process utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. This pulp is used to manufacture a variety of papers with clays and fillers contents less than eight percent. Included in this subcategory are mills producing paperboard (B), coarse (C) papers, and tissue (T) papers.
5. PAPERGRADE SULFITE means the production of pulp, usually bleached, by a "full-cook" process using an acidic cooking liquor of bisulfites of calcium, magnesium, ammonia, or sodium containing an excess of free sulphur dioxide. This pulp is used to manufacture a variety of paper products such as tissues and fine papers.
6. DISSOLVING SULFITE means the production of highly bleached and purified pulp by a "full-cook" process using very strong solutions of bisulfites of calcium, magnesium, ammonia, or sodium containing an excess of free sulphur dioxide. This pulp is used principally for the manufacture of rayon and other products requiring the virtual absence of lignin and a very high alpha cellulose content.
7. SODA means the production of bleached pulp by a "full-cook" process utilizing a highly alkaline sodium hydroxide cooking liquor. This pulp is used principally to manufacture a wide variety of papers such as printing and writing papers.

(*) Adapted from References (1) and (5) of Bibliography.

8. GROUNDWOOD: CHEMI-MECHANICAL means the production of pulp, with or without brightening, utilizing a chemical cooking liquor to partially cook the wood followed by mechanical defibration by refining at atmospheric pressure. This pulp is used to produce a variety of products including fine papers, newsprint, and molded fiber products.
9. GROUNDWOOD: THERMO-MECHANICAL means the production of pulp, with or without brightening, by a brief cook utilizing steam, with or without the addition of cooking chemicals such as sodium sulfite, followed by mechanical defibration by refiners which are under pressure. This pulp is used in a variety of products such as newsprint and tissue products.
10. GROUNDWOOD: FINE PAPERS means the production of pulp, with or without brightening, utilizing only mechanical defibration by either stone grinders or refiners.
11. GROUNDWOOD: C.M.N. PAPERS means the production of pulp, with or without brightening, utilizing only mechanical defibration by either stone grinders or refiners. This pulp is used to manufacture coarse (C) papers, molded (M) fiber products, and newsprint (N).
12. DEINK means the production of secondary pulp, sometimes brightened or bleached from recycled waste papers in which an alkaline treatment may be utilized to remove contaminants such as ink and coating pigments. The pulp is used, frequently in combination with chemical pulp, to manufacture a wide variety of papers such as printing, tissue, and newsprint.
13. NON-INTEGRATED FINE PAPER means the manufacture of fine papers from wood pulp or deinked pulp prepared at another site. Fine papers are relatively high in price, and include grades such as printing, writing, and technical.
14. NON-INTEGRATED TISSUE PAPER means the manufacture of tissue papers from wood pulp or deinked pulp prepared at another site. Tissue papers include grades such as facial and toilet papers, paper diapers, and paper towels.
15. NON-INTEGRATED TISSUE PAPERS (FROM WASTE PAPER) means the manufacture of tissue papers from recycled waste papers. Tissue papers include grades such as facial and toilet papers, paper diapers, and paper towels.
16. UNBLEACHED KRAFT means the production of pulp without bleaching by a "full-cook" process, utilizing a highly alkaline sodium hydroxide and sodium sulfide cooking liquor. This pulp is used principally to manufacture linerboard, the smooth facing of "corrugated boxes," but is also utilized for other products such as grocery bags and cement sacks.

17. SODIUM BASE NEUTRAL SULFITE SEMI-CHEMICAL means the production of pulp without bleaching utilizing a neutral sulfite cooking liquor having a sodium base. Mechanical fiberizing follows the cooking stage, and the principal product made from this pulp is the corrugating medium or inner layer in the corrugated box "sandwich."
18. AMMONIA BASE NEUTRAL SULFITE SEMI-CHEMICAL means the production of pulp without bleaching, using a neutral sulfite cooking liquor having an ammonia base. Mechanical fiberizing follows the cooking stage, and the pulp is used to manufacture essentially the same products as is sodium base NSSC.
19. UNBLEACHED KRAFT—NSSC (CROSS RECOVERY) means the production of unbleached kraft and sodium base NSSC pulps in the same mill wherein the spent NSSC liquor is recovered within the unbleached kraft recovery process. The products made are the same as outlined above for the unbleached kraft and NSSC subcategories, respectively.

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

RODENTICIDES

GUIDELINES FOR USE

1. Several World Bank projects include transporting, storing and processing food grain. Minimizing losses due to pests, mainly rodents, is a major consideration.
2. Rodenticides are being used whose toxicity to mammals, including man, varies widely. This guideline describes the main rodenticides being used and gives the important characteristics of each product.

Choice of Rodenticide

3. The basis of choice for pesticide use should also be applied here. Biodegradability and toxicity are the two most important criteria.
4. The rodenticides have been separated into three different classes.
 - In Class I the products whose use require only normal precautions.
 - In Class II the products whose use should be discouraged or severely controlled.
 - In Class III the products whose use should be banned.

Class I - Normal Precautions

5. This class includes the anticoagulants, and the following rodenticides: Red Squill, Norbormide and Zinc Phosphide.
6. The anticoagulants are the safest of all rodenticides. Unfortunately the rapid spread of resistance to them among rats and mice has made necessary the use of other types. The anticoagulants should be the first choice in areas where rodents are not yet resistant to them.
7. Red Squill, known also as Dethdier (powder) or Rodine (liquid extract), is the powdered bulb of Urginea Maritima, a perennial growing in the Mediterranean area. It is extremely irritating to the skin and causes vomiting in most mammals (but not rats). Despite reported cases of cattle, sheep and chicken poisoning, the possible hazards to man are quite remote. Red Squill being a natural product, its potency is not uniform.
8. Norbormide has a good efficacy against rats with a low toxicity to

other mammals. The other name is Raticate.

9. Zinc Phosphide (Zn_3P_2). This gray powder with high melting point is widely used. Stable when dry, but decomposes slowly in moist air. Reacts violently with acids to form inflammable phosphine gas (PH_3) giving off the characteristic garlic-like odor. While highly toxic to domestic fowl, this product has a good safety record.

Class II - Severe Control

10. These products should only be applied by trained operators under the conditions specified by the manufacturer. This class includes the following products: sodium fluoroacetate, fluoroacetamide and strychnine.

11. Sodium fluoroacetate ($CH_2FCOONa$). Odorless, tasteless and fast acting, this chemical is extremely toxic to warm-blooded animals. It acts chiefly on the heart with secondary effect on the central nervous system. The possession, transport and sale of this compound are strictly regulated in the US. Its use should be restricted to areas (i.e. locked warehouses and sewers) to which access by unauthorized persons or by animals can be prevented completely. The acute oral LD50 (rat) is 0.22 mg/kg. One trade name is 1080.

12. Fluoroacetamide ($CH_2C - CO - NH_2$). It is a highly toxic material and all precautions that apply to sodium fluoroacetate should also apply to it. Its acute oral LD50 (rat) is 15 mg/kg. Trade names are:

1081
Fussol
Fluorakil 100

13. Strychnine. This alkaloid is extracted from the seeds of nux vomica. Mainly used as strychnine sulfate in poison baits for jackrabbits, coyotes and wolves. It is only moderately successful in rodent control but can be quite hazardous to human beings and domestic animals. The LD50 for man is 30 - 60 mg/kg.

Class III - Banned Usage

14. The products in this class should be banned because they are too dangerous for man and/or the environment. They include arsenic trioxide, phosphorous, thallium sulfate, naphtylurea (ANTU) and gophacide.

15. Arsenic trioxide. This chemical has been used for many centuries and is very effective against rodents. It is also dangerous to man as a toxicant and a carcinogen.

16. Phosphorous. White phosphorous is sold in many LDCs in a 1 - 2% paste formulation as a cockroach poison and a rodenticide. This has led to poisoning, especially in children eating the formulation. A dose of 15 mg is highly toxic and one of 50 mg is nearly always fatal.

17. Thallium sulfate. It is highly toxic to rodents but also to man and useful animals that can be poisoned if they eat other animals already poisoned by thallium. It is rapidly absorbed through the skin and the gastrointestinal tract and its elimination from the system is very slow. There have been a growing number of accidental poisonings coming from its use in household pesticidal baits. In the US, only government agencies can use it.

18. Naphthylthiourea (ANTU). A 2% impurity of this product is 2-naphthylamine, itself a known carcinogen.

19. Gophacide. This organic phosphate is highly toxic to rats and other mammals with ready absorption through the skin as an increased hazard. Toxicological studies have also shown that gophacide may have delayed neurotoxic effects.

New Anti-Coagulant

20. On December 5, 1979, the US EPA announced that it had approved a new poison that kills rats immune to the lethal effects of WARFARIN or other anti-coagulants. The new toxin made by ICI Americas, Wilmington, Delaware is used in 4 different baits to control rats and mice and is called "TALON". This product should be kept away from children.

THE WORLD BANK

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OFFICE OF ENVIRONMENTAL AFFAIRS

CRUMB RUBBER PRODUCTION

EFFLUENT GUIDELINES

1. Solid rubber, for the fabrication of various products, is produced both as a natural material extracted from plant life, and synthetically from the chemical reaction of specific materials. This document will confine itself to natural rubber only, since this is the type usually produced in countries to which Bank projects are directed.
2. Although many varieties of plants are known to contain natural rubber, only a few of these are considered to be of commercial significance. Today, the major portion of the world's supply of natural rubber comes from a single species of tree -- the Hevea brasiliensis. Although native to the Amazon Basin, it is now cultivated in tropical regions throughout the world.
3. The most favorable rubber growing areas are located within a range of 10° to 15° latitude on either side of the equator, where rainfall is heavy and evenly distributed, and the temperatures range from 20° to 32° C. The largest producers of natural rubber, as of 1976, were Malaysia, Indonesia and Thailand. Other significant producers included Sri Lanka, India, Liberia, Nigeria, Brazil, Cameroon, Ivory Coast, Cambodia and Burma. These countries were producing about 95% of the world supply.

PRODUCTION PROCESSES

4. Natural rubber is marketed in a variety of forms and grades, of which the chief forms are categorized as latex, crude dry rubber, and crepe. The major share of production is for crude dry rubber.
5. Latex is obtained from the tree by cutting into the latex vessels in the bark, using a procedure called "tapping". A spout is inserted at the end of the cut (which slopes downward), and the latex flows through the spout and into a cup attached to the tree. A small amount of preservative (sodium sulfite) is usually placed in the cup to prevent coagulation. Three to four hours after tapping, the latex is collected in buckets and carried to a receiving station.
6. At the receiving station the latex is strained to remove particles of bark, dirt and other foreign matter and then transferred to the factory by tank trucks or other means. More preservative is added to assure that the material will arrive at the factory in a well-preserved liquid condition. Sodium sulfite is generally used to preserve latex destined for dry rubber production.

7. In recent years new developments have been made in preparing, packing, and grading natural rubber. The tendency has been towards small compressed, neatly wrapped bales marketed on the basis of technical specifications in only a few grades.

8. The material received at the factory is treated by coagulation in order to separate the rubber. Acetic and formic acids are the reagents most commonly used for this purpose. The latex coagulates into thick curds at this point. The solid forms of rubber are produced by various processes in which the rubber coagulum is reduced to small particles, washed thoroughly and dried as a crumb, either in hot air tunnels or extrusion driers.

9. In many of the plants the coagulum is mechanically reduced to small particles by a rotary knife cutter or similar chopping or shredding device. The chopped granules are dried in deep bed trays by a forced air draft, at fairly high temperatures. Following drying the granules are compressed into bales and wrapped in plastic for marketing.

10. The Rubber Research Institute of Malaysia has developed a mechano-chemical granulation process for the production of crumb rubber. The process uses conventional equipment but combines this with the application of a very small amount of castor oil (0.4 to 0.7 percent) as a crumbing agent. The resulting crumb is easily dried in hot air circulating driers. The product is marketed as "Heveacrum".

11. Crumb rubber is generally marketed in bales weighing about 35 kilograms. Crumb rubber is also frequently referred to as "technically specified rubber" and as block rubber.

WASTE SOURCES AND CHARACTERISTICS

12. Large quantities of water are used for washing, cleaning, and dilution purposes in rubber processing operations. Some H₂S odors may be emitted from stabilization ponds used to treat the effluent, but under normal conditions there are no gaseous emissions of any significance.

13. Liquid effluents constitute the most important source of pollution from natural block (crumb) rubber production. The most important parameters are biochemical oxygen demand (BOD), chemical oxygen demand (COD) total suspended solids (TSS), total solids (TS), ammonia nitrogen (NH₃ - N), and hydrogen-ion concentrations (pH). The quality of effluent from a typical plant is given in Table 1.

TABLE 1 - Characteristics of a Typical Waste from Natural Block (Crumb) Rubber Production

Parameter	Concentration in Effluent
BOD ^(a)	1,140 Mg/L
COD	1,620 Mg/L
Total Susp Sol.	230 Mg/L
Total Solids	995 Mg/L
NH ₃ -N	55 Mg/L
pH	6.3
Flow ^(b)	54 L/MT Produced

(a) 3 day - 30° C.

(b) Estimate based on Malaysia experience, covering 86% block rubber and 14% latex concentrate production.

EFFLUENT LIMITATIONS

14. Liquid effluents discharged from block rubber plants should conform to the limitations given in Table 2, below.

TABLE 2 - Effluent Limitations for Natural Block (Crumb) Rubber Plants

Parameter	Limitation
BOD (5-day, 20°C)	100 Mg/L
COD	225 Mg/L
Total Susp. Sol.	100 Mg/L
NH ₃ -N	15-20 Mg/L
pH	6 - 9

CONTROL AND TREATMENT OF WASTES

15. As shown above, wastewater from rubber processing contains organic matter and nitrogenous materials at sufficiently high levels to cause pollution if discharged to receiving waters without prior treatment. Measures to reduce effluent concentrations include a combination of internal measures before treatment, followed by treatment systems.

16. Internal measures prior to treatment could include, but not be limited to:

- a) Application of good housekeeping practices.
- b) Use of rubber and/or settling trays to recover lost rubber particles and reduce solid matter in the effluent.
- c) Proper mixing and combining of all effluents to assure maximum dilution prior to treatment.

17. Simple biological treatment, such as aerobic-anaerobic pond systems have been found effective in treating these effluents. Such systems have been found to remove 80 to 95% of the BOD, 80 to 85% of the COD, 80 to 95% of the suspended solids, and 40 to 50% of the ammonia nitrogen. Such a system requires a large land space and hence may not be practical for factories situated in urban areas.

18. Land disposal of effluent has also been used successfully, especially where the land is planted with mature rubber or oil palm trees. While this technique has not been extensively used thus far it has been found to have the following advantages:

- a) Increases the yield of both rubber and oil palm in the range of 11 to 19%.
- b) Results in cost savings for fertilizers which might otherwise be required.
- c) Supplies moisture to the land, from the water in the effluent, during periods of low precipitation.
- d) Eliminates direct discharge of effluents into waterways.

19. Rotating bio-disc systems have also been used successfully for this purpose. Average reductions of 78% in BOD, 67% in COD, 93% in ammonia nitrogen, and 75% in total nitrogen have been achieved by this method.

20. Experimental work is now underway on the use of water hyacinth (Eichhornia crassipes) to remove a major part of the pollutant in block rubber/concentrate effluents.

21. Other experimental work is underway to produce methane from anaerobic treatment of the effluent.

BIBLIOGRAPHY

1. "Summary of Proceedings of the Twenty-Fourth Assembly". International Rubber Study Group. Jakarta, 28-31 October 1975.(Printed by Bell, Logan & Carswell, Ltd., Belfast)
2. Polhamus, Loren G. "Rubber-Botany, Production and Utilization". Leonard Hill (Books) Ltd., London and Interscience Publishers, Inc., New York (1962).
3. "Rubber and Energy Crisis". The Economist Intelligence Unit, Ltd., London (1974).
4. "The Vanderbilt Rubber Handbook". G. G. Winspear, ed. R.T. Vanderbilt Co., Inc. New York (1968).
5. "Rubber Technology". M. Morton, ed. Second Edition. Van Nostrand Reinhold Company. New York (1973).
6. Sittig, Marshall. "Pollution Control in the Plastics and Rubber Industry". Noyes Data Corporation. London and Park Ridge, New Jersey. (1975).
7. Rubber Research Institute of Malaysia. "Annual Report - 1978" pp. 201-203. Kuala Lumpur (1979).
8. Rubber Research Institute of Malaysia "Annual Report - 1975" pp. 158-159. Kuala Lumpur (1976).
9. "Treatment of Effluents from Rubber Processing Factories". International Rubber Conference. Kuala Lumpur (1975).
10. "Land-Disposal of Rubber Factory Effluent: Its Effects on Soil Properties and Performance of Rubber and Oil Palm". Proceedings of the Rubber Research Institute of Malaysia Planters' Conference, 15-17 October 1979. pp 436-457. Kuala Lumpur (1979).
11. "Technology and Standards for Treatment of SMR Block Rubber Effluent". Proceedings of the Rubber Research Institute of Malaysia Planters Conference, 17-19 October 1977. pp. 201-214.Kuala Lumpur (1977).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

SECONDARY ENVIRONMENTAL EFFECTS OF INDUSTRIAL PROJECTS

1. When the Bank is financing a project in the heavy industry or in a labor intensive industry, secondary effects on the environment will be important and must be taken into account.
2. These effects are the consequences of a population influx in the town or the region and they include water and power distribution, sewage collection and treatment, housing, schools and roads.
3. In developed countries, the ratio between employment in the new plant and new employment in the region is usually one to seven, or one to eight. Although the conditions are different in LDC's, the same ratio can be applied. If satellite industries, like mechanical repair shops for instance are less likely to be created, the necessity of additional services like banking or schools is apparent.
4. As an example, a steel plant employing a little less than 1000 people was built close to a town of 6000. Five years after start up, the town population had jumped to 42,000, with appalling results for the environment and the quality of life.
5. Urban Development Planning or Financing is the field of specialized departments in the Bank. They should be consulted on problems likely to arise. The goal of this guideline is only to draw the attention on the potential for trouble and to suggest economical solutions in certain areas, thus preventing the expansion of urban slums.
6. In the forecasts for water and power consumptions, not only the plant requirements but also the town future uses should be taken into consideration. A common water intake and pumping station or a common power line whenever possible, will usually prove more economical for both parties.
7. Sewage collection and treatment should receive special attention. In the case of the steel plant mentioned above, the town had no treatment whatsoever with direct discharge into a river estuary. The assimilative capacity of the estuary was sufficient at the time but totally inadequate for a town of 42,000. The steel plant did not help by discharging untreated industrial sewage into the same river. After a few months the river was dead, the beaches close to the estuary became unhealthy and their access had to be forbidden. Finally, commercial fishing in the bay stopped for lack of fish.
8. A pretreatment of the industrial effluent followed by treatment in a sewage plant common to both the town and the plant has advantages for both parties. Usually both the costs for industrial wastes control and for municipal sewage treatment are decreased when this solution is adopted.

9. Domestic and industrial garbage disposal has created problems in the steel plant project. The disposal should be addressed in the planning stages and a suitable dump area identified.
10. Finally, adequate housing, schools, as well as road and transportation should be provided.
11. Financing of these additional expenses may again complicate the situation. The industrial project cannot always be saddled with costs for improving the general infrastructure of the town or the region. On the other hand, the town may not have the necessary resources to face important expenditures.

OFFICE OF ENVIRONMENTAL AFFAIRS

SLAUGHTERHOUSES

PART I — INDUSTRIAL WASTE DISPOSAL

1. Slaughterhouses generally limit their operations to killing of cattle and hogs, and processing of carcasses for consumer markets or preparation of a variety of products. Sheep, lamb and calves are generally handled in the same manner. Such a facility may be a simple installation limited to killing and marketing of carcasses only, or it may be part of a large meat processing installation.

2. This guideline will be confined to slaughtering operations for large animals only. Separate guidelines have been prepared to cover meat processing and rendering and to cover the poultry industry.

INDUSTRIAL PROCESS

3. For a simple slaughterhouse operation, the steps generally involved include holding in stockyards or pens, killing, blood removal, hide removal or hog dehairing, evisceration, trimming, and cutting for market. Simple slaughterhouses are small to medium in size, with small installations having a live weight kill (LWK) of under 45 megagrams per day while medium installations may range as high as 350 megagrams LWK per day.*

4. A complex slaughterhouse is one which carries out at least three by-product operations such as paunch and viscera handling, blood processing, hide or hair processing and rendering. Most complex slaughterhouses are medium to large in size, and will normally have a LWK above 350 megagrams per day. A process flow diagram is shown in Figure 1.

SOURCES AND CHARACTER OF WASTES

5. Liquid wastes, carrying varying amounts of solids, are the major concern in this industry. Volumes of solid wastes, produced mainly from screening and housekeeping, will depend upon the degree of separation and by-product recovery practiced at each individual plant. Other than odor problems, gaseous wastes are not significant. The purely hazardous types of waste components, such as heavy metals and pesticides, are not normally found in the effluents.

6. The most significant pollution parameters are the 5-day biochemical oxygen demand (BOD_5) total suspended solids (TSS), oils and greases (O + G), hydrogen-ion concentration (pH), and fecal coliform organisms.

7. Odors originate from various sources, and generally result from bacterial activity on organic matter. Putrescible substances result from unloading

* 1 Mg = 1 megagram = 1 metric ton

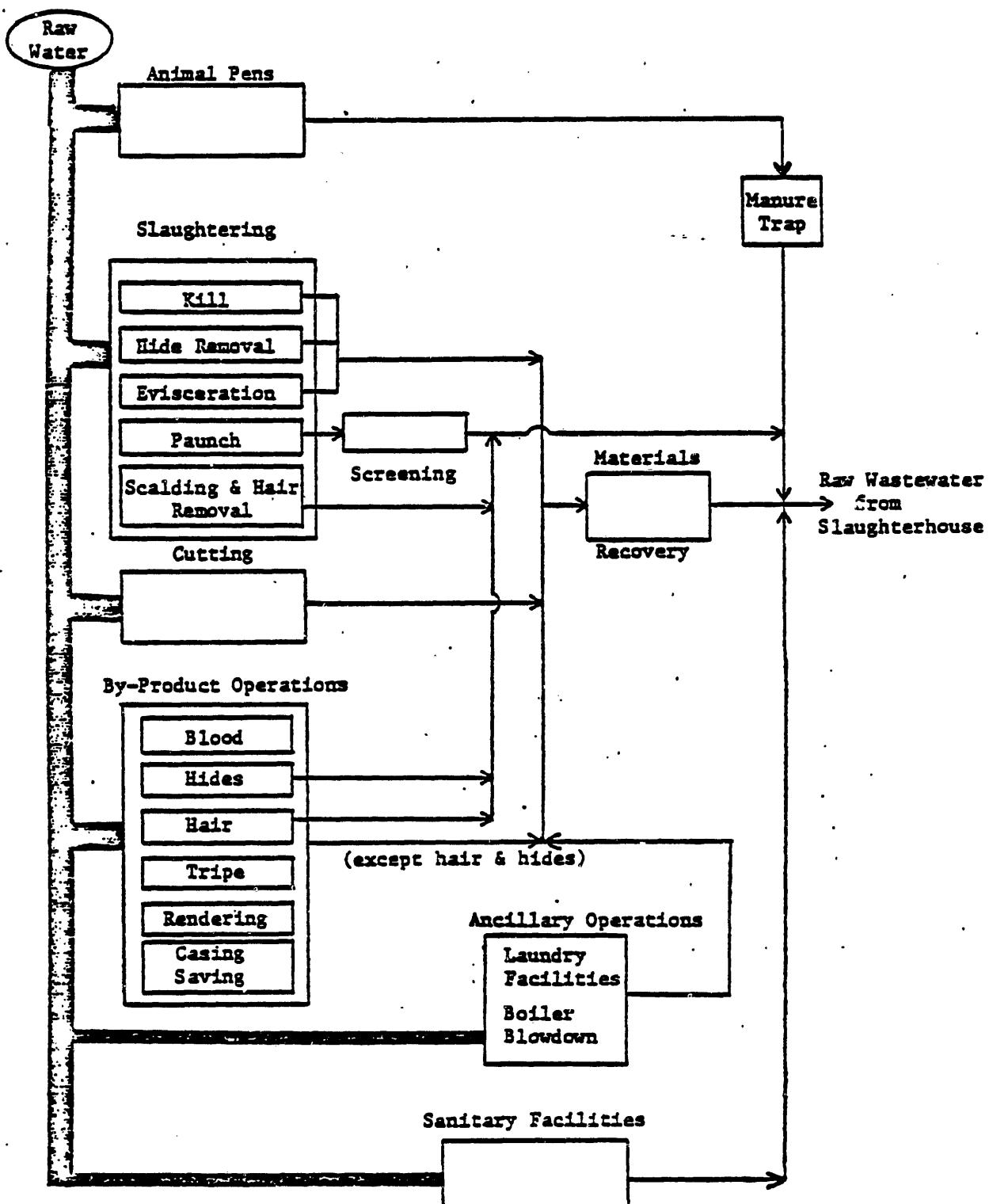


Figure 1. Operating and Wastewater Flow Chart for Simple and Complex Slaughterhouses. (From Ref. 4)

and stockpen operations, manure handling and storage, blood collection and storage, and storage piles of solid trash or garbage.

8. The slaughtering operation is the largest single liquid waste source in the meat industry, and blood is the major contribution. Cattle, for example, contain up to 23 kg of blood per animal, and only 70 percent is typically recovered for further processing. The stomach contents, when washed out, constitute another source. However, this material is often isolated and either processed or hauled to landfill, and thus does not contribute to the waste effluent. Other pollution sources from slaughtering operations include carcass washing, along with viscera and offal processing. In some plants hides are treated by arsenic dipping, producing spent arsenic solutions which can present a special disposal problem.

9. Raw waste characteristics for a typical slaughterhouse operation are presented in Table 1.

Table 1. Typical Raw Waste Characteristics - Slaughterhouse Operations.

Type of Plant	Flow (Liters)	BOD ₅ (kg)	TSS (kg)	O+G a/ (kg)
Per megagram Live Weight Killed				
Simple Plant	5,330	6.0	5.6	2.1
Complex Plant	7,380	11	9.6	5.9

a/ O + G = Oils and Greases

EFFLUENT LIMITATIONS

10. Effluent limitations for slaughterhouse wastes, based on technology currently known to be available, are presented in Table 2.

Table 2. Maximum Daily Liquid Effluent Limitations - Slaughterhouse Operations

Type of Plant	BOD ₅ (kg) b/	TSS (kg) b/	O+G a/ (kg) b/	pH
Simple Plant c/	0.12	0.20	0.06	6 - 9
Complex Plant c/	0.21	0.25	0.08	6 - 9

a/ O + G = Oils and Greases

b/ Per megagram Live Weight Killed

c/ MPN Fecal Coliform count less than 400 per 100 mL (milliliters)

11. For installations where the kill is less than 50 head of cattle (or the equivalent weight in other animals) then these limitations need not be applied. The appraisal or supervision mission should, however, be certain that adequate precautions are taken to avoid irreversible damage to the environment and the creation of any occupational health problems.

CONTROL AND TREATMENT OF WASTES

12. Odors are the only significant air pollution problem connected with this industry, and these can be controlled by air scrubbers. Scrubber waters may be recycled in most cases.

13. Liquid waste discharges can be reduced in volume and concentration through effective water management, in-plant waste controls, process modifications, and by the use of treatment systems. The wastes may also be released to municipal sewers provided that certain pretreatment measures are taken prior to discharge. These measures will depend upon local regulations and the degree of treatment provided by local facilities.

14. In-plant control techniques include the use of screening, skimming, or settling (alone or in combination) to reduce the discharge of solids. Because these solids, to a large degree, can be processed into saleable by-products, this primary treatment is routinely employed in most plants. Excess solids can be hauled to a landfill. Where possible, measures should be taken to prevent useful materials (such as blood, paunch manure, pieces of tissue, etc.) from reaching the floor, in order to reduce general cleanup operations. This conserves water and reduces effluent volumes. Catch basins should be used for separation of greases and other solids.

15. Biological systems can generally be used to treat slaughterhouse wastes, particularly where in-plant primary treatment for recovery of useful solids is being applied. Secondary treatment, such as anaerobic processes, aerobic lagoons, activated sludge and high-rate trickling filtration are the techniques most frequently used. If additional treatment is required, the effluent may be subjected to slow sand filtration, microstraining, spray-irrigation, ion-exchange or other tertiary treatment systems.

16. Where arsenic dipping is used for treating hides, then measures will be required to protect the health of workers and to prevent spills outside the plant. Special measures must be taken for the safe disposal of spent arsenic solutions.

BIBLIOGRAPHY

1. "Information Sources on the Meat Processing Industry". UN Industrial Development Organization. Doc. UNIDO/LIB/SER.D.1/Rev. 1. New York (1976).
2. Jones, Harold R. "Pollution Control in Meat, Poultry and Seafood Processing". Noyes Data Corporation. Park Ridge, N.J., and London (1974).

3. Levia, Albert. "The Meat Handbook". AVI Publishing Co., Westport, Conn. (1963).
4. U. S. Environmental Protection Agency - "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Red Meat Processing Segment of the Meat Product and Rendering Processing Point Source Category". Doc. EPA-440/1-74-012-a. Washington (February 1974).
5. U. S. Environmental Protection Agency - "Upgrading Meat Packing Facilities to Reduce Pollution". EPA Technology Transfer Seminar Publication. (3 Vols.) Washington (October 1973).
6. Moodie, S.P. and P.F. Greenfield - "Treatment of Abattoir Effluent by Trickling Filtration". J. Water Pollution Control Federation. V.50, pp 2741-2751. Washington (December 1978).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

SLAUGHTERHOUSES

PART II -- PLANT DESIGN AND EQUIPMENT

1. Most slaughterhouses conform to certain basic design principles, irrespective of minor variations in layout and equipment. The modest throughput of some slaughterhouses calls for a simple structure, but regardless of size it must be suitably equipped to function efficiently and economically under good sanitary conditions. Knowledge of local conditions, consumer habits and butchers' interests must all be considered in the final planning. Operational problems can be avoided if basic requirements are considered equally applicable to both small and large installations.
2. A firm specializing in slaughterhouse design, construction and operations should be engaged to prepare necessary layouts and drawings, together with the construction and engineering specifications required for tender documents. The designs should be prepared in close collaboration with the National and local health authorities. Following competitive bidding, a contract for the construction of the slaughterhouses can be awarded. The award may be as a turnkey if this is deemed to be most advantageous for the client. The contract should include not only the construction of buildings but also the supply of all plant and machinery, and the engineering supervision required to initiate operations. Ancillary facilities, utility services, administration offices and staff amenities should also be included in the design and construction.
3. A contract for the construction of one small slaughterhouse unit would probably be of interest to local contractors only, as would the supplying of the necessary equipment and materials. However, a contract for several units would be of international interest and would receive much wider attention. Many large firms manufacturing slaughterhouse equipment and machinery can provide a wide range of services through design offices staffed by specialists to cover all phases of the planning. Competitive proposals should be obtained from such firms.

LOCATION AND SITING

4. A slaughterhouse should be sited in a strategic location for live-stock procurement either from the local market or from supplies delivered by transport. The availability of good communications and transportation is also essential for providing easy access to consumer markets. The location should be away from built-up areas or those zoned for future residential development. Labor and technical services, adequate power and water supplies, and easy means of effluent disposal should also be readily available.

5. The site area for a small slaughterhouse should be not less than 3 hectares for any size plant, however, it is desirable to appropriate as much land as possible in the beginning to provide for (a) possible future expansion, (b) the holding of excess livestock in an emergency and (c) ready means for disposal of effluent, particularly paunch contents and other solid wastes. There is little advantage to locating an installation adjacent to a receiving body of water from the standpoint of waste disposal. Waste effluents are subject to specified limitations, as discussed in Part I of this Guideline, in order to protect receiving water quality.

PLANT BUILDINGS

6. The slaughterhouse should be designed and constructed to meet the sanitary standards established by the National and local Public Health, Veterinary, and other authorities involved. The main building should be a single story structure of simple design to contain separate slaughter sections for cattle and for hogs, including provisions for an efficient meat inspection service. Carcasses from slaughter floors are to be carried on rails to a hanging hall which is also part of the main building. A small partitioned area is to be provided to serve as a detention bay for holding doubtful carcasses awaiting further examination by meat inspectors.

7. If the receiving market is limited to purchasing fresh meat only, and shipment is made on an "as killed" basis, then chill rooms and refrigeration plants need not be included in the investment cost. However, it is desirable that provision be made for chilling carcasses, in case of marketing or other changes in the future. Therefore, space should be provided in the hanging room area to install a chill room unit. Loading facilities for carcasses and one for offal and other "dry" wastes should adjoin the carcass hanging hall. A section of the main building, next to the slaughter floors, is to be partitioned off for cleaning and washing the hides.

8. All slaughterhouse building walls are to be finished on the inside with a flat, washable surface. Floors should be of concrete with a minimum slope of 1.5% to standard drains and should be surfaced with non-slip, impact-resistant materials. Ample ventilation is required throughout the building and all openings to the outside must be screened. Working and inspection areas must be provided with adequate illumination.

9. If all intestines, lungs, blood and remains are sold for off-site use and consumption, very little remains for conversion as by-products apart from any condemned carcasses. However, it is necessary to provide for whatever must be stored or otherwise handled and a separate building is considered best for this purpose. A structure having high walls, a smooth impervious interior finish, and a solid concrete floor with suitable drainage leading to the catch basin should be provided. The same building can also accommodate a small maintenance workshop, the boiler, and laundering facilities for the industrial clothing. A well ventilated building will be required for the salting and storage of hides. The administration offices, change rooms, showers and toilets require separate

buildings suitably finished and equipped. This building should be simple and utilitarian.

10. To minimize fly nuisance and insect infestation, animal receiving and holding areas for livestock awaiting slaughter should be located well away from the slaughterhouse. The two are to be connected by a race or crush. The livestock pens will have a roof for shade, and concrete floors with drains located outside the enclosures. The pens should be surrounded by curbs to prevent the spread of manure and liquids beyond the holding area. If the pens are to be washed down, a manure trap will be required to recover solids. A drinking trough with a piped supply of water should be placed in each holding pen. A small quarantine enclosure is required for isolating sick animals.

PLANT OPERATIONS AND EQUIPMENT

11. Complex and costly machinery is not required to process the modest throughput of small plants, and significant savings can be achieved by local procurement of many equipment items. For example, hanging rails and supporting steelwork can be fabricated without difficulty. Guillotine doors, working platforms, paunching tables, offal tanks, paunch and hide tanks can all be constructed locally.

12. All equipment in contact with edible products should be stainless steel, while working platforms and other heavy equipment should be galvanized. Tubular legs are considered best for all tables, platforms, and tank stands. Angle irons which collect dirt are to be avoided and wood should not be used for any purpose in the production areas. Wash basins and knife sterilizers must be strategically located in the slaughter and dressing sections.

13. A strict routine of preventive maintenance must be established and followed. Equipment manufacturers are to supply details on the routine maintenance required for the items which they furnish, including a list of recommended spare units and parts to be acquired. Where several slaughterhouses are to be constructed in a region, consideration should be given to standardizing parts and equipment, and to the establishment of a central workshop and spare parts inventory for replacing or repairing large items such as hoists, electric saws, and motors. In case of a mechanical breakdown at any of the regional installations, the spare item could be readily supplied from the central stores and installed. At the same time the faulty item would be brought back to the central workshop for repair and overhaul. Each slaughterhouse should be responsible for minor day-to-day maintenance and repairs, and should carry the spare parts and equipment needed for this purpose.

14. For the cattle slaughter floor, a simple bed system of flaying (skin removal) is desirable, using mobile dressing trolleys. Back flaying will be from an elevated position using a manual hoist. A small daily slaughter of less than 20 animals does not justify electric stunning equipment, electric hoists or mechanical flaying machines. The hog section usually has a larger throughput and will be equipped with electric stunning apparatus, mechanical scalding tanks and de-hairing machines.

15. Where only small amounts of inedible materials are available for processing, the high cost of purchasing or operating pressure cookers, centrifuges, or expellers is not warranted. Instead, any necessary rendering can be carried out by cooking in locally made tanks fitted with open and closed steam coils. A small grinding machine should be included in the equipment initially provided.

16. A conical tripe washer, tables, and washing tanks should be provided for cleaning intestines and tripe where the quantities of these by-products are too small to justify the cost of a mechanized plant. In addition, for small plants, all animals passing through the slaughtering will be numbered so that the viscera will reach the offal cleaning room in the same sequence as the slaughtering. In small plants, viscera cleaning will be carried out by the butchers and their crews until such time as other provisions can be made. To maintain good sanitary conditions in the plant and in the meat delivery vans, as well as for identification purposes, the butchers are to be provided with plastic bags to hold the cleaned intestines.

17. Steam will be required to heat water for the de-hairing of pigs, to clean the slaughterhouse and plant, to render inedible products, and to sterilize utensils such as knives and cleavers. For these purposes, an oil-fired boiler using diesel fuel oil should be installed. The boiler would be supplied with all necessary valves, gauges, pump and electrical connections for automatic operation and control.

18. The slaughterhouse production crews should be provided with protective clothing. To maintain the garments in a clean condition, a washing machine and dryer are to be included in the initial equipment installation.

WATER SUPPLY

19. A slaughterhouse must have an adequate supply of water available at a suitable pressure throughout the plant and, in addition, a sufficient supply of hot water during working hours. If a constant and ample municipal supply is not available then a study of water supply sources must be included as part of the site selection and approval process. Provision should be made in the investment cost estimates for a ground supply, with the required pumps and piping. For estimating purposes, water usage will amount to 1,200 liters per animal unit, as a minimum. A head tank, with a capacity of at least 25,000 liters should also be provided.

20. Only supplies which meet the bacterial standards for drinking water should be used. The supply should show no coliform bacteria in 100 mL of sample. Natural waters will often meet this standard, depending upon the source. Since such quality is readily attainable by effective treatment, a chlorinated supply will be suitable. Surface water is likely to be heavily polluted and contain high amounts of organic matter. Full treatment, (including sedimentation, filtration, and chlorination) is necessary before use. However, it is unlikely that supplies from deep wells would require this degree of treatment.

21. The plant water supply should be chlorinated, as a minimum of treatment, regardless of source. Chlorine dosage should be sufficient to provide a residual of at least 0.5 mg/l after a 20-minute contact period. Automatic chlorine dosing facilities should be included in the list of equipment to be installed if the supply is not otherwise treated.

EFFLUENT DISPOSAL

22. For waste disposal purposes, traps should be located at strategic points in the drainage system to separate large solids from the effluent. Ideally, the site plan should be arranged so that the land falls away from the "dirty" side of the buildings, (the stock pens, slaughter floor and offal cleaning sections) to open land below. For a small plant, such a situation lends itself to a simple gravity system of effluent disposal-first through a catch basin to trap fats and solids, then through filter beds and finally to irrigation of crops.

23. Slaughterhouse drains should lead directly to one or more catch basins suitably located away from the premises. A conventional over/under gravity flow type basin, with four or five chambers is suitable. Pumps and piping or other means will be required for periodic draining of the basins. Since most of the offal, organs, and other remains are converted to useful by-products, there should be little material present in the effluent which might create difficulties with an excess of fatty materials.

24. Effluent characteristics, discharge limitations, and currently available treatment technology are discussed in Part I, of this Guideline.

PERSONAL HYGIENE AND WASHDOWN FACILITIES

25. In order to determine what facilities need to be provided to assure acceptable personal hygiene and plant washdown procedures, it is essential that such procedures be established during the planning stages. Suggested measures for avoiding contamination of the plant's output are presented below to identify the provisions which should be made for this purpose.

26. Each slaughterhouse unit should be provided with a separate nearby building, housing personnel hygiene facilities such as showers, wash basins, clothes lockers, toilets and first-aid facilities. Each person reporting for duty should be required to wash hands, preferably in a sodium hypochlorite solution. The individual would then be issued clean coveralls, apron and cap and leave whatever personal clothing that is not necessary for work in the lockers situated in the locker room. Provisions should be made for all personnel to wash hands after using the toilets and before returning to the work area. Before entering the slaughterhouse, it is desirable that each person walk through a shallow bath containing a disinfectant solution. Hand washing should be required again after entering the slaughter room.

27. Prior to commencement of the day's operations, each section of the slaughterhouse is to be washed down with hot water. During each shift, floors should be frequently cleared of waste and washed down thoroughly with hot water, followed by spraying with a bactericidal solution. Particular attention should be given to drains.

28. Any trays or containers used in processing should be left in an inverted position after washing. All knives, sharpening steels, cleavers, and other utensils should be sterilized in boiling water at the end of the day's work and again before resuming work the next day. All waste traps should be cleaned daily. At least twice each week catch basins should be completely emptied of both liquid and solid contents, and thoroughly cleaned. Livestock pens and slaughterhouse surroundings must be cleaned daily and sprayed with insecticides. A constant watch should be kept for possible breeding places for flies or other insects.

THE WORLD BANK

NOVEMBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

SULFUR DIOXIDE EMISSIONS

GUIDELINES

1. Man-made emissions of sulfur dioxide originate from a variety of sources discharging to the atmosphere. The major source is from the combustion of fossil fuels such as coal and oil. Some 90 to 95 percent of pollution-related sulfur oxide emissions are in the form of sulfur dioxide. Another source of sulfur dioxide is auto exhaust gases, although it accounts for a relatively small portion of such discharges to the atmosphere. This guideline will concern itself with stationary sources only, particularly those resulting from combustion of fuels containing sulfur.
2. Sulfur dioxide oxidizes in the atmosphere to form sulfates, a particulate form of sulfur compounds. These compounds may have adverse effects on human health and property, depending upon particle sizes, the particulate form of sulfur present, dispersion as affected by weather conditions, and the presence of other pollutants which may magnify the effects.

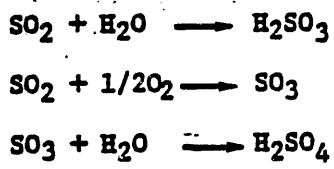
SOURCES AND EFFECTS

3. Sulfur dioxide, has a sharp and choking odor, and is considered to be one of the most dangerous gases to man. It is one of several forms in which sulfur circulates globally. The sulfur cycle also includes hydrogen sulfide gas, sulfuric acid aerosol, and several sulfate salts in aerosol form. For purposes of this discussion, an aerosol is defined as a suspension of liquid droplets or solid particles in a gas.
4. The concentration of populations into large metropolitan areas, with the resulting energy needs and industrial activity, causes the emissions to accumulate over these areas and disperse slowly. A US study, made in 1968, showed nationwide distribution of sulfur oxide emission sources to be as follows:

Fuel combustion	73.5%
Coal	60.5%
Residual fuel oil	11.8%
Distillate fuel oil	1.2%
Industrial Processes	22.0%
Transportation	2.4%
Coal Refuse	1.8%
Solid Waste Disposal	0.3%

5. Electric power plants, the bulk of which utilize coal and oils as fuel, are the leading sources of sulfur dioxide emissions, as shown above. Except for transportation sources (which include motor vehicles, vessels, and railroads), over 97% of the man-made sources are stationary. The degree of sulfur dioxide production from any individual source depends not only on the amount, but also on the type of fuel burned.

6. Sulfur, in a free or combined state, occurs in practically all fossil fuels. When freed to the atmosphere, usually by combustion, the sulfur or its compounds react with the oxygen present in the air to form oxides. These can combine with moisture to form sulfurous acid, followed by formation of sulfuric acid, as follows:



7. Acids formed in the atmosphere fall with rain and can affect crops and plants, and surface waters (particularly lakes). Some lichens, for example, store acid in their roots then die, and they are sometimes used as indicators of sulfur dioxide fallout.

8. Sulfur dioxide emissions, through the formation of acids and other salts in the atmosphere, can cause damages to human health and property. High levels of sulfate concentrations will aggravate asthma, lung and heart disease. Sulfur dioxide in the presence of photochemical oxidants and by-products such as sulfuric acid and hydrogen sulfide has been shown to affect the respiratory tract. It is also widely believed that long term exposure to sulfates may increase the likelihood of respiratory illness such as bronchitis, emphysema and asthma. This effect is more probable when high concentrations of particulates are present.

9. Sensitive vegetation can be severely damaged by low levels of sulfur dioxide, levels even lower than those said to cause distress to lung diseased patients. Such effects result from the synergistic action of sulfur dioxide with low levels of ozone or nitrogen oxide which may be present. Wheat, barley, oats, white pine, cotton, alfalfa, buckwheat, sugar beets, and other crop plants have been reported killed by relatively low levels of sulfur dioxide fallout. Studies made in the USSR during the past decade showed that pine trees growing in an atmosphere having SO_2 concentrations of $500 \mu\text{g}/\text{m}^3$ had a growth loss of 48 percent in comparison with pine trees growing in an atmosphere free of SO_2 .

10. Sulfur oxides and their acid by-products will attack any exposed metal surface, including steel rail tracks. Reactions will also occur on other substances such as brick, stonework and even granite, (such as statues and monuments). Plastics, rubber, paper, and many other similar materials will become discolored and brittle when exposed. Buildings, bridges, steel girders, automobiles and highways are all affected by excessive emissions.

EMISSION SAMPLING AND MEASUREMENT

11. Although several units have been used in the past to express the concentrations of sulfur dioxide in the air, the unit in most common use today is in terms of weight per unit volume of air-micrograms of SO₂ per cubic meter of air ($\mu\text{g}/\text{m}^3$). This unit should be used by the Bank's staff in their reports dealing with this pollutant. Where analytical results are given in parts per million (ppm) of SO₂, the data can be converted to $\mu\text{g}/\text{m}^3$ as follows:

$$1 \text{ ppm SO}_2 = 2620 \mu\text{g}/\text{m}^3$$

It is important to note that this conversion factor applies to SO₂ only, and will not apply to any other substance having a different molecular weight.

12. Because industrial operations may involve frequent cyclic changes, the timing of testing or monitoring must be properly coordinated. Individual polluting substances should be identified and fluctuations of peak loadings determined in advance. All the variables associated with source testing should be considered so that the sampling and analytical results will be representative of the entire source process.

13. Procedures for the collection and analysis of both stationary and ambient source samples, for determining sulfur dioxide levels, are contained in the guideline titled "Sulfur Dioxide Sampling and Analyses", available from the Bank's Office of Environmental Affairs.

ACCEPTABLE STANDARDS

14. Standards are generally of two types — emission and ambient. Emission standards apply to allowable concentrations at the source, such as stacks, ventilating systems and other discharge points. Ambient standards apply to the allowable concentrations of a contaminant in the air surrounding an industrial area or community. Emission levels are necessary for identification of specific pollution sources and design of remedial works. Ambient levels are essential for determining possible environmental damages and for avoiding adverse physical, health and other effects upon the surrounding area and its inhabitants. The standards presented below represent the concentrations of SO₂ which may be permitted in the area surrounding the emission source.

15. For all Bank projects ambient air concentrations of sulfur oxides should not exceed the following for new plants:

Inside plant fence	Annual Arith. mean: Max. 24-hr. peak	100 $\mu\text{g}/\text{m}^3$ 1000 $\mu\text{g}/\text{m}^3$
Outside plant fence	Annual Arith. mean: Max. 24-hr. peak	100 $\mu\text{g}/\text{m}^3$ 500 $\mu\text{g}/\text{m}^3$

16. In special situations strict adherence to these standards may be difficult. All such cases are to be carefully documented by the Bank missions. Factors which may affect the ability to meet these standards include:

- Expansion of existing plant — The annual arithmetic mean and the Max. 24-hr peak resulting from the combination of the old units with the new ones should be no greater than the values obtained for the old units alone.

More simply, emission plumes from new and existing sources should not mix to the extent that combined ambient concentrations exceed maximum ambient concentrations obtained from the existing source alone. This may be accomplished by (a) increasing the stack height of the new source, (b) changing the stack location of the new source, or (c) reducing new source emission levels. Furthermore, if plume mixing is not a problem, the new source units should by themselves meet the above standards.

- Revamping of existing plants — Every effort should be made to decrease existing pollution levels and provide measures which will minimize concentrations without placing unreasonable economic burdens on the industry.

- Inversions — When the SO_2 source location is in a valley or surrounded by mountains, inversion layers which may occur during certain seasons of the year, could trap the stack emissions. These emissions can drop back to ground level, stagnate there, and damage crops sensitive to SO_2 and NO_x . In some projects, it may be impossible to change the site location (i.e. in case of an expansion of an existing plant). In this case, to protect crops, the peak concentration will be decreased from 500 $\mu\text{g}/\text{m}^3$ during 24 hours down to 350 $\mu\text{g}/\text{m}^3$ during 4 hours, unless it can be shown that the effluent will not be trapped by the inversion layer.

- Non-ferrous metal smelters — Substitutions of flash or electric furnaces may be necessary to meet guideline requirements.

17. The existing US national ambient air quality standards are given below for comparison with the above figures.

- Primary — based on health effects on humans

Annual arith. mean:	80 $\mu\text{g}/\text{m}^3$
Max. 24-hr. — once yearly:	365 $\mu\text{g}/\text{m}^3$

- Secondary — based on environmental effects

Annual arith. mean:	60 $\mu\text{g}/\text{m}^3$
Max. 24-hr. — once yearly:	260 $\mu\text{g}/\text{m}^3$
Max. 3-hr. — once yearly:	1300 $\mu\text{g}/\text{m}^3$

CONTROL TECHNOLOGY

18. Technology to be applied for control of emissions must be designed for each individual case since, in most instances, the system used must be capable of removing or reducing more than one pollutant at the same time.

19. Since SO_2 emissions are due principally to the content of sulfur and its compounds in the coal and oil used for fuel, the first measure to be considered is the substitution of low sulfur fuels or natural gas. Any increase in fuel costs should be balanced against the cost of treating the gaseous wastes.

20. Emissions may be reduced through process changes. In-plant measures could include changing raw materials, modifying process operations, or recovering and reusing materials otherwise being wasted through the stack. Raising the point of discharge above the ground, by increasing the stack height, will reduce contaminant concentrations at ground level.

21. When measures such as those outlined above cannot be applied, chemical or physical processes should be utilized. Sulfur dioxide may be removed by adsorption, absorption, or a chemical process such as catalytic conversion. In some of these processes, the SO_2 can be removed and serve as the raw material for sulfuric acid production.

22. One of the promising methods for flue gas desulfurization utilizes the reaction of magnesium oxide with SO_2 to form magnesium sulfite. The magnesium sulfite solids are separated by centrifuging, dried to remove the moisture, and then calcined to regenerate the magnesium oxide for recycling, and generate concentrated SO_2 to be used for sulfuric acid production.

23. Limestone scrubbers have been used successfully for desulfurization of flue gases. Injection of lime or magnesium into the fuel combustion chamber has also been effective in reducing sulfur dioxide emissions. However, it should be noted that these processes produce calcium sulfate wastes, which can present a disposal problem. They are therefore recommended in areas where land is both available and inexpensive.

24. Ammonia scrubbing systems have been in successful operation in sulfuric acid plants since the mid 1930's. The main drawback has been the disposal of the ammonium sulfate by-product. Any World Bank financed sulfuric acid plant where the sponsor insists on a single absorption design should be equipped with ammonia scrubbing.

BIBLIOGRAPHY

1. U.S. Environmental Protection Agency. "Health Effects of Air Pollution". Washington (June 1976).
2. "Environmental Considerations for the Industrial Development Sector". The World Bank. Washington. (August 1978).
3. Pasztor, L., Selmeczi, J. G., and Labovitz. C. "Stack Gas Desulfurization Residue Management". Presented at National Conference on Management and Disposal of Residues from Treatment of Industrial Wastewaters. Washington (February 3-5, 1975).
4. U.S. Environmental Protection Agency. "Capsule Report-Flue Gas Desulfurization and Sulfuric Acid Production Via Magnesia Scrubbing". Doc. EPA-625/2-75-007. Washington, (1975).
5. "Air Quality Criteria and Guides for Urban Air Pollutants". Report of a WHO Expert Committee. WHO Technical Report Series No. 506. World Health Organization. Geneva (1972).
6. Andrews, W.A. Moore, D.K., and LeRoy, A.C. "A Guide to the Study of Environmental Pollution". Prentice-Hall, Inc. Englewood Cliffs, New Jersey (1971).
7. "Manual on Urban Air Quality Management". European Series No. 1 World Health Organization, Regional Office for Europe. Copenhagen (1976).
8. Ismerov, N.F. "Control of Air Pollution in the USSR". Public Health Paper No. 54. World Health Organization. Geneva (1973).
9. Proceedings - "Seminar on Desulfurization of Fuels and Combustion Gases". UN Economic Commission for Europe, Held in Geneva, 16-20 November 1970. Doc. ST/ECE/AIR POLL/1. United Nations, New York. (1971).

10. Proceedings - "Seminar on Control of Emissions from the Non-Ferrous Metallurgical Industries". UN Economic Commission for Europe. Held in Dubrovnik, 19-24 November 1973. Doc. ECE/ENV/5. United Nations, New York (1974).
11. U.S. Environmental Protection Agency. "Performance Test Methods". Doc. EPA 340/2-78-011. Washington, D. C. (1978).

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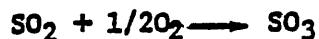
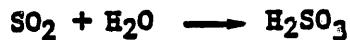
DECEMBER 1982

OFFICE OF ENVIRONMENTAL AFFAIRS

SULFUR DIOXIDE SAMPLING AND ANALYSES

1. This document supplements an earlier Bank document, titled "Sulfur Dioxide Emissions", by providing specific details on the collection and analysis of samples. Both documents should be reviewed and the guidelines applied as required in situations involving sulfur dioxide emissions, and related oxides.

2. When released to the atmosphere, sulfur or its compounds will react with the oxygen in the air to form mainly sulfur dioxide. When exposed to moisture the dioxide can undergo the following reactions:



3. Two types of monitoring will be required in connection with industrial operations: The first is stationary source or stack emission testing, to determine emission concentrations at the source. The second type is ambient monitoring, which measures the pollutant concentrations in the areas surrounding a plant.

STATIONARY SOURCE MONITORING

Sampling

4. Stack sampling ports should be provided, and located at least eight stack diameters "downstream" of any bends, constrictions, abatement equipment, or other flow disturbances. If this is not possible then the sampling location should be at least two stack diameters "upstream" of the stack exit or other flow disturbance. Where these criteria cannot be met a stack extension may be required. Ports should be installed flush with the interior stack wall, and extend outward from the exterior stack wall for between 5 and 20 centimeters, unless additional length is needed for installation of gate valves or other appurtenances.

5. If the sum of the stack inside diameter plus one port length is less than 3 meters, two ports should be installed on diameters, 90 degrees apart. If this sum is greater than 3 meters, then four ports should be installed on diameters 90 degrees apart.

6. For SO_2 , a gas sample is taken at a single sampling point located at the center of the stack, or no closer to the inside wall than 1 meter, for large-diameter stacks. The gas sample must be drawn at a continuous rate through a sampling train similar to that shown in Figure 1. It may be advisable to conduct a series of exploratory tests across a stack to determine whether the gas which is being measured is uniform in concentration or stratified.

7. As the gas passes through the sampling apparatus, the sulfuric acid mist and sulfur trioxide are separated and the sulfur dioxide is removed by a chemical reaction with a hydrogen peroxide solution. Upon completion of the sample the H_2SO_4 mist and the SO_3 are discarded. The collected material, containing the SO_2 , is recovered for analysis at the laboratory.

8. The minimum sampling time is 20 minutes per sample. Two separate samples constitute a "run". Three runs are normally taken, giving six separate portions. An interval of at least 30 minutes should elapse between each sample. Longer sampling times may be required if larger samples are needed. It is important that constant process operations, preferably at maximum levels, be maintained during the duration of the sampling periods.

9. Current technology for continuous monitoring of stack gases is in a state of flux. Most units are subject to interference from pollutants other than that being analyzed. The units are also subject to electronic instability.

Analyses

10. Sulfur dioxide concentration in stack samples may be measured by the barium-thorin (*) titration method, currently designated as a reference method by the U.S. Environmental Protection Agency. The minimum detectable limit by this method has been determined to be 3.4 milligrams of SO_2 per cubic meter (mg/m^3).

11. Tests have shown that SO_2 concentrations as high as $80 \text{ mg}/\text{m}^3$ can be efficiently collected in two midget impingers, each containing 15 milliliters of 32 percent hydrogen peroxide, at a rate of one liter per minute for 20 minutes. Based on theoretical calculations, the upper concentration limit in a 20-liter sample would be about $93,300 \text{ mg}/\text{m}^3$. The barium-thorin method is also applicable in these ranges.

12. Some laboratories specify a sampling method that collects sulfuric acid, sulfur trioxide, and sulfur dioxide. The analysis then gives total sulfur oxides. This method usually yields values from one to five percent higher than those obtained by the barium-thorin method, in which the sulfur trioxide and sulfuric acid are discarded.

(*) The Thorin indicator is 1 - (o - arsenophenylazo)
- 2 naphtol 3, 6 disulfonic acid, disodium salt.

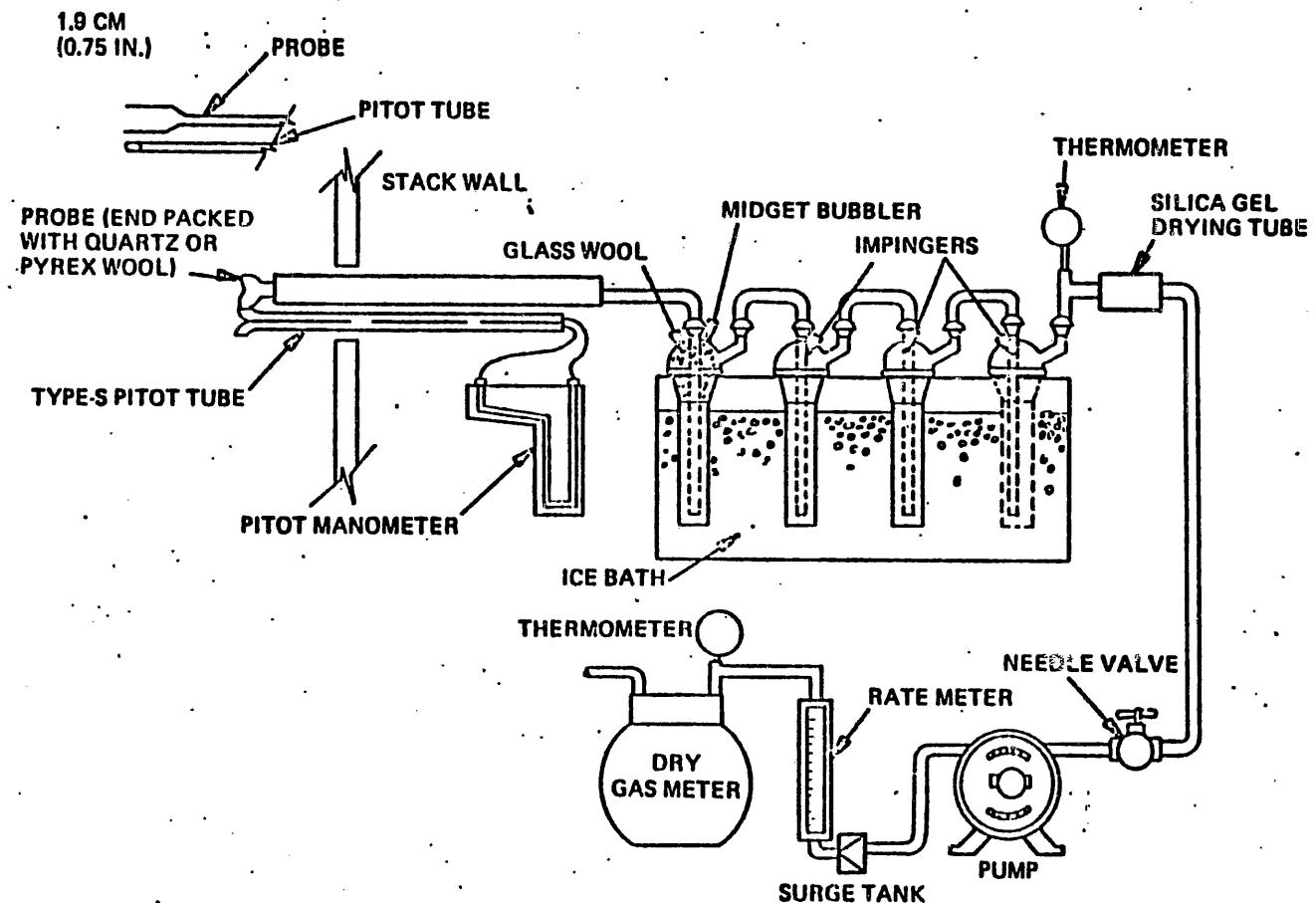


Figure 1. Sulfur Dioxide Sampling Train (From Reference EPA-625/6-78-004).

AMBIENT AIR MONITORING

Sampling Site Selection

13. The number of points to be included in an ambient air monitoring network will depend largely on the data required to meet the stated program objectives. For a small source, where one wind direction predominates, monitors are usually operated at two sites: one to monitor the effects of the source and the other to provide upwind or background concentrations. Where wind directions are variable or other similar emission sources are operating nearby, additional sampling points will be required to identify the concentrations that are attributable to specific sources.

14. The principal factors in setting up the sampling locations are topography and meteorology. Other considerations include:

- (a) Location of the sampling site, in terms of the pollutant source, accessibility, and operation.
- (b) Delivery of samples to the location of laboratory facilities.
- (c) Handling of sample to prevent deterioration or conversion of pollutant to a form that would produce an inaccurate result. Sample temperatures, between the collection point and the laboratory, should be kept under 29° C.
- (d) Availability of suitable analytical procedures and instrumentation for generating acceptable quantitative and qualitative data.
- (e) Legal restrictions (such as effluent limitations) affecting the discharges from existing sources.

15. It is desirable to place the collection devices in the areas most likely to receive the highest ground-level concentrations of pollutants. The path of pollution from the emission source to the point of ground-level impact may be predicted roughly from a knowledge of predominant wind directions. A convenient tool for performing such an analysis is the "wind rose", a chart which plots the wind directions and the percentage of the time, annually, that the wind is blowing from that direction. Where more precise information is required for site selection, computerized atmospheric dispersion models may be necessary.

Sample Collection

16. Ambient sulfur dioxide levels may be monitored by two principal techniques: (a) the dynamic sampler, which utilizes a bubbler train and provides 24-hour analyses and (b) the continuous sampler which utilizes various instrument techniques and provides variable time averages. Static samplers, such as the sulfation plates, are very crude and imprecise, and are no longer considered useful for this purpose.

17. The dynamic and continuous sampling units usually consist of a system incorporating several components, as shown in Figure 2. A typical dynamic collection systems would include an inlet section, absorption section, flow regulation device, and a pump, as the prime mover.

18. A typical continuous monitoring device would consist of an inlet section, gas pretreatment section, detector, photomultiplier, spectrometer, and readout device. Depending upon the conditions of the gas to be monitored, the pretreatment section could include pressure adjustment, removal of particulates (usually a filter), removal of moisture (usually a silica gel column) and temperature adjustment (usually a condenser).

Analyses

19. The U.S. Environmental Protection Agency, after examination of the various methods used world-wide, has adopted the pararosaniline method for determination of sulfur dioxide in the atmosphere. In this method the sulfur dioxide is absorbed in a solution of potassium tetrachloromercurate. A complex is then formed, which is stable to strong oxidants. The complex is reacted with pararosaniline and formaldehyde to form paraosaniline methyl sulfonic acid. The absorbance of the solution is then measured spectrophotometrically. This is the method to be used in connection with World Bank projects. The method is applicable to the measurement of sulfur dioxide in ambient air, using sampling periods of up to 24 hours.

20. Concentrations of sulfur dioxide in the range of 25 to 1050 micrograms per cubic meter ($\mu\text{g}/\text{m}^3$) can be measured by this method. Concentrations below $25 \mu\text{g}/\text{m}^3$ can be measured by sampling larger volumes of air, but only if the absorption efficiency of the particular system is first determined. High concentrations may be analyzed by using smaller gas samples, a larger collection volume, or a suitable aliquot of the collected sample.

BIBLIOGRAPHY

1. UN Economic and Social Council, ECE. "Draft Report on Effects of Sulfur Compounds on Soil, Groundwater, and Vegetation". Doc. ENV/IEB/WG.1/R.5. New York (28 June 1982).
2. "Pollution Engineering Practice Handbook". Edited by P.N. Cheremisinoff and R.A. Young. Ann Arbor Science Publishers, Ann Arbor, Michigan (1976).
3. UN Economic and Social Council, ECE, :Cooperative Programme for Monitoring and Evaluation of Long-Range Transmission of Air Pollutants in Europe (EMEP)". Doc. ENV/IEB/R.12. New York (5 August 1981).
4. U.S. Environmental Protection Agency . "Handbook-Industrial Guide for Air Pollution Control". Document EPA-625/6-78-004. Washington (June 1978).

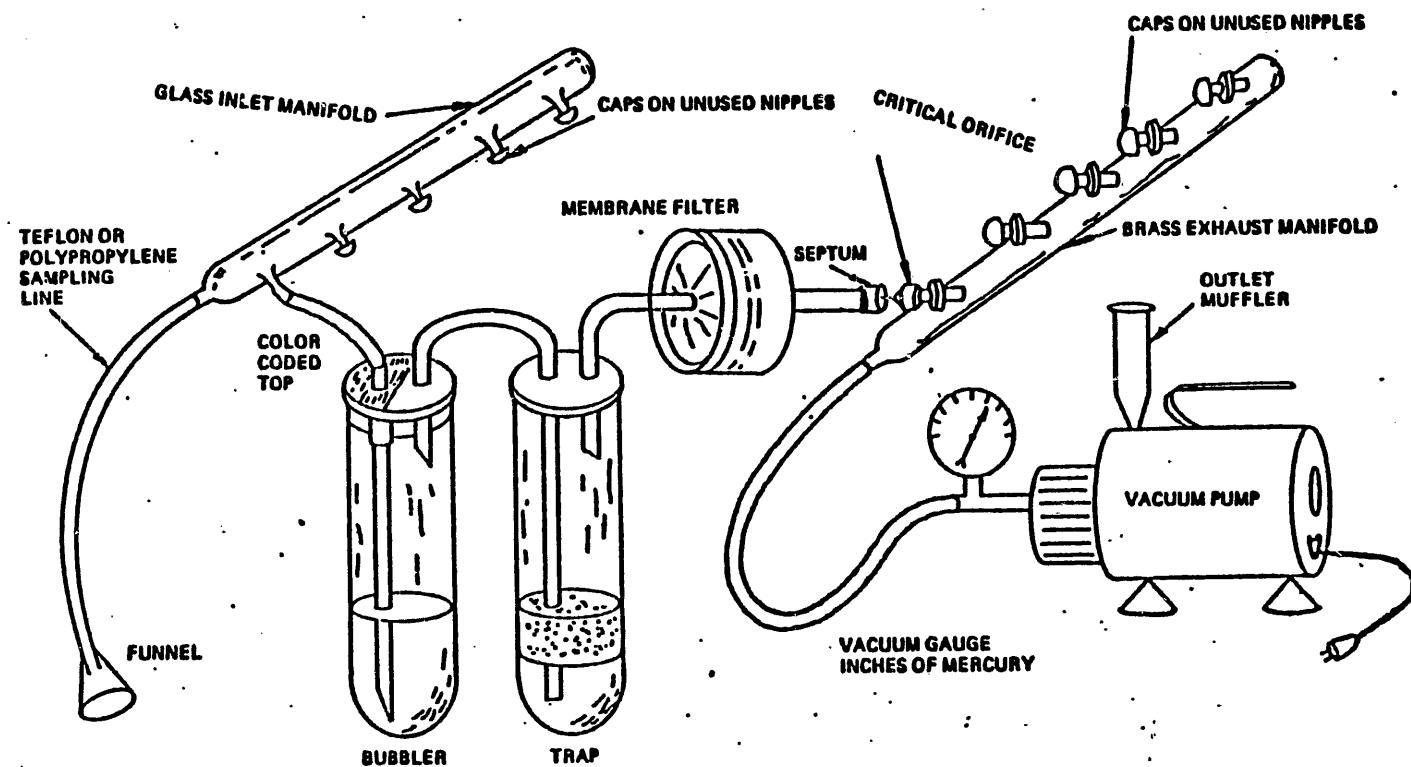


Figure 2. Dynamic (Bubbler Train Sampling Unit (From Reference EPA-625/6-78-004).

5. U.S. Environmental Protection Agency. "Handbook-Continuous Air Pollution Source Monitoring Systems". Document EPA 625/6-79-005. Washington, D. C. (June 1979).
6. U.S. Code of Federal Regulations, Title 40, Subchapter C, Part 50, Appendix A. "Reference Method for Determination of Sulfur Dioxide in the Atmosphere (Pararosaniline Method)". Office of the Federal Register, GSA. Washington. (July 2, 1981).
7. Ball, R.J. and Anderson, G.E. "Optimum Site Exposure Criteria for SO₂ Monitoring". USEPA Publication No. EPA-470/3-77-013. Research Triangle Park, N. C. (April 1977).

OFFICE OF ENVIRONMENTAL AFFAIRS

LEATHER TANNING AND FINISHING

1. Tanning is the process by which animal skins are converted into leather. The skin consists of three layers: flesh, derma or corium and epidermis. The epidermal and corium layers constitute the leather making portion, consisting mainly of the protein collagen. Basically, leather is formed by the reaction of collagen fibers with tannin, chromium, alum or other tanning agents.
2. Waste production in the leather tanning and finishing industry will be affected by the manufacturing process used to convert various types of animal skins to the tanned and finished leather. In terms of the waste loads, four general processes are used in this industry: beamhouse; tanhouse; retan, color and fatliquor; and finishing. The principal chemicals employed in these processes include lime, sodium sulfide and sulfhydrate, basic chromium sulfate, vegetable compounds, mineral acids and sodium chloride.
3. This document will deal with the processing of cattle hides, sheep skins and pig skins. These are the raw materials of principal concern in Bank projects, and will serve as typical examples for illustrating waste production and control in this industry.

INDUSTRIAL PROCESSES

Cattle Hide Tannery

4. The beamhouse process provides for receiving the hides and for the initial cleaning and preparation for the other operations. Nearly all hides as received will have been trimmed and graded, and salted or brined at the meat packing plant prior to shipment to the tannery. They are normally received and stored at the tannery in packs of 1.5 to 2 meters high. The moisture content in the hides, as received, is maintained during storage.
5. The first step in the processing is to unfold and trim each hide, and cut it in half along the backbone, the step being frequently referred to as halving or siding. The trimmings are collected for shipment to glue or other by-product manufacturing plants.
6. The sides (or whole hide, in some instances) are transferred to vats, drums, or hide processors for washing and soaking to restore moisture. This serves to remove dirt, salt, blood, manure and non-fibrous proteins from the skins.
7. The skins are next transferred to a fleshing machine, in which they are carried through rolls and across rotating spiral blades to remove any flesh still clinging. Most hides are fleshed at the packing house or in a separate facility. Fleshings are normally recovered and sold for rendering or conversion to glue. With proper handling this operation contributes very little liquid or solid waste.

8. The final beamhouse operation is the removal of hair. This is done by chemical loosening, followed by either machine pulling or chemically dissolving the hair. Machine removal is practiced where the hair is to be recovered. Removal is accomplished in vats, drums or hide processors with a lime slurry. "Sharpeners", such as sodium sulfide and sodium sulfhydrate, are added in varying strengths depending upon whether or not the hair is to be saved. The unhairing process is one of the principal waste sources in tannery operations.

9. The basic tanning is accomplished in the tanhouse process. The first step is the "bating", which prepares the stock for tanning. The hides are placed in a solution of ammonium salts and enzymes in order to de-lime the skins, reduce smalling, peptize fibers and remove the protein degradation products. Bating is followed by "pickling", frequently done in the same containers. A brine and acid solution is used to bring the hides to an acid condition for subsequent tanning. This treatment also prevents precipitation of chromium salts in the chrome tanning procedure.

10. Nearly all cattle hides are either chrome or vegetable tanned. In a few instances alum or other tanning materials are used. For heavy leathers such as sole, mechanical, and saddle leathers, vegetable tanning is used, in a solution containing vegetable tanners or other plant extracts. Shoe upper leathers are usually tanned in a bath containing chromium sulfate. The tanned hide is then split to produce a grainside piece of essentially constant thickness and a flesh side layer.

11. The retan, color and fatliquor operations constitute the third major step. Retanning is done principally to impart different characteristics to the finished leather. Chrome, vegetable, or synthetic tanning agents may be used for this purpose. Bleaching with sodium bicarbonate and sulfuric acid commonly follows the tanning in producing sole leather. Coloring is done in the same drums as the retanning, using natural dyes or synthetic products. The fatliquoring operation adds oils to the leather in order to replace the natural oils lost in the beamhouse and tanhouse procedures.

12. After the wet processes the hides are subject to the finishing steps such as drying, staking or tacking, and plating prior to marketing. Staking or tacking involves stretching the hide to make it more pliable and avoid shrinkage. The plating operation "presses" the hide in order to give it a smoother surface.

Sheep Skin Tannery

13. Sheep skin tanneries generally omit the beamhouse process but do include a degreasing operation. Thus, the three major processes are the tanhouse; retan, color and fatliquor; and the finishing.

14. The tanhouse process includes receiving, storage, fleshing, degreasing, tanning and reflashing. After fleshing, the skins are placed in drums, washed, and soaked. A solvent or detergent is then added to remove the grease, which is recovered as a by-product from those skins where the wool has been removed. Grease recovery is not normally practiced when the wool (shearlings) is still attached to the skin. The solvent is recovered and reused.

15. Sheep skins may be either chrome or vegetable tanned, with chrome being most frequently used. Where skins are received in the pickled condition there are no liming or bating operations. In some cases tanning is followed by reflashing, which results in a small amount of solid wastes.

16. Skins to be dyed are immersed in drums containing a dye (usually synthetic) solution. Some bleaching may be done prior to coloring of shearlings. Fatliquoring follows the dyeing, and is usually carried out in the same containers.

17. The finishing process, following the color and fatliquor operations, includes drying, skiving, (removal of the skin's thin surface layer), staking, carding, clipping, sanding (use of abrasives or wheels to produce a specific texture), and buffing.

Pig Skin Tannery

18. Pig skin tannery operations are similar to those for sheep skins. There are essentially no beamhouse operations, but degreasing is generally required in the tanhouse processing. The skins are received at the tannery in a fresh frozen or brined and refrigerated state. Refrigerated storage is provided if they are to be held before tanning.

19. Degreasing is practiced by many of these tanneries. After washing and soaking in warm water a solvent is added to remove the grease. The resulting solution of solvent, grease, and water is pumped to large tanks, where some separation is achieved by decanting. The solvent is recovered for reuse. Grease is recovered by decanting or skimming from the top of the holding tanks.

20. Liming (to remove embedded hair), bating, and pickling follows the degreasing. Tanning is done next, using either chrome or vegetable compounds. Pig skins are generally fully tanned at this point, thus eliminating the need for retanning. After tanning, the skins are tumble dried, split, and shaved or skived to produce the desired thickness. The splits (small pieces of non-uniform thickness) are sold for fertilizer production.

21. From the tanhouse, the skins go to the coloring and fatliquoring operations. The drying, coating, staking, and sanding operations follow next to complete the process. These are principally dry operations and are considered as minor sources of wastes.

WASTE SOURCES AND CHARACTERISTICS

22. Wastes from tannery operations will contain a number of constituents, of varying quantities and significance according to the raw materials, processes and final products. Materials which can appear in tannery wastes include hair, hide scraps, pieces of flesh, blood, manure, dirt, salt, lime, soluble proteins, sulfides, amines, chromium salts, tannin, soda ash, sugars and starches, oils, fats, greases, surface agents, mineral acids, dyes and solvents.

23. Waste constituents, when present, may be discharged in the gaseous, liquid, or solid state. The liquid wastes are of major significance. However, gaseous and solid materials are important in certain individual operations, and consideration should be given to their disposal.

24. The most important parameters for defining the characteristics of the liquid wastes are: 5-day biochemical oxygen demand (BOD_5); total Kjeldahl (ammonia plus organic) nitrogen (TKN); total suspended solids (TSS); chromium (Cr); oils and greases (O/G); sulfides; hydrogen-ion concentration (pH); and fecal coliform organisms.

25. Particulate matter and hydrogen sulfide are the two potential gaseous discharges of significance. The principal sources of hydrogen sulfide are the reactions involving sulfide wastes from unhairing operations. The removal of nitrogen from the wastes by ammonia stripping, when required, creates another potential air pollution problem. Emissions from tannery boilers can also be a source of gaseous discharges, and fly ash emissions generally occur when coal is used as a fuel. Sulfur dioxide will be found in boiler stack gases when high sulfur coals or heavy fuel oils are burned.

26. Solid wastes include fleshings, hair hide trimmings, sanding dusts, sludges, greases and general plant wastes. Most plants recover fleshings and raw hide trimmings for sale to rendering plants or conversion into glue. Where hair is recovered, it is sold as a by-product.

27. In terms of liquid wastes, certain operations are common to nearly all tanneries. These include: washing and soaking; degreasing (for sheep and pig skins); unhairing; bating, pickling; tanning (including bleaching for some vegetable tanning); retanning; coloring; fatliquoring and finishing. The principal waste constituents contributed by each of these various operations are presented in Table 1.

28. Not all plants utilize all of the operations indicated in Table 1. Based on the combinations most frequently encountered in the industry, tanneries may be categorized by primary processes, as shown in Table 2. The color and fatliquor processes are not included since their wastes are normally of very low strength, even though highly variable in volume.

Table 1. Principal Liquid Waste Constituents Contributed By Specific Operations.

Operation	Waste Constituents
Washing and Soaking	BOD ₅ , TSS
Degreasing	BOD ₅ , TSS, O/G
Unhairing	BOD ₅ , TSS, pH, Sulfides, Nitrugens
Bating	Ammonia nitrogen
Pickling	Acids, salts
Tanning	Chromium, vegetable tannins
Retanning, Coloring, Fatliquoring	Color, Oil
Finishing	Essentially none

29. Average raw waste water characteristics based on the categories given in Table 2, are presented in Table 3 for the more important pollution parameters.

EFFLUENT LIMITATIONS

30. The collection and disposal of gaseous and solid wastes should provide for essentially no discharge of such materials to the environment. The sources and methods of handling these substances are discussed below.

31. Limitations on liquid effluent discharges to surface waters are presented in Table 4. These are based on the best technology currently available and considered to be economically feasible.

32. Liquid effluent quality requirements for industries discharging to municipal sewers can be less stringent than those discharging to a water course. However, wastes discharged to municipal facilities usually will require some degree of pretreatment, depending upon the volume and strength of the wastes, degree of municipal treatment and local regulations.

Table 2. Plant Categories By Primary Processes. a/

Category	Primary Process		
	Beamhouse	Tanning	Finishing
A	Pulp Hair	Chrome	Yes
B	Save Hair	Chrome	Yes
C	Save Hair	Vegetable	Yes
D	Hair Previously Removed	Previously Tanned	Yes
E	Hair Previously Removed or Retained	Chrome	Yes
F	Pulp or Save Hair	Chrome or No Tanning	No

a/ From EPA Doc. 440/1-74-016-a

CONTROL AND TREATMENT OF WASTES

33. While there are variations in individual operations between plants, available control and treatment techniques are generally applicable to most situations. Control of wastes is accomplished through a combination of in-plant measures, disposal to municipal facilities, or discharge to the air, water and land environments.

Gaseous Wastes

34. Gaseous emissions of hydrogen sulfide, principally from the unhairing procedures, may be controlled by oxidation of the sulfides with a catalyst prior to discharge to the main plant sewers. This not only avoids potential air pollution and odor problems but also protects the safety of workers exposed to the waste streams. Removal of nitrogen through biological systems rather than by ammonia stripping avoids potential problems created by venting ammonia from highly concentrated wastes.

Table 3. Average Tannery Raw Wastewater Characteristics -
Kg per Megagram of Raw Hides Processed. a/ b/

Parameter	Category					
	A	B	C	D	E	F
Flow	53	63	50	20	63	28
BOD ₅	95	69	67	37	67	110
TKN	17	13	9.2	3.7	6.0	16
TSS	140	145	135	47	88	110
Tot. Cr	4.3	4.9	0.2	2.6	1.2	4.4
O/G	19	43	33	7.9	24	6.6
Sulfides	8.5	0.8	1.2	2.1	4.5	3.7
pH	1.0- 13.0	4.0- 12.6	2.0- 13.0	3.4- 11.2	1.5- 12.5	9.2- 10.4

a/ From EPA Doc. 440/1-74-016-a.

b/ Except flow and pH. Flow = m³/Mg Raw Hides Processed.
1 megagram = 1 metric ton

35. In addition to process sources, air pollution problems can also result from operation of the tannery boilers. Wet scrubbers or electrostatic precipitators can remove over 98 percent of the fly ash from coal fired facilities. Sulfur dioxide emissions can be greatly reduced by burning coal and fuel oils having a low sulfur content. Gas scrubbers capable of removing sulfur dioxide from boiler flue gases are currently under development.

Liquid Wastes

36. The use of hide processors (essentially concrete mixers), in place of vats, paddles, or drums, will greatly reduce water consumption in applicable wet processing operations. Other in-plant measures to reduce waste flow include: employee awareness and application of water-saving measures, changing continuous rinses to batch rinses; using meters or timers to limit individual flows, and use of wash or rinse waters for process solution makeup.

Table 4. Daily Maximum Effluent Limitations - Leather Tanneries.

Constituent a/	Plant Category					
	A	B	C	D	E	F
BOD ₅	2.8	3.2	2.6	1.0	3.2	1.4
TSS	3.0	3.6	2.8	1.2	3.6	1.6
O/G	1.1	1.3	1.0	0.48	1.3	0.68
Sulfides	0.010	0.012	0.010	0.004	0.012	0.006
Tot. Cr	0.10	0.12	0.10	0.04	0.12	0.06
TKN	0.54	0.64	0.50	0.20	0.62	0.28
pH	6.0 to 9.0					
Fecal Col.	Not over 400 per 100 mL					

a/ All limitations, except pH and Fecal Coliforms, expressed as kg/Megagram of Raw Hides Processed.

37. Tan liquor discharges can be reduced through recycling in vegetable tanneries or reuse in retanning operations. Chrome tanning solutions can be regenerated and reused by settling the spent liquor, and adding chromium salts, sulfuric acid, and sodium chloride to restore the proper concentration. Un-hairing solutions are also amenable to "regeneration" and reuse. Final disposal of chrome liquors should be given special attention, since chrome in its various valence states is hazardous to man, aquatic life, and vegetation. The chrome can be precipitated, in clarifiers or equalization basins, as chromium hydroxide at a pH of 8.5 to 10.5. Disposal of chrome sludges is discussed below, in paragraph 41.

38. Pretreatment may be required for sewer safety and maintenance, protection of biological treatment systems, meeting final effluent discharge limitations, or conforming with sludge disposal criteria. The following methods, alone or in combination, may be applied for this purpose: screening, flow equalization, sedimentation, coagulation, pH adjustment, and separate sludge disposal.

39. For plants discharging wastes directly to surface waters, on-site treatment should be provided in order to meet effluent limitations. Biological systems are most effective. The specific system to be used should be designed for the volume and characteristics of the wastes discharged. Trickling filters aerobic and anaerobic lagoons, and activated sludge systems have been effective.

40. Additional treatment may be required in certain cases. When there are high concentrations of nitrogen compounds, nitrogen removal may be necessary. Microscreening, carbon adsorption (using fixed beds of activated carbon), color removal, ion exchange, and reverse osmosis are effective in providing additional treatment where necessary.

Solid Wastes

41. Sanitary landfills are best suited for disposal of those solid wastes which are not recovered as valuable by-products. Incineration and high temperature treatment are not recommended for sludges or other wastes containing chrome, to avoid oxidation of the chrome from the trivalent to the hexavalent state. These sludges should be spread on land until such time as their impact upon the environment is better understood.

42. Proper selection of a site for use as a landfill is of primary importance in avoiding environmental damages. Site selection factors should include: sufficient area; reasonable haul distance; distance from existing or planned residential, commercial and recreational areas; soil conditions and rock formations; access to transportation networks; location of existing flood plains; and potential fire hazards.

BIBLIOGRAPHY

1. "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Leather Tanning and Finishing Industry". U.S. Environmental Protection Agency. Document EPA-440/1-74-016-a. Washington (March 1974).
2. Villa, J.A. "The Interrelationship Between Parameters of the Leather Industry". UN Industrial Development Organization. United Nations. New York (1973).
3. "Information Sources on the Leather and Leather Goods Industry". UN Industrial Development Organization, Guides to Information Sources No. 3. United Nations. New York (1972).
4. "International Glossary of Leather Terms". International Council of Tanners. London (1967).
5. Harris, D. "Dictionary of Terms Used in the Hides, Skins, and Leather Trade" Agriculture Handbook No. 465. U.S. Dept. Agriculture. (April 1974).

THE WORLD BANK

OCTOBER 1980

OFFICE OF ENVIRONMENTAL AFFAIRS

GUIDELINES

TEA AND COFFEE PRODUCTION

1. Tea can be grown under a wide range of climatic conditions, from Mediterranean to tropical. Developing countries in South Asia and East Africa account for about 97% of world tea production and exports. During the period 1971-1973 India accounted for 39.2%, Sri Lanka 18.6%, Japan 8.2%, and other Asian countries for 18.9% of world production. In the same period Kenya accounted for 4.3%, Malawi and Uganda for 1.8% each, and other African countries for 4.2% of the total world production. Latin America accounted for 3% of the total, of which Argentina was responsible for 2.4%. Total world production during this period was over 3.5 million metric tons.

2. Latin American has been the dominant world coffee producer during the last 100 years. During the period 1968-1972 South America accounted for 43.3%, with Brazil in the lead at 26.4% and Colombia next, at 12.1%. North and Central America and the Caribbean area accounted for 18.5% of world production, with Mexico, Guatemala and El Salvador being the leading producers. During this same period 30.2% of the world production came from Africa, with Ethiopia, Angola and Uganda in the lead. The remaining production of about 8% came from Asia, with the major portion coming from Indonesia. Over 65 million bags were produced.

MANUFACTURING PROCESS

Tea Production

3. Tea is processed by two principal methods, to yield either green or black tea. Of these, black tea is the more important in the world market. Because tea is hygroscopic—readily absorbing moisture from the air—it cannot be stored for any extended periods in most of the producing countries.

4. The first stage in black tea manufacturing is called "withering". This consists of spreading the tea leaves in thin layers on trays or "tats", made of tightly stretched jute or wire netting. The density of spreads is usually one kilogram of tea per 2 to 3m² of tray area. Banks of tats are arranged in layers, 12 to 15 cm apart, to allow for free access of air. Withering takes 18 to 24 hours.

5. In place of the withering tats some factories are using perforated revolving drums, through which hot air is blown to dry the tea leaves. Each drum can hold up to nearly 700 kg of leaf. Both space and time required to achieve the proper wither are reduced by this method.

6. Withering is followed by rolling, which twists the leaf, breaks it up, and presses out the juices. A batch of withered tea may be rolled from three to six times in half hour periods, depending upon the type of tea to be produced, the degree of wither of the leaf and the kind of roller used. The tea from the rollers is fed into a hopper, in which masses are broken up by beaters, and then fed onto the sifters to separate the small size particles.

7. The portions passing the sifters are spread into thin layers to continue the fermentation process started in the rollers. The fermentation, including that occurring in the rollers, takes 3 to 4 hours. The tea changes into a dark copper color and develops its typical aroma. Time of fermentation is critical to the quality of the final product and the soluble content capable of extraction. The coarse leaves not passing the sifters are passed again through the rollers.

8. Fermentation is followed by firing (or drying), grading and sorting. Firing takes 20 to 40 minutes, at an initial temperature of about 93°C. Worldwide, the grades in general production include Broken Orange Pekoe, Broken Pekoe, Orange Pekoe, Pekoe, Souchong, Broken Orange Pekoe Fannings, Fannings, and Dust. The sieve standards adopted for regulating grades differ among the various countries.

9. Green tea is produced and consumed mainly in China, Japan and Formosa. Morocco and Afghanistan are principal importers of this product. Preparation of the tea involves heating of the plucked leaf, either by placing into hot iron pans or by steam. It is next rolled and then subjected to subsequent firing and further rolling, during which it turns a dark olive green and finally assumes a bluish tint.

Coffee Production

10. There are two main types of coffee grown currently: arabicas and robustas. Arabicas require lower temperatures and can be grown either at higher altitudes or farther from the equator than the robustas. The robustas are grown in hot and humid climates. Arabica coffees are generally preferred by consumers, since they have a milder flavor and contain less caffeine than the robustas. In the 1968-1972 period, robustas constituted about 30 percent of world production, and arabicas accounted for the remaining 70 percent.

11. When ripe, the coffee berry changes color from green to red, and is commonly referred to as the "cherry". In most countries, the crop ripens gradually on the trees, and the cherries are picked individually, since the quality of the coffee depends upon picking ripe cherries only. Two coffee beans, face to face, are contained in each cherry. The exception is the cherry at the end of each branch, which contains only one bean. Coffee preparation may utilize either the dry process or the wet process.

12. The dry process is generally used in Brazil and in robusta-producing countries in Africa. The cherry is first sun-dried. It is then "hulled" in machines which remove the dried husk of the cherry, the "silver skin" and the "parchment" covering over the beans, thus producing the "green coffee", which is

the unroasted coffee of commerce. Where the coffee farms are large, as in Brazil, hulling and subsequent grading by size and removal of defective beans takes place on the farms. In other areas, as in Africa, this is commonly done in central plants to which the farmers sell the dried cherries.

13. The wet process is used in the countries with mild climates and, although more complicated, yields a much better quality product. The cherry is first washed to float off any stalks and "light" cherries, and then pulped to remove the flesh of the cherry. The beans are then fermented and washed to remove the silver skin. They are next thoroughly dried while still in their parchment covering, usually by sun, but sometimes by hot air. Finally, the parchment is removed by machines, and the green coffee graded and picked over for defects. The arrangements for these processes vary in different countries, but the steps are essentially the same everywhere.

14. Green coffee beans are normally roasted in revolving metal cylinders, directly or indirectly heated by gas or fuel oil. The more common method is batch roasting, in lots of 230 to 635 kg, at temperatures increasing from 200°C to 220°C over a cycle lasting from 8 to 18 minutes. The continuous roasting method utilizes a temperature of 260°C, with a contact time of about 5 minutes.

15. Either wet or dry methods are used to cool the roasted beans. In the wet process water is sprayed over the hot beans while still in the roaster. The water is partially evaporated and partially absorbed into the bean. In dry roasting the beans are cooled by air and by contact with the cooling apparatus. In order to preserve the aroma the roasted coffee should be cooled rapidly so that the oil in which the aroma lies is not lost through the surface of the bean.

WASTE SOURCES AND CHARACTERISTICS

16. Under efficient operating conditions relatively small volumes of wastes originate from the production of tea and coffee. Purely hazardous pollutants are not normally found in these wastes. Provisions must be made for disposal of human wastes originating at the plant, for which the 5-day biochemical oxygen demand (BOD_5), total suspended solids (TSS), and coliform organisms would be of significance. Acceptable methods, using biological systems, are readily available for this purpose. The human wastes can also be discharged to a municipal treatment system without any pretreatment, if isolated and kept separate from any other plant wastes. Wastes may also originate from plant cleanup operations.

Tea Production

17. Some gaseous wastes may result from tea production. Hot air from the drying operation is generally exhausted to the atmosphere, at a temperature of 50° to 55°C, as it leaves the dryers. It may also contain some leaf particles, but this should be relatively minor, since it represents a loss of product and hence a loss of profit for the plant. Atmospheric discharge of combustion products may be significant where coal or oil fired boilers are used as sources of heat. Sulfur dioxide and particle emissions may be of concern.

18. There are essentially no liquid wastes from the processing of tea. Some liquid wastes will result from cleaning operations. Daily washing of fermentation surfaces, once or more daily, is essential to avoid bacterial contamination which can cause tainted and soft teas. Rollers also require frequent cleaning. Plain water is generally adequate for washing purposes, but disinfectants are used in some plants. Washup wastes may contain some suspended solids.

Coffee Production

19. Wastes from the wet processing of cherries is generally the major process liquid flow from coffee production. This will contain pieces of stalks and other trash. Although cooling of the beans following the roasting operation does not normally produce any wastes, a few plants are reported to have wet stack scrubbers which generate small quantities of waste water. Some housekeeping operations may also generate liquid wastes.

20. Solid wastes are generated from a number of sources. Skins, hulls and other trash result from separation of the beans from the cherries in the dry process. Parchment removal, following fermentation, will produce some wastes. Cleaning of roasting equipment is normally a dry operation and can produce some waste residues.

EFFLUENT LIMITATIONS

21. Gaseous emissions, from gas or oil fuel combustion, will produce sulfur dioxide and particulates. Permissible limits are as follows:

SO₂ at Ground Level

Inside plant fence	Annual Arith. mean:	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr peak	1000 $\mu\text{g}/\text{m}^3$
Outside plant fence	Annual Arith. mean:	100 $\mu\text{g}/\text{m}^3$
	Max. 24-hr peak	500 $\mu\text{g}/\text{m}^3$

Particulates at Ground Level

Ann. Geom. Mean:	75 $\mu\text{g}/\text{m}^3$
Max. 24-hr:	260 $\mu\text{g}/\text{m}^3$

22. It is feasible to achieve essentially total elimination of liquid waste discharges to surface waters through such means as land application, ponding and lagooning, discharge to municipal treatment, or some combination of these.

23. Solid waste materials may be deposited on controlled land fills, either within or outside the plant grounds.

CONTROL AND TREATMENT OF WASTES

24. Gaseous emissions may be controlled by means of proper stack design, wet stack scrubbers, or a combination of the two. Substitution of other fuels for coal or oils, where possible, will also reduce these emissions.

25. Liquid wastes from the wet processing of cherries to separate the coffee beans contain broken stalks and other trash. This effluent may be screened to separate the solids. General housekeeping wastes will originate from both tea and coffee processing. A third possible source may be the effluent from the wet stack scrubbers, where these are used. These effluents may all be combined and disposed of by spray irrigation, lagoons, or evaporation ponds. Discharge to a municipal treatment system may be possible, either with or without pretreatment. Human wastes should be kept separate from process wastes, and disposal made to either municipal or private on-plant facilities.

26. Solid materials are best disposed of by depositing on land, in controlled areas either within or outside the plant grounds. Where necessary, suspended materials should be separated from the liquid carrier by screening, settling, or other means. Selection of a land site for disposal of solid wastes should consider such factors as sufficient area; reasonable haul distances; distance from existing or planned residential, commercial and recreational areas; natural drainage and runoff patterns; and soil conditions.

BIBLIOGRAPHY

1. Singh, S., deVries, J., Hullay, J.C.L., and Yeung, P. "Coffee, Tea, and Cocoa - Market Prospects and Development Lending". World Bank Occasional Papers, No. 22. The World Bank. Washington (1977).
2. Eden, T. "Tea". 2nd Ed. Longman, Green and Co. Ltd. London (1965).
3. Harler, C.R. "Tea Manufacture". Oxford University Press. London (1963).
4. Rowe, J.W.F. "The World's Coffee". H.M.S. Office. London (1963).
5. Haarer, A.E. "Modern Coffee Production". Leonard Hill Books Ltd., London (1962).
6. U.S. Environmental Protection Agency. "Draft Development Document for Effluent Limitation Guidelines and New Source Performance Standards for the Miscellaneous Foods and Beverages Point Source Categories". Prepared by Environmental Science and Engineering, Inc., Gainesville, Florida (February 1975).

OFFICE OF ENVIRONMENTAL AFFAIRS

TEXTILE AND SYNTHETIC FIBER INDUSTRIES

1. The basic raw materials in the textile industry are wool, cotton and man-made fibers, with the most important man-made fibers being rayon, acetate, nylon, acrylic, polyester, polypropylene and glass fiber.

2. With the exception of silk, the natural fibers are available in staple (or short fiber) form. The man-made fibers are available as either staple or continuous filament forms. In the staple form, the elements are spun into yarn. Both forms, in turn, are woven or knitted into fabrics. In most cases fabrics are dyed and treated to impart shrink resistance, crease resistance, and other characteristics, and then delivered to manufacturers for production of textile commodities. Fabrics may also be sold as grey, bleached or printed goods.

3. Both dry and wet processes are used to transform fibers into fabrics and thence into final products. Dry processing includes spinning, weaving, knitting, bonding and laminating. The major wet processes--from which effluent disposal problems arise--include scouring, desizing, mercerizing, bleaching, dyeing and finishing.

MANUFACTURING PROCESSES

Wool Fibers and Fabrics

4. The initial treatment given to raw wool after shearing is a scouring or washing in order to free it from natural grease, soluble salts (from the perspiration of sheep), and sand and dirt which are always present. Scouring may be accomplished either with detergents or solvents, with the detergents being most commonly used. The process is carried out (usually) in a series of open bowls (or baths). The first ones contain sodium carbonate and a little soap or ionic detergent. The next bowls contain a small quantity of ionic detergent, and the final bowl contains only water. Essentially, the first bowls provide the detergent or alkali solvent and accomplish the scouring, while the last bowls perform the rinsing. Solvents such as carbon tetrachloride, petroleum ether, or kerosene are also sometimes used to remove the grease and other impurities.

5. The next step is the carbonizing, to remove cellulosic impurities present as vegetable burrs and seeds or as vegetable fibers in the form of loose wool. The process consists of impregnating the material with a dilute solution of a mineral acid (generally sulfuric), drying, baking, and subjecting the wool to mechanical action to remove the degraded cellulose as dust.

After carbonization, the wool is thoroughly rinsed and neutralized with sodium carbonate, and the materials rinsed again before the fulling and dyeing operations.

6. The fulling process shrinks and thickens the goods, as required by the final use to be made of the material. Either alkali or acid fulling are commonly employed. The alkali method utilizes soap or detergent, sodium carbonate, and sequestering agents. In the acid process the wool is impregnated with an aqueous sulfuric acid solution. After either method the goods are washed to remove the fulling chemicals. Wool is dyed either as yarn or as woven piece goods, with dye formulations varying according to the final use of the goods. One of three classes of dyes are generally used: acid, metallic, or mordant (chrome) dyes. The use of mordant dyes is diminishing.

Cotton Fibers and Fabrics

7. Raw cotton is received in bales, opened, cleaned, mixed and thoroughly separated. It is next carded, a process in which the fibers are separated and aligned in a thin web, and then converted into a continuous untwisted strand called a "sliver". In some cases it is necessary to comb the sliver to remove short fibers and tangles, and to place the fibers in parallel to each other. Several strands of sliver are then combined into a single strand and drawn in order to improve sliver uniformity. The sliver is then further reduced in size and wound around a bobbin to form a "roving". The roving is transferred to a spinning frame to produce a yarn of specified twist and strength. The yarn from several bobbins is wound onto a large spool and fed to a "warper". Several warper beams are wound together, fed through sizing machines, and then wound on a loom beam for use in the weaving operation.

8. Prior to weaving, the finished yarn is strengthened by "slashing". This requires coating the warp yarns with "sizing" to stiffen or strengthen them to minimize yarn abrasions during the weaving operation. Starch, starch substitutes, polyvinyl alcohol, carboxy methyl cellulose, gelatin glue, and gums are among the sizing agents generally used. After slashing, the yarns are woven into fabrics. Excess sizing is removed from the woven fabrics, and the fabric rinsed clean. Desizing is followed by scouring or "kiering" (boil out), using hot alkaline detergents or soap solutions to remove cotton wax and other non-cellulosic components. The scoured goods receive a final rinse to remove residual detergents or soaps.

9. After scouring, the material is bleached to remove the natural yellowish color of the cotton fiber and to render it white. Sodium hypochlorite and hydrogen peroxide are the two most commonly used bleaching agents. In some instances the bleaching is done after desizing. Fabrics in the unbleached and undyed state are sometimes referred to as "greige" or "gray goods".

10. Bleaching is followed by mercerizing, which gives a brighter luster, increases dye affinity, and improves the tensile strength of the fabric. With the increasing use of cotton-polyester blends, fewer cotton fabrics are being

mercerized. The dyeing or printing process follows the mercerizing, either in batch process machines, for small volumes, or by continuous dyers for large volumes.

Synthetic Fibers and Fabrics

11. Synthetic textile fibers may be grouped under two broad categories: cellulosic and non-cellulosic. Rayon and cellulose acetate are the two major cellulosic fibers; nylon, polyester, acrylics, and modacrylics are the major non-cellulosic fibers. The synthetics are produced entirely by chemical treatment and processing of raw materials such as wood pulp, cotton fibers, petroleum derivatives, and other substances. The fibers so produced have an almost unlimited range of uses.

12. Synthetic fibers are produced as continuous filaments or in staple form. The filament yarns are generally used to produce 100 percent synthetic goods, while the staple forms are used to produce blends of synthetics or combinations of man-made and natural fibers. Since the manufacturing process can be closely controlled, synthetic materials are essentially free of chemical impurities. Therefore, only light scouring and little or no bleaching is required prior to dyeing. The yarns are sometimes dyed before use in a final product, unless the material is to be piece dyed, printed, or used as produced.

SOURCES AND CHARACTERISTICS OF WASTES

13. Many of the operations for producing yarns and fabrics are common to the industry as a whole and the characteristics of the wastes are similar. Basically, the fibers are converted to yarns, the yarns are converted to fabrics and eventually to final products. The fabrics, after manufacturing, are subjected to several wet processes known as finishing. Waste effluents are produced in varying degrees from the bleaching, mercerizing, dyeing, printing and finishing operations.

14. Normally, air-borne wastes do not present problems in the production of textiles and synthetic fibers. Air contamination may result from combustion of fuels used for steam generation. Flue gas discharges contain carbon monoxide and sulfur dioxide, depending upon the type and quality of fuel used. Environmental contamination can usually be controlled by discharging through a stack of adequate height. Data on the concentrations of possible air-borne contaminants existing at ground level should be determined in the general plant area prior to the start of industrial operation.

15. Fibers and dusts may originate from various in-plant sources, particularly the spinning and weaving operations. The sources of such substances should be equipped with filters or other devices to prevent their discharge to the atmosphere, both within and outside the plant.

16. In many textile production operations, particularly for synthetic fibers, a finish is applied to improve the running characteristics during the processing. Synthetic fibers are frequently subjected to heat treatment in

order to improve certain desirable properties. Such treatment volatalizes the finish into a mixture of volatile oils and waxes. The mixture escapes as a gas and this effect is commonly referred to as "smoking". If discharged to the atmosphere the fumes may be irritating to workers and may condense on machinery. The condensation causes housekeeping problems, potential flammable conditions and sometimes degradation of the quality of the product.

17. The principal parameters used to characterize liquid textile industry wastes are the flow, 5-day biochemical oxygen demand (BOD₅), chemical oxygen demand (COD), total suspended solids (TSS), oils and greases (O + G), chromium, phenols and sulfides.

18. In order to facilitate definition of effluent characteristics and limitations, manufacturing operations can be categorized according to the process being utilized as part of the production of a textile and its final consumer product. An individual plant will carry out one or more of these operations concurrently, but only in rare cases will all of these operations be carried out at one plant at the same time. Therefore, total effluent discharge allowances may be determined by taking the sum of the permissible effluent loadings applicable to the individual process categories which are being carried out at the individual plant.

19. Hence, the liquid wastes from this industry may be categorized as follows:

- | | |
|--------------------------|---------------------------------------|
| — Raw wool scouring | — Knit fabric finishing |
| — Wool finishing | — Carpet mills |
| — Dry processing | — Stock and yarn dyeing and finishing |
| — Woven fabric finishing | — Commission finishing |

Raw Wool Scouring .

20. Liquid wastes from raw wool scouring differ from all other categories of wastes in that they contain significant quantities of oil and grease, even after in-process recovery. Sulfur, phenols, and other organic substances appear intermittently in the effluents, and originate from the sheep urine, faces, blood, tars, branding fluids and insecticides used in sheep dips. The scouring bowls separate the heavier dirt and grit from the wool, and this residue settles to the bottom, from which it can be removed for disposal.

21. Wool finishing wastes are distinguished from other textile finishing effluents because of the wide variety of process chemicals used, the BOD₅ loading, and the higher water usage per unit of product. The heaviest flows appear in the rinsing applied after fulling. Orthophenols, phenols, diphenols or benzoic acid derivatives will be present in significant quantities in the wastes from mills working on polyesters and other blends. The finished fabric receives a wash (or "heavy scour") prior to the dyeing, to remove all foreign materials either introduced by or remaining from previous processing procedures.

Other finishing stages contributing liquid wastes in varying degrees include the carbonizing, fulling, crabbing (applied to give rectilinear alignment to the fabric), final cleaning and dyeing.

Dry Processing

22. These wastes originate at mills producing greige goods from cotton stocks, and consist principally of the residues in sizing boxes and water used for cleanup. Starches and polyvinyl alcohols are the most commonly used sizing materials. Cooling waters are generally separated and are not included in the flows from this source. Typically, over 90% of the effluent from a dry processing mill is sanitary waste.

23. The carpet backing industry produces an unusual waste, because of the use of foamed and unfoamed latex backing. The 1 tax, which is not soluble in water, is used in a highly dispersed form and may cause suspended solids and COD problems from equipment washdowns.

Woven Fabric Finishing

24. The wastes resulting from the finishing of woven goods originate from removal of foreign materials during the finishing process and from the various chemicals used for this purpose. Enzymatic removal of starches in desizing produces an effluent containing dissolved and suspended solids, fats and waxes, at a pH of 6 to 8. Effluents from sulfuric acid removal of starches contain dissolved and suspended solids, oils, and greases at a pH of 1 to 2. Mercerizing, bleaching, dyeing, and printing—which also constitute a part of the finishing process—contribute minor to significant waste loads. Such wastes may contain NaOH, HClO, HClO₂, Na₂SO₃, and other constituents, depending upon the process chemicals used.

Knit Fabric Finishing

25. The principal differences in wet process operations between knit and woven fabrics are that knit yarns are treated with lubricants rather than starches or polymer sizes, and that mercerizing is not applied to knit goods. Otherwise, the wastes generated from comparable unit operations performed on cottons, synthetics and blends are similar to those resulting from woven fabric finishing. Lubricating finishes applied to knitting yarns generally contain a base of mineral oil, vegetable oil, synthetic ester type oil or wax. The finishes may also contain antistatic agents, antioxidants, bacteriostats and corrosion inhibitors. Knitting oils are readily soluble in water and are removed from the goods by washing prior to dyeing.

Carpet Mills

26. Carpet industry wastes are similar in character to those from knit fabric finishing operations. When polyester is dyed disposal of the carriers (auxiliary chemicals) presents a problem. Most wool used for carpets is dyed in the yarn form, thus minimizing chromium use. Where carpets are printed or dyed continuously, the thickeners (used to give the print paste the viscosity required for the method of printing and the pattern to be printed) contribute to a high BOD₅ load.

Yarn Dyeing and Finishing

27. Wastes from yarn processing will depend principally on whether natural fibers, blends or synthetics are processed. When only synthetics are being handled, low levels of detergents, soda ash, sodium phosphate, and bleaches are discharged, and these will have a low BOD₅. Scouring, bleaching and mercerizing of cotton generate BOD₅ and color because of fiber impurities, and high dissolved solids because of the mercerizing.

Commission Finishing

28. This type of plant will frequently have a high hydraulic loading and a less treatable waste than encountered in other operations. "Problem" type materials, generally in batches, are processed and several processes may be carried out in sequence or simultaneously. Operations do not readily permit water recycling and reuse. The characteristics of the effluents are subject to wide fluctuations because of the constantly changing mix of processes and products.

EFFLUENT LIMITATIONS

29. Effluent limitations for various textile process operations, based on the best treatment technology currently available, are presented in Table 1. These are for plants carrying out the indicated processing on a continuous basis. For plants carrying out commission finishing the limitations are double those shown.

Table 1. Daily Maximum Effluent Limitations - Textile Plants.

PROCESS <i>a/</i>	BOD ₅	TSS	COD	TOTAL CHROMIUM	PHENOL	SULFIDE
	Kg/Megagram Final Product					
Wool Scouring <i>b/ c/</i>	10	32	138	—	0.10	0.20
Wool Finishing	22	35	163	0.14	0.14	0.28
Dry Processing <i>d/</i>	1.4	1.4	2.8	—	—	—
Woven Fabric Finishing	6.6	18	60	0.10	0.10	0.20
Knit Fabric Finishing	5.02	22	60	0.10	0.10	0.20
Carpet Mills <i>e/</i>	7.8	11	70	0.04	0.04	0.08
Stock & Yarn Dyeing-Fin.	6.8	17	85	0.12	0.12	0.24

- a/ For those plants identified as "Commission Finishing" multiply effluent limitation by 2.
- b/ Limitations expressed as kg/Mg* raw wool.
- c/ Oil and Grease limitation is 7.2 kg/Mg raw wool.
- d/ Fecal coliform MPN Limitations = 400 per 100 mL. (For all processes)
- e/ Limitations expressed as kg/Mg primary backed carpet.

Note: pH limitation for all effluents is 6 to 9.

CONTROL AND TREATMENT OF WASTES

30. Wastes from textile production may be reduced in both volume and strength through in-plant measures, through the application of end-of-pipe-technology, or through a combination of the two. In-process control requires altering the process requirements that generate contaminants and controlling water use in both process and non-process operations.

31. An effective water management program is a major factor in reducing waterborne pollutants. Measures would include the use of liquid level controls, flow meters and regulators, adequate hot water capacity, an effective leak and spill prevention program, strict attention to housekeeping procedures, and use of better hand and machine working methods. The more extensive use of soluble sizers and desizers has been suggested as a means of reducing liquid BOD₅ and COD waste loads, though their feasibility has not been fully demonstrated. Reducing water consumption for individual processes, strict control of dyeing operations, and selective process automation and instrumentation will all contribute to in-plant waste reduction. Chromium wastes, originating from the dyeing and finishing operations, may be eliminated by substituting for the chromium dyes. If treatment is necessary the chromium may be removed by coagulation with alum.

32. Since a large proportion of the biodegradable material in textile wastes is in the soluble form the effluents are readily susceptible to biological treatment. Activated sludge systems (including extended aeration), trickling filters, anaerobic lagoons, anaerobic contact systems, aerobic lagoons, and rotating biological contactors have all been successfully applied to the treatment of these effluents.

33. Where very high removals are required to meet effluent standards, one of the advanced treatment technologies may be applied. These have achieved varying degrees of success. Processes which have been used or considered for this purpose include phase change (distillation, freezing), physical separation (filtration, reverse osmosis, ultrafiltration, electrodialysis), sorption systems (activated carbon, ion exchange, absorption resins), and chemical clarification. Each situation must be carefully analyzed and evaluated on its own merits before applying any specific advance waste treatment technique.

* 1 Mg = 1 megagram = 1 metric ton

BIBLIOGRAPHY

1. Powers, Philip W. "How to Dispose of Toxic Substances and Industrial Wastes". Noyes Data Corporation. Park Ridge, N. J. and London (1976).
2. U. S. Environmental Protection Agency -- "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Textile Mills Point Source Category". Doc. EPA-440/1-74-022a. Washington (June 1974).
3. U. S. Environmental Protection Agency -- "Economic Analysis of Pretreatment Standards for the Textile Industry". Doc. EPA-440/1-77-009. Washington (July 1977).
4. Bhaskaran, T.R. "Guidelines for the Control of Industrial Wastes - Cotton Textile Wastes". Doc. WHO/WD/73.16. World Health Organization. Geneva (1973).
5. Isaac, P.C.G. and Ruscombe-King, N.J. "Guidelines for Control of Industrial Wastes -- Woollen Textile Wastes". Doc. WHO/WD/75.17. World Health Organization. Geneva (1975).
6. Linton, George E. "Natural and Manmade Fibers". Duell, Sloan and Pearce, New York (1966).
7. Kastens, Anita S. "Synthetic Fiber Markets to 1970". Noyes Development Corporation, Pearl River, N. Y.
8. "Fairchild's Dictionary of Textiles". Ed. by Isabel B. Wingate. Fairchild Publications, Inc. New York (1967).

THE WORLD BANK

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OFFICE OF ENVIRONMENTAL AFFAIRS

WOOL SCOURING

EFFLUENT GUIDELINES AND PROCESS

1. Wool scouring is the first wet process that the raw fibers receive. It removes all the natural and acquired impurities from the fibers. Two methods exist; detergent scouring and solvent scouring. The first process is used almost exclusively because solvent scouring is too costly.

2. Two types of detergent scouring are used; the soap alkali process and the neutral detergent process. In the soap alkali, a soap or a detergent is added to a milk alkali such as sodium carbonate at a pH 9.5 to 10.5. The bath is heated to 55° C and requires an average of 80 liters of water per mega gram of wool fiber.* Part of that water is recycled. In the neutral detergent process, nonionic detergents are added to water at a pH 6.5 to 7.5 and at a temperature from 55° to 70° C.

3. The process is carried out in a series of 4 open bowls called "scouring train". The first two bowls contain the detergent or soap alkali and perform the "scour". The last two rinse the fibers clean; then the wool is dried.

4. For every kilo of scoured woolen fiber, one to 1.5 kilos of waste impurities are produced. Therefore, wool scouring is one of the strongest industrial wastes in terms of BOD.

5. A general flow sheet is given in ANNEX.

6. The grease wool contains 25 to 75% non-wool materials consisting of wool grease and other excretions and secretions of the sheep, such as urine, feces, sweat and blood, as well as dirt. Additional products such as pesticides and dyes may be present. This impurity variability causes the same variability in raw waste loads.

Waste Characteristics

7. The raw waste contains significant quantities of oil and grease whose difficult biodegradability constitutes a special problem. Therefore, a grease recovery step is important to decrease pollution.

8. Sulfur is brought in with the wool as well as phenolic and other organic materials.

9. In centrifuging, the top low density stream contains concentrated grease, the medium density stream is recycled upstream, and the heavy density bottom (dirt and grit) is sent to the treatment plant. 60% of the grease is recovered; the rest goes with the dirt and grime.

* 1 Mg = 1 megagram = 1 metric ton

10. In acid cracking, sulfuric acid breaks the grease water emulsion; after the grease separation, the liquor is neutralized with lime. 90-95% of grease recovery is possible.

11. 1-3% of the wool grease remains in the wool as a conditioner.

Waste Treatment and Cost

12. If, when recirculating some of the water at different stages, ponding the waste after a rough filtration and letting the water evaporate without any overspill in waterways is possible, then this treatment can be considered. This is, of course, the most simple and for a 6Mg/D scoured wool plant in the U.S. the investment has been estimated at \$15,000 in 1974. The smell from the pond can create problems.

13. If some of the waste discharges in a waterway, then primary screening followed by primary clarification and biological treatment should be recommended. A reduction of 95% in BOD5 can be achieved. The investment for the same 6Mg/D plant has been estimated at \$41,000. The additional cost is \$0.002/kg product. (*)

Results of Treatment

14. The average raw waste BOD5 load resulting from wool scouring is around 50 kg per megagram of grease wool as received in the plant. The treatment described in the preceding paragraph should remove 95% of that BOD.

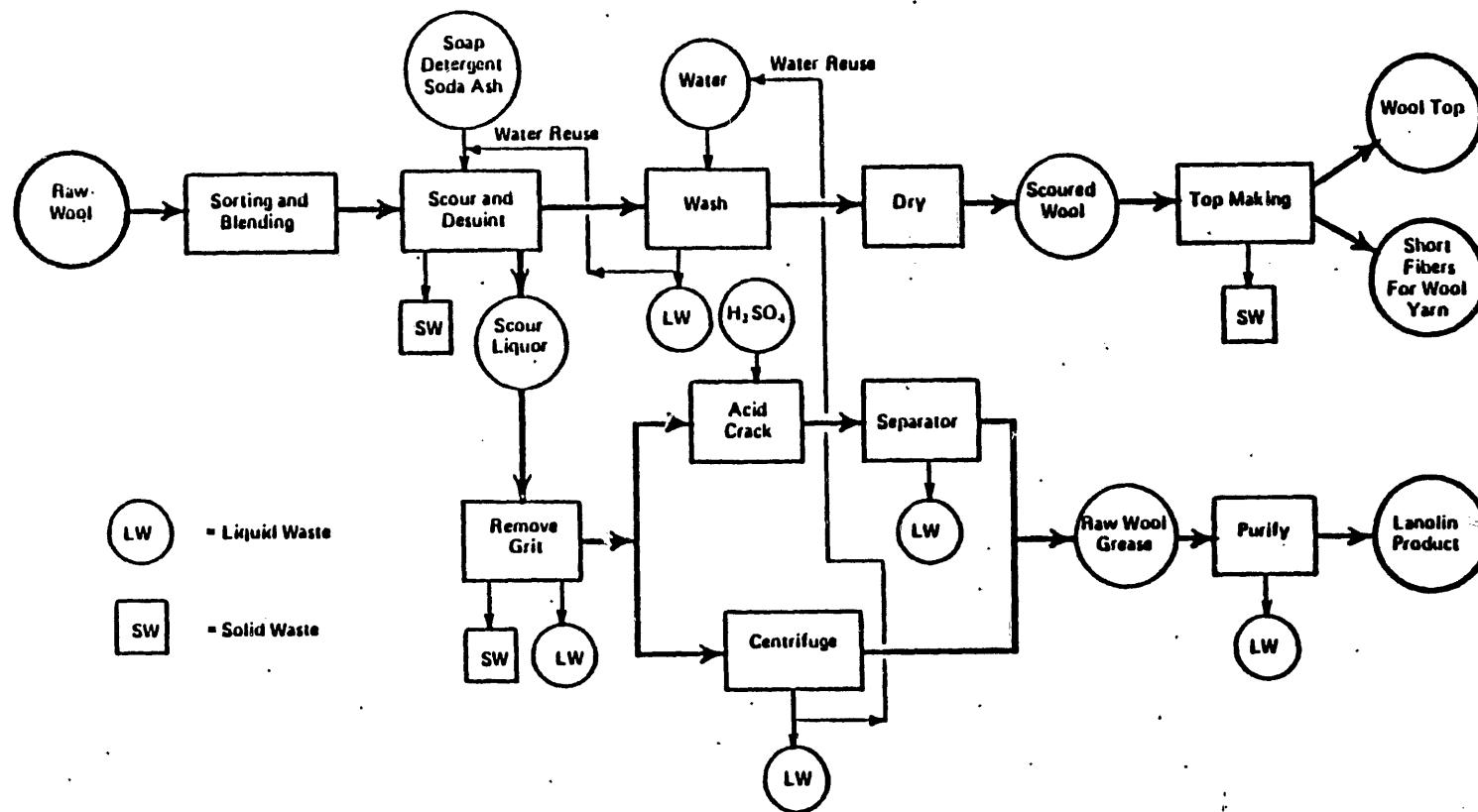
15. If any liquid effluent reaches the waterways, the following guideline should apply:

BOD5	5 kg/Mg product
TSS (total suspended solids)	4 kg/Mg product
COD	20 kg/Mg product
Oil and Grease	7.2
Chromium (total)	0.1
Phenol	0.1
Sulfide	0.2
Pesticides	0.01

For more information, consult EPA 440/1 - 74/022
"Textile Mills" - Point Source Category

Publisher: United States Environment Protection Agency, January 1974

(*) All \$ figures are in 1973 US\$



Source: "Chemical/Physical and Biological Treatment of Wool Processing Wastes," by Hatch, et al, 28th Annual Purdue Industrial Waste Conference, West Lafayette, Indiana, 1 May 1973.

Figure 1 Subcategory 1: Wool Scouring