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Wastewater Treatment in Asian Cities

Metropolitan
Environmental
Improvement
Program

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Foreword

The UNDP-assisted, World Bank-executed Metropolitan Environmental Improvement Program (MEIP) began work in 1990 in five Asian metropolitan areas—Beijing, Bombay, Colombo, Jakarta, and Metro-Manila. In 1993, this intercountry program began its second phase and Kathmandu joined as the sixth MEIP city. By 1996, MEIP will enter its third phase—with multi-donor assistance—and launch new programs in additional Asian cities.

MEIP's mission is to assist Asian urban areas tackle their rapidly growing environmental problems. The MEIP approach emphasizes the cross-sectoral nature of these problems and the failure of traditional sectoral development strategies to adequately address urban environmental deterioration or the linkage between industrial and urban development.

The work program in each city is therefore guided by Steering Committees and technical working groups that reflect the cross-sectoral, interagency nature of urban environmental issues. The policy and technical committees develop Environmental Management Strategies (EMS) for their metropolitan regions; incorporate environmental considerations into the work of economic and planning agencies; contribute to the strengthening of environmental protection institutions; and identify high priority environmental investments.

The MEIP city office serves as secretariat to the Steering Committee and is managed by a local environmental professional, the National Program Coordinator (NPC). The NPC coordinates all MEIP activities and is responsible for developing the environmental network of government, private sector, non-governmental organizations (NGOs), research institutions, and communities. MEIP supports workshops, demonstration projects, and community environmental actions, and links these growing environmental network efforts with government policy and investment initiatives.

A further focus of MEIP is the exchange of experience and sharing of information among MEIP cities. This has been carried out through a series of intercountry workshops that review the city work programs, exchange useful experience, and develop intercountry projects.

MEIP has established the city programs, set in motion a variety of city subprojects, and mobilized the intercountry exchange. MEIP publications are intended to share insights and experiences developed from the MEIP process and its projects. The MEIP city programs work independently, with each other, and with international partners to reverse urban environmental degradation and provide useful and replicable lessons in urban environmental management.

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Preface

Industrial wastewater management has been a neglected area due to the artificial division between the urban and industrial sectors. Municipal wastewater has always been managed by the urban and infrastructure sectors, but the industrial sector has not always paid sufficient attention to industrial wastewater. In light of the rate at which many Asian urban centers are industrializing, MEIP felt that industrial wastewater management was a priority issue.

This paper is based on the findings of recent feasibility studies assessing the potential for centralized (treating several facilities' industrial wastewater) or joint (treating industrial and residential effluents) wastewater management in two Asian developing countries. In light of the current interest in this approach, it is expected that this review will disseminate the initial findings which could be useful to those making decisions on these types of wastewater management schemes over the next two or three years. This work will be followed by monitoring and evaluation of these wastewater treatment schemes after their implementation.

The feasibility studies were conducted in five industrial zones, two in the Greater Colombo (Sri Lanka) area and three in the Jakarta (Indonesia) area. The Colombo studies were conducted by Soil and Water Ltd. in association with Enviroplan Ltd. (Ja-Ela Ekala), and Associated Engineering and Surath Wickramasinghe Associates (Ratmalana-Moratuwa). The Jakarta studies were conducted by DHV Consultants BV in association with IWACO, P.T. Waseco Tirta, P.T. Indah Karya, and P.T. Bita Bina Semesta. Layout of this paper was designed and executed by Julia Lutz. The author of this paper is Kumi Kitamori, with reviews by David Williams, Tom Walton, and P. Illangovan.

Abbreviations, Acronyms, and Data Note

BOD	biochemical oxygen demand substance
BOI	Board of Investment (formerly the Greater Colombo Economic Commission)
BOO	build-own-operate
BOOT	build-own-operate-transfer
BOT	build-operate-transfer
CEA	Central Environmental Authority (Sri Lanka)
COD	chemical oxygen demand substance
EIA	environmental impact assessment
EIE	Ekala Industrial Estates
GOSL	Government of Sri Lanka
IDA	International Development Authority (World Bank)
JIEP	Jakarta Industrial Estate at Pulogadung
MEIP	Metropolitan Environmental Improvement Program (World Bank/UNDP)
NEA	National Environmental Act (Sri Lanka)
NWSDB	National Water Supply and Drainage Board
O&M	operations and maintenance
pH	measurement of acidity or alkalinity
PS	Pradeshiya Sabha
SCOPE	Scheme for the Control of Pollution of Existing Industries
SS	suspended solids
TSS	total suspended solids
TTKI	Tata Tertib Kawasan Industri (Indonesia)
UASB	upflow anaerobic sludge blanket
USEPA	U.S. Environmental Protection Agency

Data note:
Unless otherwise indicated, dollars refer to U.S. dollars.

1
Introduction

Many Asian cities are experiencing rapid urbanization and industrial growth, and subsequently, are paying the price of severe water pollution. In coming years, as these cities' population and level of industrial activities increase, water pollution problems in the region will be exacerbated. If Asian cities are to achieve environmentally sustainable development, active and effective pollution abatement measures must accompany further industrial growth. This paper will review issues in industrial wastewater management, normally neglected in traditional sectoral development strategies; municipal wastewater treatment falls under urban infrastructure, but the industrial sector has not always paid sufficient attention to industrial wastewater treatment.

Despite new laws and regulations requiring industries to treat their wastewater, many industries in developing countries are unwilling or unable to comply, often due to lack of effective enforcement. Also, especially for small-scale industries, it is often financially and technically not feasible to individually treat their wastewater. Centralized wastewater treatment for a group of industries can be a practical and economically sound solution.

The primary advantage of centralized wastewater treatment is economy of scale. For a given group of industries, centralized treatment of their wastewater can be significantly less expensive than the combined cost of individual treatment, both in investment costs and in operation and maintenance costs. It can also be more reliable, since a larger treatment facility can afford better equipment and employ well-trained, full-time operational staff; these may not be affordable to a smaller, on-site treatment facility.

On the other hand, implementing a centralized treatment scheme can be cumbersome. The mixture of effluents from the different industrial activities must be compatible with the selected treatment processes. To ensure this, appropriate standards for on-site pre-treatment must be established, monitored, and enforced. In addition, a sound and sustainable institutional framework must be established to delegate responsibilities of ownership, management, operations, cost recovery, and meeting influent and effluent standards. Perhaps most importantly, industries must be persuaded to participate in a centralized treatment scheme rather than treating on their own. For this, the total cost of centralized or joint treatment must be more attractive than individual treatment.

For a given industrial area, issues involved in identification of the optimal wastewater management scenario can be summed into the following questions:

1. Is centralized (treating several plants' effluents together) treatment of industrial wastewater preferable to individual on-site treatment?
2. Should municipal wastewater be included (i.e., joint wastewater treatment)?
3. Which treatment option should be pursued?
4. Who will own or manage these centralized or joint treatment facilities?
5. How should standards be monitored and enforced?
6. How should financing and cost recovery be arranged?

The Metropolitan Environment Improvement Program (MEIP) commissioned feasibility studies to assess the potential for centralized wastewater treatment plants in urban industrial areas facing water pollution problems. This paper reviews the wastewater management scenarios recommended by these studies conducted in five industrial areas:

Ja-Ela Ekala and Ratmalana-Moratuwa, both in the Greater Colombo area, Sri Lanka; and Mookervart, Cipinang, and Jakarta Industrial Estate at Pulogadung (JIEP) in the Jakarta area, Indonesia. The recommendations for each of the study areas are briefly summarized in this section. More details on each of the study areas are given in appendix A.

Chapter 2 reviews the polluter inventory of the study areas, and examines the types of data and information necessary for answering questions 1 and 2 above. Chapter 3 outlines available wastewater treatment process technologies. Chapter 4 examines different institutional models for ownership, management, and financing of centralized or joint wastewater treatment facilities. Issues behind determination of tariff structures and resultant financial viability of centralized and joint wastewater treatment schemes are discussed in chapter 5. Finally, chapter 6 reviews the regulatory frameworks governing wastewater treatment plants for the study areas in Sri Lanka and Indonesia.

The Study Areas

Table 1.1 summarizes the recommended wastewater management options for the study areas.

Ja-Ela Ekala Study Area[1]

As depicted in maps C.1 and C.2 in appendix C, this study area covers a total land area of 65.3 square kilometers, has a population of 156,400, and contains 135 industrial establishments in operation employing a work force of over 21,700 in 1993. Ja-Ela Pradeshiya Sabha (PS) is located about 15 kilometers north of Colombo. Ekala is located in the northern part of PS, covering about one-third of PS. The Ja-Ela Urban Council covers the central part of the study area inside the PS. The main industrial concentration in the study area is in Ekala and includes the Ekala Industrial Estate (EIE). The industrial areas outside EIE are interspersed among residential and agricultural areas. Seventy-three industries are proposed to be served by a centralized treatment plant (sixty-eight through piped connections, five outside the network transporting effluent by tankers). Municipal wastewater will not be included. The centralized treatment plant would employ the conventional activated sludge method with primary settling. All industries would have pre-treatment facilities for their effluents at source. Sludge treatment would also be included.

The study recommends a build-own-operate (BOO) arrangement; the participating industries

Table 1.1: Recommended Wastewater Management Scenarios

Study Area	Location	Number of Industries	Centralized Treatment	Joint Treatment	Treatment Technology Choice	Disposal	Ownership, Management, and Financing
Ja-Ela Ekala	Colombo, Sri Lanka	73	Yes	No	Biological	Inland surface water	BOO with a company owned by participating industries
Ratmalana Moratuwa	Colombo, Sri Lanka	225	Yes	Yes	Primary only	Ocean outfall	NWSDB owns and operates collection system,a BOO/BOT firm operates treatment plant and outfall
Mookervart	Jakarta, Indonesia	176	Yes	Yes	Biological	Inland surface water	PDPAL owns and operates the entire system
Cipinang	Jakarta, Indonesia	122	No	n.a.	n.a.	n.a.	n.a.
JIEP	Jakarta, Indonesia	239	Yes	No	Biological	Inland surface water	Industrial estate management, P.T. JIEP (parastatal) owns, but contracts out O&M

would establish and manage a limited liability company, with possible Government shareholding for the future capacity reservation, to be sold to other industries joining the scheme in the future. The company would assume the responsibility and risk for the construction and operation of the centralized treatment plant. Also, this company would be required to obtain the environmental protection license and would be monitored by the authorities for compliance. The performance of the individual pre-treatment plants would be monitored by the operating company.

Ratmalana-Moratuwa Study Area[2]

The Ratmalana area covers the southern part of the Dehiwela-Mt. Lavinia Municipal Council, as depicted in map C.1. The Moratuwa area lies within the Moratuwa Urban Council. Covering 40 square kilometers, the study area currently has a population of approximately 350,000. The area is characterized by mixed land use with approximately 225 industrial establishments interspersed among residential and commercial establishments. The predominant industries include textiles and garments, chemicals, metal finishing, food, and asbestos products. In addition, there are a number of cottage and small-scale industries. Residential development generally occurs as single-family lots, although pockets of higher-density multi-family developments are also present. Low-income and squatter settlements occur throughout the area, particularly along canal banks and lake and lagoon shorelines. The study recommends joint primary treatment (fine screening and grit removal) of industrial and domestic wastewater from industries as well as municipal wastewater, and disposal via an ocean outfall. All industries would be required to install their own pre-treatment facilities to meet pre-treatment standards. The outfall would extend 2,000 meters into the ocean.

The study recommends some form of government and private-sector partnership, suggesting an arrangement where the National Water Supply and Drainage Board (NWSDB) would have direct responsibility for the collection network, effluent monitoring, and revenue collection. The BOO or build-operate-transfer (BOT) company would be responsible for financing, design, construction, and operation of the wastewater treatment plant and the ocean outfall.

Mookervart Study Area[3]

This study area (see maps C.3 and C.4 in appendix C) covers a long, narrow stretch of industrial zone containing 176 industrial establishments; only a few of them currently have their own on-site treatment facilities. Most are located along the Mookervart River, into which they discharge effluents. The length of the study area is approximately 12.25 kilometers. About half of the study area lies in the Tangerang Regency, while the other half is in the city of DKI Jakarta. The predominant polluters (75 percent of wastewater volume in the study area) are textile, food, and beverage industries. However, the proposed joint treatment plant is aimed mostly at municipal wastewater, presently small but expected to increase more rapidly than industrial wastewater, eventually representing over 70 percent of the total flow by 2015. The joint treatment plant would employ biological treatment processes without physicochemical treatment.

The study recommends ownership and management by a well-established public enterprise for both the joint treatment plant and the collection system. It suggests the wastewater enterprise PDPAL as the suitable owner and managing institution of the facilities.

Cipinang Study Area

This study area (see maps C.3 and C.4 in appendix C) is also a long and narrow stretch of industrial area, approximately 13 kilometers long and no wider than 2.25 kilometers. The area partly lies in DKI Jakarta, and the remainder in Bogor Regency. The area has 122 industrial establishments, and their effluents are discharged into the Cipinang and Baru Timur Rivers. The area contains many highly polluting industries such as food and beverages, textiles, and pharmaceuticals, but most of them already treat their effluents or the effluents already comply with current standards. The study, therefore, recommends additional investment in new individual treatment facilities and upgrading existing facilities, rather than a centralized treatment plant for this area.

Jakarta Industrial Estate at Pulogadung (JIEP)

This study area (see maps C.3 and C.4 in appendix C) is an industrial estate managed by P.T. JIEP, a parastatal enterprise, and is located in DKI Jakarta. JIEP contains 239 small- to medium-scale industries producing small volumes of wastewater. Thus, it is economically more attractive to treat their effluents collectively than individually, which would otherwise be almost 2.5 times more expensive. The proposed centralized treatment plant would employ anaerobic and facultative lagoons constructed within the industrial estate, eliminating additional land costs.

The study recommends that both the centralized treatment plant and the collection system be owned and managed by a well-established public enterprise. Since the area served by the joint treatment plant is an organized industrial estate, JIEP would be the most suitable choice. However, since JIEP has no previous experience in wastewater collection and treatment, it is recommended that it enter into an operation and management (O&M) contract with a firm specializing in wastewater management.

Endnotes

1. Soil and Water Ltd. in association with Enviroplan Ltd. *Feasibility Study for the Establishment of a Joint Wastewater Treatment Plant for Industrial Estate/Industries in Ekala and Ja-Ela*, April 1994.
2. Associated Engineering and Surath Wickrasinghe Associates. *Feasibility Study for the Establishment of a Central Wastewater Treatment Plant for Industrial Estates/Industries at Ratmalana and Moratuwa, Greater Colombo Area,* July 1994.
3. DHV Consultants BV in association with IWACO, P.T. Waseco Tirta, P.T. Indah Karya, P.T. Bita Bina Semesta, as part of *Third Jabotabek Urban Development Project: Environmental Protection Component (A). Joint Waste Water Treatment for Industrial Estates*, June 1993.

2
Polluter Inventory

Effluent Data from Industrial Point Sources

Who contributes how much to the total water pollution in a given area must be identified by a thorough inventory of existing industrial activities and effluents. For each industry, effluent data on flow, pollution load, and efficiency of existing individual treatment are needed. The effluent characteristics should be analyzed for parameters such as pH, temperature, BOD, suspended solids, metals, and other pollutants. The standard parameters are listed in table 2.2 and table 3.4, but for preliminary assessment, flow volume and BOD load[1] alone are often sufficient to identify the largest sources in a given area. Often most of the water pollution in an area is caused by only a few industries.

Mookervart is an example of an industrial area where most of the water pollution is generated by a few large-scale polluters. Based on the inventory of 176 existing industries, the total flow of industrial effluents in the area was estimated to be 14,501 cubic meters per day, with BOD load of 7,670 kilograms per day. Existing treatment facilities at a few of the industries reduces the total BOD load by 38 percent to net BOD load of 4,777 kilograms per day. The study further found that 82 percent of net BOD load and 50 percent of total flow are contributed by the ten largest polluters: six food and beverage industries, three textile industries, and a paper mill. Only four of the top ten polluters currently have individual treatment facilities. This is summarized in table 2.1 and figure 2.1, and inventories of industries in Mookervart and other study areas are presented in appendix A.

Characteristics and intensity of pollution can be estimated from identifying industrial subsectors. The typical pollutants from various industries are summarized in table 2.2.

Whether a group of industries should opt for a centralized wastewater treatment plant or individual on-site treatment facilities depends not only on flow and pollution contribution by the industries, but also on how much individual treatment capacity already exists. For example, the study concludes that centralized industrial wastewater treatment is not the optimal solution for the Cipinang area. Most of the total BOD load in the area is generated only by four out of 122 industries, many of which already have individual treatment facilities with the overall treatment efficiency of 60 percent for the entire area, or discharge effluents already in compliance. This is summarized in table 2.3, and elaborated further in

Table 2.1: Wastewater Contribution by 176 Industries in Mookervart

Source of Effluents	Top Ten Polluters	Study Area Total (176 factories)	Share of Top Ten as Percentage of Total
Flow (cubic meters/day)	7,290	14,501	50.3
Raw BOD (kg/day)	6,346	7,670	82.7
Treatment Efficiency	38%	38%	--
Net BOD (kg/day)	3,991	4,777	83.5

Figure 2.1: Wastewater Contribution by 176 Industries in Mookervart

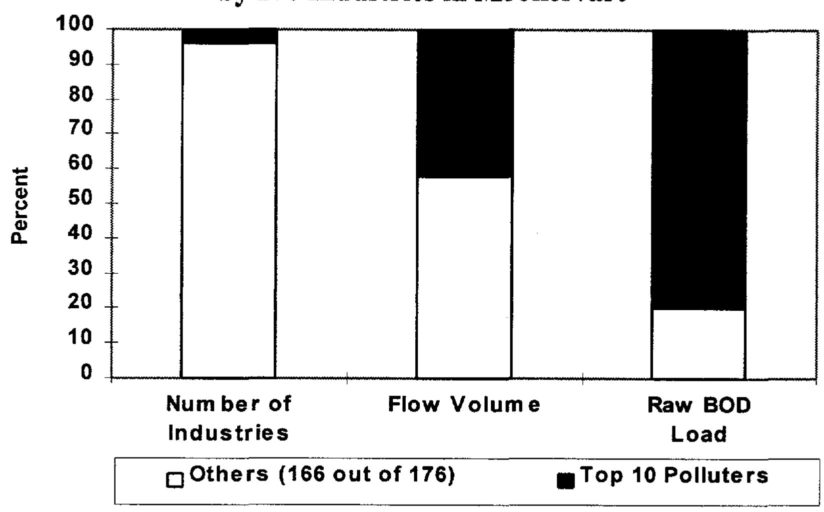


Table 2.2: Industry Types and Typical Effluents

Types of Industries	Pollutants
Food and beverages	BOD, COD, SS, pH, nitrogen, oil, grease
Pharmaceutical, chemical, plastic, rubber	BOD, COD, SS, pH, oil, grease, phenols, heavy metals, surfactants
Textiles	BOD, COD, pH, SS, phenols, heavy metals, sulphates
Leather tanning	BOD, COD, pH, SS, oil, grease, chromium, sulphates
Metal, electroplating	SS, pH, heavy metals, phenols, ammonia, cyanides, sulphates
Paper	BOD, COD, SS, heavy metals, phenols, ammonia, oil, grease
Ceramics, glass	COD, SS, pH, phosphorus, sulphates
Paints, dyestuffs	BOD, COD, pH, SS, heavy metals, oil, grease
Printing	BOD, COD, SS, heavy metals

appendix A. A centralized treatment plant just for the remaining industries would be more expensive than additional investments in individual treatment facilities and upgrading existing facilities.

In contrast, it makes sense to opt for centralized wastewater treatment in JIEP because the overall water pollution in this study area is generated by many small- to medium-scale polluters; the ten largest polluters contribute only 20 percent of total flow and 65 percent of the total net BOD load. In addition, only about 9 percent of the total BOD is currently removed by existing individual treatment facilities in JIEP. This is summarized in table 2.4, with additional data in appendix A.

Data on Municipal Wastewater

Relative significance of municipal wastewater in a given area must be understood in order to determine whether or not to jointly treat municipal wastewater at the centralized industrial wastewater treatment facility. For example, the mixed industrial-residential land use in the Ratmalana-Moratuwa study area produces almost as much municipal as industrial wastewater; total flow from 222 industrial sources is estimated to be about 8,000 cubic meters per day, and municipal wastewater flow is estimated at 7,260 cubic meters per day. The current government policy is for new high- and medium-polluting industries to locate on industrial estates served by centralized treatment plants. Therefore, no significant increase in highly polluting industries is anticipated in this area. The study projects a 30 percent increase in total flow of industrial effluents in the area by the year 2017 from ex-

Table 2.3: Wastewater Contribution by 122 Industries In Cipinang

Source of Effluents	Top Ten Polluters	Study Area Total (122 Factories)	Share of Top Ten as Percentage of Total
Flow (cubic meters/day)	10,059	15,942	63.5
Raw BOD (kg/day)	4,608	7,956	57.9
Treatment Efficiency	41%	60%	--
Net BOD (kg/day)	2,694	3,192	84.4

Table 2.4: Wastewater Contribution by 239 Industries At JIEP

Source of Effluents	Top Ten Polluters	Study Area Total (239 Factories)	Share of Top Ten as Percentage of Total
Flow (cubic meters/day)	975	4,679	21
Raw BOD (kg/day)	1,414	2,182	64.8
Treatment Efficiency	8%	9%	--
Net BOD (kg/day)	1,301	1,992	63.5

pansion of existing industries and the potential conversion of presently non-effluent generating industries. During this same period, a 50 percent increase in municipal wastewater flow is projected. Based on this, the study recommends joint treatment of industrial and municipal wastewater.

In addition, deciding on joint or centralized treatment should consider whether significant amounts of municipal wastewater can be economically connected to the collection system. This largely depends on whether the area is already sewered. For example, the study recommends that municipal wastewater in Ja-Ela Ekala area not be jointly treated. Due to the semi-urban characteristic of the area, only 40 percent of municipal wastewater can be economically connected to the collection network and, even for this, O&M cost recovery would not be affordable for most households. Since these households do not yet have piped water supply, let alone a sewerage system, the study concludes that joint treatment of municipal wastewater is not a high priority at this time.

Estimates of municipal wastewater are often based on estimates of per capita pollution generation multiplied by population. The assumptions made by the studies are summarized in table 2.5.

Where different assumptions are used for different studies, wastewater data from different study areas can be misleading. For example, the municipal wastewater projections for study areas around Jakarta project the gradual development of a municipal sewerage network, while this factor is not reflected in the Ratmalana-Moratuwa study. The latter instead captures different levels of per capita domestic wastewater generation from housing, commercial, and industrial establishments.

Wastewater Growth Projections

Wastewater growth projections need to be made in order to establish treatment plant design criteria. Projections of future industrial effluent flow and characteristics of plant design are made based on expected future industrial development in the area and pollution reduction measures likely to be taken by individual industries. Municipal wastewater projections are based on population growth and plans for future construction of municipal sewers. Specifically, wastewater growth projections are based on the following elements:

increase in flow and pollution load due to growth in industrial activities, in turn, influenced by land use policies;

decrease in flow and pollution load due to increased individual treatment and on-site waste minimization measures; and

Table 2.5: Per Capita Domestic Wastewater Generation

Colombo Area (Ratmalana-Moratuwa Study)

	Residential	**Commercial**	**Industrial**
Flow (liters per capita/day)	135	50	50
BOD (grams per capita/day)	55	25	25

Jakarta Area

	Non-Sewered Area		**Sewered Area**	
	Flow (liters per capita per day)	**BOD (grams per capita per day)**	**Flow (liters per capita per day)**	**BOD (grams per capita per day)**
1995	10	5	50	30
2005	20	5	60	30
2015	30	5	70	30

is generated by industries, but by 2015, domestic wastewater is expected to represent over 70 percent of the total flow, due to anticipated population growth and sewerage projects in the area, connecting more residences to the proposed joint treatment plant collection system. Based on this, the study recommends joint treatment of municipal wastewater.

increase in flow due to population growth and development of municipal sewerage networks.

Wastewater growth projections are important in deciding between individual, centralized, or joint treatment. Inventories of the current situation alone are insufficient. Currently in Mookervart, 75 percent of the total wastewater volume in the area

Endnotes

1 Instead of analyzing actual effluent samples, BOD load is often estimated from production output and effluent flow, based on certain industry-specific BOD-flow or BOD-output ratios.

3
Technical Options

Treatment Options

Wastewater treatment methods separate and remove pollutants from water so that it will not cause environmental degradation when discharged. Wastewater treatment processes are classified into three basic categories: 1) physical treatment, 2) chemical treatment, and 3) biological treatment. One, or some combination of these three, are used, depending on the wastewater's concentration and types of pollutants. Centralized and joint wastewater treatment plants normally use biological treatment, while physicochemical pre-treatment is necessary for effluents from certain industries. If effluent standards are not met after biological treatment, more sophisticated physicochemical treatment is applied in combination or as a tertiary treatment.

Physicochemical Treatment

Physical or mechanical treatment—screening out large objects, and a grit chamber to remove sand, gravel, and other materials that could damage pumps—is normally the first step in most wastewater treatment plants. After that, primary treatment removes settleable solids, typically by gravitational sedimentation. This removes about 60 percent of influent suspended solids but only about 30 percent of the influent BOD. For substances that do not settle slowly, such as oil and grease, flotation is preferred. These processes are relatively simple and are necessary before secondary biological treatment. Large substances screened out are usually sent to landfills. The settled sludge is usually thickened, stabilized at a digester, and disposed.

Chemical treatment is normally used in combination with other treatment methods. Chemicals are often added in order to enhance primary treatment, especially if the wastewater is not bound for secondary biological treatment, or as a means of augmenting existing wastewater treatment capacity. Chemical treatment becomes necessary when toxic compounds, dyestuff, or heavy metals are present in the wastewater, as is typical in textile, paint, battery, metal plating, leather tanneries, and chemical industries' wastewater. Chemical treatments can also remove suspended solids, BOD, and COD, but BOD removal efficiency is 30–70 percent that of biological treatment, depending on the wastewater's characteristics. A precipitant (normally a metal salt) is added to form a precipitate of suspended solid particles, colloidal matter, a phosphorus metal compound, and a metal hydroxide compound. This precipitate is removed in a separation process such as settling or flotation.

Biological Treatment

The main purpose of biological treatment is removing organic waste. The treatment can be applied to raw, physically- or chemically-treated wastewater, but certain biological processes require pre-treatment. Biological removal of BOD uses a variety of microorganisms, principally bacteria, and produces sludge as a by-product. This sludge consists of suspended solids removed from the wastewater and surplus organisms from the biological treatment. Treating this sludge is an important part of wastewater treatment, and can be expensive. Sludge management is discussed separately below. Biological treatment employs either aerobic or anaerobic processes; the former uses microorganisms that require oxygen and the latter microorganisms that work without oxygen. The most commonly used aerobic methods include 1) oxidation ponds or aerated lagoons, 2) activated sludge, and 3) biofilm.

Pond- or lagoon-based methods are relatively low-cost, and require minimal technical skills for operation and maintenance. They are highly adaptable to a wide range of wastewater mixtures and provide adequate capacity reservation for shock or seasonal loads. However, they require larger land areas than other methods. Aerated lagoons rely on mechanical oxygen transfer to promote decomposition of wastes, whereas oxidation ponds rely solely on biological activation.

In the **activated sludge process,** organic matter is partly oxidized to carbon dioxide and partly converted to sludge. The microbiological process is identical in **biofilm process**, but the reactor designs are different. In both designs, the reactor supplies oxygen needed to oxidate organic matter. In both processes, the wastewater is brought into contact with a large biomass, from which the wastewater must be separated after treatment, usually by settling. For the activated sludge process, microbes are in suspension, while in biofilm processes they are attached to a filter or a disk.

Biofilm plants can be configured as trickling filters, submerged aerated filters, or rotating disks. Preliminary treatment is always needed. Biofilm plants are preferred for medium- to high-organic loads. An advantage of biofilm reactors is that they require smaller residence times and thus smaller area for reactors. A disadvantage is their extreme sensitivity to load fluctuations.

Anaerobic processes convert organic matter into methane, which can yield energy. The main advantage of anaerobic treatment is that it produces less sludge, minimizing the sludge disposal problems associated with biological treatment. Anaerobic processes also require less power and fewer nutrients. Disadvantages include the higher temperatures and longer residence time required. Also, anaerobic processes work only on wastewater with a relatively high concentration of pollution load, limiting their applicability to diluted wastewater. One example is upflow anaerobic sludge blanket (UASB) reactors.

Combining biological and chemical treatment significantly improves phosphorus removal (to 90–95 percent) as well as TSS and BOD removal. However, the quantity of sludge increases, and it requires concentration, stabilization, and dewatering.

A process diagram of a typical biological treatment plant is given in figure 3.1.

Evaluating Treatment Systems

Selecting an optimal treatment system from the many technologies available is a site-specific exercise, considering the quantity and quality of the effluent mix at the site. The main objective is ensuring that, after treatment, the final effluent complies with local standards. Cost-effectiveness of treatment technology options, both in terms of investment costs and operations and maintenance (O&M) costs is another important factor. Selection criteria should also include the level of sludge production, since sludge treatment and storage costs can represent a significant share of a wastewater treatment facility's total costs. Area required for a treatment facility can also be a critical point in selecting a treatment system if it must be built in a urban area with high land prices. Advantages and disadvantages of some of the more prevalent treatment options in terms of the above selection criteria are summarized in table 3.1.

Cost Summary

For the proposed wastewater treatment plants serving the four study areas, investment and O&M costs relative to plant capacity and treatment performance are summarized in table 3.2. It must be remembered that the cost estimates in table 3.2 are taken from studies conducted by different consultants (see chapter 1) and are not based on standard calculations. Second, the differences in relative

Figure 3.1: Typical Activated Sludge Process

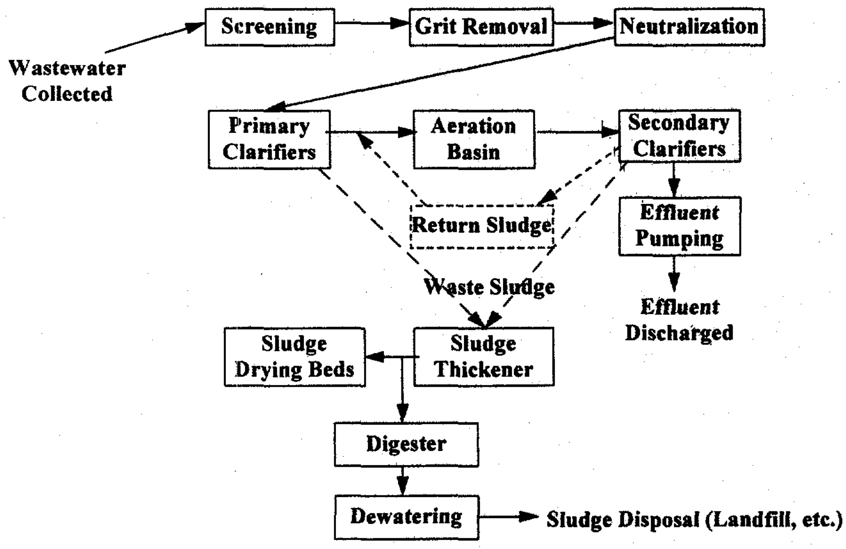


Table 3.1: Advantages and Disadvantages of Treatment Options

Treatment Options	Investment Costs	O&M Costs	Sludge Production	Area Requirement	BOD Removal
Aerobic					
Aerated lagoon	low	low	small	high	good
Activated sludge	high	moderate	medium	moderate	good
Trickling filter	moderate	low	moderate	moderate	fair
Rotating biodisc	high	low	moderate	moderate	good
Anaerobic					
UASB	high	low	low	low	fair
Chemical					
Chemical treatment	low	high	high	low	moderate

costs for the four proposed treatment regimens reflect the site-specific conditions behind them. For these reasons, the data in table 3.2 are presented in order to facilitate simple comparisons between these studies, rather than cost-effectiveness analysis of different treatment processes.

It is evident from table 3.2, for example, that the proposed treatment plant for Ja-Ela Ekala is significantly more expensive relative to its size compared to others. The design flow capacity of the proposed treatment plant for Ratmalana-Moratuwa area is more than six times that of the Ja-Ela treatment plant (21,740 cubic meters per day and 3,500 cubic meters per day, respectively), yet its investment cost is only slightly more (US$2.83 million and US$2.05 million). However, it should be noted that the JIEP treatment plant investment cost is markedly lower than others relative to their capacities (see further analysis in table 3.3). These differences in relative costs arise partly because the four proposed treatment plants employ four different treatment methods: the Ja-Ela Ekala plant employs the activated sludge process while the Ratmalana-Moratuwa plant is only for primary treatment. Investment costs for the JIEP treatment plant are relatively low because land is available at no cost on estate premises.

For reference, some capacity and cost figures for existing centralized treatment plants in India are included in table 3.2. Appendix B includes an additional cost summary including the costs of collection networks and the complete project costs from the four feasibility studies.

Waste Minimization at the Source

Although most studies tend to focus on end-of-pipe treatment of wastewater, waste minimization at the

Table 3.2: Centralized Joint Treatment

		Influent Characteristics			Plant's Design Average Daily Capacity				Cost of Centralized/Joint Treatment Plant*		Effluent Characteristics After Treatment		
Study Area	Number of Enterprises Served	BOD (mg/l)	COD (mg/l)	TSS (mg/l)	Flow (m3/day) (industrial sources**)	TSS (kg/day)	BOD (kg/day)	Type of Treatment	Investments Costs***	O&M Costs (US$/year)	BOD (mg/l)	COD (mg/l)	TSS (mg/l)
Ja-Ela Ekala	73	420	n.a.	390	3,500 (100%)	607	1,620	activated sludge	2.05 (102.6MRs.)	202,300 (10.115MRs.)	30	246	28
Ratmalana-Moratuwa	225	390	n.a.	310	21,740 (40%)	6,803	8,509	primary only	2.83 (141.61MRs.	153,960 (7.698MRs.)	n.a.	n.a.	n.a.
Mookervart	176	294	736	294	29,138 (53%)	8,600	8,600	oxidation ditch	5.12 (11.22MRp.)	331,053 (726MRp.)	10	100	20
JIEP	208	184	367	184	8,217 (100%)	1,508	1,508	anaerobic and facultative lagoons	0.76 (1.67MRp.)	20,520 (45MRp.)	25	100	40
Centralized Wastewater Treatment Plants in India													
Andankoil, Tamil Nadu	47	600 to 750	13,000 to 15,000	350 to 450	1,900 (100%)	n.a	n.a.	chemical and anaerobic	0.41 (12.9 MRs.)	n.a.	<30	<250	<100
Pallavaram, Tamil Nadu	106	1,500 to 1,750	3,000 to 3,700	800 to 1,000	3,000 (100%)	n.a.	n.a.	activated sludge	1.35 (42.5MRs.)	n.a.	<30	<250	20 to 30
Vapi, Gujarat (industrial estate)	966	400	700	300	55,000 (100%)	n.a.	n.a.	activated sludge	4.5 (141.5MRs.)	n.a.	20	200	30
Panoli, Gujarat (industrial estate)	209	550	1,200	450	20,000	n.a.	n.a.	activated sludge	1.24 (39.08MRs.)	n.a.	100	250	100

* US$1 equals Rs.31.5 (India), Rp.2,193 (Indonesia), and SL Rs.50 (Sri Lanka).

** Balance from municipal sources.

*** Base costs of the treatment plants only, except for the Vapi and Panoli plants, whose figures include collection systems as well. However, since they are located in industrial estates, the collection networks are not extensive, and thus are assumed to represent small shares of the total cost figures.

Table 3.3: Investment Cost Relative to Treatment Plant Capacity

Study Area	Design Average Daily Capacity (flow cubic meters/day)	Investment Costs (million US$)	Investment Costs/ Capacity (US$/cubic meters design average daily capacity)
Ja-Ela Ekala	3,500	2.05	585.7
Ratmalana-Moratuwa	21,740	2.83	130.2
Mookervart	29,138	5.12	175.7
JIEP	8,217	0.76	92.5
Andankoil	1,900	0.41	215.8
Pallarvaram	3,000	1.35	450.0
Vapi	55,000	4.50	81.8
Panoli	20,000	1.24	62.0

source is an important aspect of an overall wastewater management plan and any industrial pollution abatement efforts. It is often much simpler and cheaper to prevent generating wastewater than to treat and dispose of it once it has been produced.

Where water supply is priced below the optimal level and industrial waste disposal practices are poor, polluting enterprises have no incentives to incorporate waste reduction measures, unless direct cost savings in production can be made. If water supply charges correctly reflect later wastewater treatment costs, industries would (in theory) want to conserve water. Similarly, once effluent charges are imposed based on volume and actual pollution load, industries would want to decrease wastewater discharge and tariff payments through waste minimization and pre-treatment.

Wastewater flow and pollution load often can be substantially reduced by better housekeeping. Factory audits often reveal that a large portion of process and production wastewater is generated by cleaning the floor and equipment. Therefore, wastewater can be minimized by preventing spills of raw material and adopting waterless cleaning methods. Also, wastewater can be significantly reduced by separating stormwater and relatively clean process or wash water from wastewater needing treatment.

More specific waste minimization measures can be classified into four categories: 1) water conservation, 2) material substitution and process modification, 3) recycling, and 4) awareness enhancement.

Water Conservation

- metering the process water supply to assess and control water consumption, preferably by each individual unit; and
- reducing water use by using proper fittings, nozzles, and high-pressure washing or dry collection of spillage.

Recycling

- recycling cooling water or condensate, either directly or treated if needed;
- reusing process water or condensate for secondary purposes with lower water quality requirements;
- recovering materials for reuse or reprocessing; and
- collecting waste materials for direct reuse or sale.

Material Substitution and Process Modification

- replacing materials with ones that are less polluting, environmentally less hazardous, or less corroding; and
- replacing water with solvents that can be recovered and reused.

Training and Awareness Enhancement

- increasing general environmental awareness; and
- disseminating information on waste minimization.

For example, the Ratmalana study reveals that water conservation through process modifications will have the greatest impact in the textile manufacturing sector, which accounts for over 50 percent of all industry process wastewater discharge in the study area. It was estimated at least 15–20 percent of the wastewater produced by this sector could be reduced at little cost to the industries.

Pre-Treatment

Pre-treatment, whether in-plant by individual industries or at a centralized plant, is often necessary prior to physicochemical or biological treatment. The objective of pretreatment is to protect collection and treatment systems from harmful substances and to prevent destroying microorganisms employed in biological treatment. Also, hazardous substances that would otherwise pass through treatment processes and be discharged into the environment must be pre-treated.

Pre-treatment criteria are concerned with general organic loading, pH, solids, temperature, oils and greases, metals, and some specific organic and inorganic matters. The type of pre-treatment depends on the characteristics of the wastewater and the type of treatment to follow. Conventional pre-treatment consists of the following:

- Equalizing irregular flow and pollution loading.
- Neutralizing pH and reducing sulfides and sulphates to prevent sewer corrosion.
- Removing oil, grease, and sediment to prevent sewer clogging.
- Reducing hydrocarbons to prevent explosions in the sewers.
- Removing heavy metals, solvents, antibiotics, pesticides, and other toxic organics to prevent disruption of the biological treatment plant and contamination of the effluent or sludge.

Typical pre-treatments necessary for different industry types are presented in table 3.4.

Where centralized treatment plants employ biological treatment methods alone to treat mixed effluents from diverse industries, required physicochemical treatment by individual industries would be considered pre-treatment, ensuring that their effluent is fit for centralized treatment and safe for the collection system. It is necessary to set pre-treatment standards for compliance by industries participating in centralized treatment. General pre-treatment standards for discharging industrial effluents into a joint collection system for centralized wastewater treatment are often set by relevant public authorities. For example, the Greater Colombo Economic Commission (now known as the Board of Investment or BOI) has developed a set of pre-treatment standards applicable throughout the country for discharging industrial effluents into common collection systems for subsequent centralized secondary treatment at facilities operated by or on behalf of BOI. This is given in column A in table 3.5. Presented in column E are similar Indian standards set under Environment (Protection) Rules of 1986, Schedule I, for small-scale industries with total discharge up to 25 kilograms per day.

Whether the plant is owned or operated by a public authority or a private company, specific pre-treatment standards should be established and agreed in service contracts between the centralized treatment plant operator and the participating industry. Compliance with these standards should be monitored and enforced by the treatment plant operator in order to protect its facilities, and also to facilitate calculation of tariffs charged to the participating industries for the treatment according to flow volume and COD and BOD loads.

Pre-treatment standards recommended by the studies for the proposed centralized treatment plants at Ja-Ela Ekala and at Ratmalana-Moratuwa are given in columns B and C, respectively, in table 3.5. The former are almost the same as the BOI standards in column A, except that the latter standards for BOD, TSS, total dissolved solids, and sulfides are more stringent. In the case of BOD, the BOI standard of 200 milligrams per liter was set to prevent overloading and oxygen depletion problems. In contrast, the BOD standard for the Ja-Ela Ekala plant is an industry-specific standard based on anticipated loading. BOD standards for the Ratmalana-Moratuwa plant were proposed as 2,000 milligrams per liter, less stringent than

Table 3.4: Required Pre-Treatment Before Discharging Into Collection and Centralized Treatment Systems: By Industry Types

Food processing	• screening for all, and • oil/grease trap for part containing fat
Textile	• pH adjustment for all effluent • neutralization/precipitation for part of effluent to remove Pb and Cr • remove color dye if present
Tanneries	• screening of all effluent • neutralization/precipitation for chromium containing effluent • sedimentation of lime containing portion of effluent
Pulp and paper	• screening • physical/chemical treatment for clay removal • pH adjustment for all effluent/central effluent
Chemical	• pH adjustment • sedimentation for solids removal • solvent recovery
Cement	• sedimentation for solids removal
Paint manufacturing	• sedimentation for solids removal • solvent recovery
Iron and steel, automotive, and machinery	• oil skimming • sedimentation for solid removal • neutralization/precipitation for removal of heavy metals
Non-ferrous, electric, electroplating, and battery manufacturing	• neutralization/precipitation of heavy metals, cyanide oxidation for cyanide-containing portion of effluent
Oil	• oil skimming
Printing	• oil skimming
Wood	• detoxification of preservatives • solvent recovery

the BOI standards but not as open-ended as the Ja-Ela Ekala standard. It must also be noted that the proposed Ratmalana-Moratuwa plant is for centralized **primary** treatment.

A two-tier structure has been proposed for the Jakarta area's proposed centralized treatment plants' pre-treatment standards, and are given in column D. The first set of standards indicate the desirable level, but it may be permissible for one industry to exceed it as long as other industries' effluents dilute the overall mixture to desirable levels.

Sludge Management

Sludge Treatment or Processing

Most wastewater treatment methods produce inorganic chemical precipitation sludge or organic biological sludge as byproducts. The sludge may contain suspended industrial wastewater solids, organic matter, nutrients, and remains of the biological treatment microorganisms (anaerobic or aerobic activated sludge). It may also contain high concentrations of heavy metals and organic chemicals, depending on the amount of industrial wastewater and the degree to which it was pre-treated.

Processing inorganic sludge requires sludge thickening and mechanical dewatering. Biological sludge requires similar treatment, but also some form of digestion to decrease the volatile solids content before dewatering and disposal. Dewatering biological sludge can be done either in dewatering beds if suitable land is available, or by mechanical dewatering. While mechanical dewatering is expensive and requires more maintenance, it is often preferred in congested areas with high land prices. It is possible to use a mechanical dewatering facility for both inorganic and organic sludge, but the two types of sludge should be kept separate at all times because each sludge type's disposal requirements are different.

Table 3.5: Pretreatment Standards for Discharge of Industrial Effluents into a Joint Collection System

Parameter (mg/l unless noted otherwise)	A BOI, Sri Lanka	B Ekala/ Ja-Ela	C Ratmalana-Moratuwa	D Jakarta (Desirable Level)	E India
BOD	200	n.d.	2,000	n.d./(2,000)	n.d.
pH (no units)	6.0–8.5	5.5–9.0	6.0–9.0	6.0–9.0	5.5–9.0
TSS	500	700	1,000	n.d./(500)	none
Total dissolved solids	2,100	none	2,100	n.d.	none
Temperature (degree Celsius)	40	40	40	45	45
Oils and greases	30	40	30	20/(10)	20
Phenolic compounds (C_6H_5OH)	5	5	5	10/(2)	5
Total chromium (Cr)	2	2	2	5/(2)	2
Hexavalent chromium (Cr_6)	0.5	0.5	0.5	1/(0.5)	2
Copper (Cu)	3	3	3	20/(5)	3
Lead (Pb)	1	1	1	5/(1)	1
Nickel (Ni)	3	3	3	10/(2)	3
Zinc (Zn)	10	10	10	20/(5)	15
Arsenic (As)	0.2	0.2	0.2	2/(1)	0.2
Boron (B)	2	2	0	5/(2)	2
Selenium (Se)	0	0.1	0.1	5/(1)	0.05
Ammonical nitrogen (N)	50	0	50	250/(150)	50
Sulfides (S)	2	5	2	10/(5)	0
Sulphates (SO_4)	1,000	1,000	1,000	250/(200)	0
Chlorides (Cl)	900	900	900	300/(200)	0
Cyanides (CN)	0.2	0.2	0.2	5/(1)	2
Fluoride (F)	0	2	0	10/(2)	15
Cadmium (Cd)	0	1	0	10/(2)	15
Mercury (Hg)	0	0.01	0	0.1/(0.01)	0.01
Radioactive material: Alpha emitters (microcuries/ml)	10^{-7}	10^{-7}	10^{-7}	0	10^{-7}
Radioactive material: Beta emitters (microcuries/ml)	10^{-6}	10^{-8}	10^{-6}	0	10^{-8}

n.d. - not determined

Note: Maximum tolerance limits, unless noted otherwise.

Sludge Disposal

There are three general possibilities for sludge disposal: 1) landfilling, 2) incineration and disposal or reuse of ash, or 3) use in agriculture if the sludge is not toxic.

Municipal wastewater sludge often can be used in agriculture because it can be a good soil conditioner and contains valuable soil nutrients. Depending on the type of agricultural use, sludge may need to be additionally disinfected to prevent microbial pollution. Landfill disposal is still common, but in many places creates a nuisance due to odor and secondary pollution. The availability of suitable land is also often a problem.

The dewatered organic sludge from industrial wastewater is frequently incinerated or buried in a municipal solid waste landfill. If the dewatered biological sludge's metal and toxic organic content are low enough, it can be used in agriculture. Despite substantial costs, sludge is incinerated where landfill sites are lacking and agricultural use is prohibited.

Dewatered inorganic sludges are most likely to be hazardous or toxic due to high metal concentrations. Agricultural use is limited since it may be contaminated by heavy metals, organic chemicals and other toxic materials, bacteria, viruses, or other hazards, especially if the sludge is derived from inadequately pre-treated industrial wastewater. Such sludges are best disposed in a secure hazardous waste landfill or a segregated, well-lined area of a municipal solid waste landfill after proper treatment, or incinerated. Incineration's disadvantages include air pollution and ash disposal.

Simply treating industrial wastewater is not a sufficient solution to industrial wastewater management; proper sludge disposal facilities are essential. Also, toxic substances should be addressed before wastewater treatment, through pre-treatment or waste minimization at source, rather than expecting the treatment plant to dispose of large amounts of toxic sludge.

Centralized Sludge Treatment

Treating and disposing of sludge is an important part of wastewater treatment and can represent a considerable share of the total cost. For many industries, individual sludge processing is too expensive. One solution is building temporary onsite storage at each factory and treating sludge at a centralized facility. Some industries in the study areas individually process their sludge, but final disposal remains a problem. For example, around Jakarta, in many cases individually treated sludge, including potentially toxic chemical sludge, is disposed of with the industries' domestic solid waste, and are collected by government agencies or disposed on their premises.

Hazardous Waste Management

What is Hazardous? Definitions and Standards

Hazardous wastes are those whose characteristics are toxic, corrosive, flammable, explosive, infectious, or radioactive. Sludge from purely organic wastewater does not contain hazardous components, but these days, even most "domestic" wastewater contains hazardous elements. Sludge must be analyzed to determine whether it should be disposed as hazardous waste. In the absence of effective pre-treatment at individual factories, centralized biological treatment facilities may produce hazardous sludge. Most pre-treated liquid wastes and sludges contain hazardous components, especially from the following industries:

- textiles (lead, chromium, colors)
- tanneries (chromium)
- chemical industries (various)
- paint manufacturing (metals)
- automotive industries (grease, oil, metals)
- metal engineering (metals, cutting oil)
- oil industries (grease, oil)
- printing (oils, chemical dyes)

Sludges containing one or more of the above ingredients in quantities exceeding standards should be treated as hazardous waste.

The first step in hazardous waste management is to clearly define what is considered hazardous waste. Inappropriate definition and inadequate legislative tools have led to situations where hazardous wastes are managed on an ad-hoc basis. For example, presently in Sri Lanka hazardous wastes are defined by the U.S. Environmental Protection Agency Resource Conservation and Recovery Act definition, which uses stringent testing procedures to define hazardous wastes. The lack of trained personnel and sophisticated testing equipment makes such a definition inappropriate and unrealistic in Sri Lanka. In addition, the country has no specialized hazardous waste treatment facility. Thus, it is left to the waste generator to treat and dispose of his wastes. Groundwater contamination resulting from the improper disposal of hazardous waste has already been reported in the study areas. Therefore, the first priority is to establish appropriate hazardous waste legislation. Realistic and locally applicable standards need to be introduced.

Storage, Treatment, and Disposal

Proper hazardous waste treatment and disposal facilities are cost-effective in the long-term. Environmental clean-ups and site remediations are significantly more expensive than adequate treatment and disposal facilities. Comprehensive hazardous waste management should consist of 1) waste minimization, 2) better on-site temporary storage of toxic sludge and other materials, 3) appropriate treatment by individual industries or at a centralized facility, and 4) suitable hazardous waste disposal at a secure landfill facility.

As noted earlier, wastewater management should emphasize waste minimization and segregation at source, including hazardous waste. For example, in the case of the Ja-Ela area, it was estimated that waste minimization would reduce hazardous waste by 20–30 percent. Industries should be encouraged to re-evaluate their needs for hazardous chemicals. Where the chemicals are still needed, means should be developed for reusing, reprocessing, or recycling them. A **waste exchange program** might be developed, so that one industry's spent chemicals could be reused as another industry's feedstock.

On-site storage facility of hazardous sludge at individual plants needs properly designed and safe containment facilities. However, such measures should be only temporary, because long-term hazardous waste management plans need economical and environmentally safe collective treatment and final disposal facilities. Simple techniques such as organic and oily sludge incineration in cement kilns and stabilization of inorganic wastes can be adopted. Any residues from incineration and solidified wastes should be disposed in a secure landfill.

Current Status in the Study Areas

Individual plants generally dry their sludges and dispose them on their premises, send them with other solid waste to a municipal landfill, or illegally dump them on waste ground or in waterways. A specialized hazardous waste treatment plant has just been built in the Jakarta study areas, and hazardous waste regulations are under preparation in Indonesia. Individual industries needing to dispose of hazardous sludge will need to arrange this with the hazardous waste plant, which will then collect fees for the services.

In all the study areas, only a few industries were classified as generating any significant amount of hazardous waste. And, as in Ja-Ela Ekala, where industries generating hazardous waste were geographically concentrated, handling and disposal were relatively manageable.

4
Ownership, Management, and Financing

Private Sector Participation

One of the most essential questions in identifying an optimal institutional arrangement for a wastewater treatment system is whether or not to involve the private sector in what has traditionally been a public domain. Constructing, operating, and managing an efficient wastewater treatment system in a cost-effective manner call for massive capital investment and prime management and entrepreneurial skills.

One major argument for wider private sector involvement is that this will provide additional sources of financing where the government's financing ability is limited, and where there are competing demands on public financial resources. *Where public resources are scarce, priority should probably be placed on monitoring and enforcing standards, rather than financing the construction, operation, and management of a wastewater collection and treatment system, as this can be jointly promoted with or delegated to the private sector.* Therefore, governments are increasingly collaborating with the private sector, local or foreign, on mutually beneficial terms of BOO, BOT, or other public-private partnership arrangements.

However, the case for public ownership should be acknowledged if the facility is to serve a mixture of industrial and municipal customers, especially if the latter produces a large share of the total wastewater treated at a treatment plant. These ventures are difficult to make both profitably attractive to a private enterprise and affordable for residential customers. Even where the joint treatment facility is owned or managed by a private enterprise, the municipal sewerage network is often best handled by a public authority, since in most cases it runs under roads controlled by provincial or municipal authorities. One example is the Mookervart area, where municipal wastewater is expected to eventually contribute 70 percent of the total flow. The Ratmalana study also recommends public ownership and management of the residential collection system.

Institutional Arrangements

Many ownership and management options can be considered for a wastewater management system. The public and private entities that might be involved in financing, constructing, managing, or operating the system separately or in combination include:

- a national, provincial, or municipal government agency;
- a specialized public authority (e.g., NWSDB in Sri Lanka);
- a concerned industry association;
- a private limited company;
- a joint venture with government; and
- a foreign collaborator.

An optimal public-private partnership for industrial wastewater management must define and distinguish between the owner's and the operator's responsibilities. In general, the owner's responsibilities are to supervise construction and management, to arrange financing, and to protect public interests by monitoring and controlling the quality and affordability of the operator's services. This may include:

- preparing feasibility studies and making investment decisions;

- determining the tariffs to be charged for the services;
- financing (except for a BOT arrangement where the operator is responsible for financing);
- selecting and supervising technical design specialists, building contractors, suppliers, and the operator;
- negotiating an operating contract; and
- providing the operator with access to the necessary underlying facilities.

On the other hand, a wastewater collection and treatment system operator's responsibilities should broadly cover O&M, including:

- general system maintenance;
- maximizing system operational efficiency;
- ensuring operating safety;
- training operating staff;
- assessing the needs for system expansion and improvement; and
- financing, if required under a BOT arrangement.

The gray area between the owner's and the operator's domains includes:

- monitoring influent into the treatment plant;
- obtaining necessary permits or clearance;
- establishing pre-treatment standards (these may have already been set by the government, as in India);
- ensuring that treated wastewater complies with effluent standards; and
- collecting payments from customers.

When ownership and O&M are separated, specific responsibilities must be defined and delegated to appropriate parties.

Industry Associations

Establishing an association of industries can be instrumental in implementing a centralized wastewater treatment project, as well as in general pollution prevention efforts. The association would be set up with the following objectives:

- creating, promoting, and maintaining mutual understanding and cooperation for reducing, abating, preventing, and controlling industrial pollution;
- promoting awareness among industrialists of environmental degradation caused by industrial pollution, and implementing local waste minimization programs;
- promoting and cooperating with the construction of a centralized wastewater treatment plant;
- helping formulate a fee structure for payment and reimbursement for constructing, operating, managing, and maintaining the facility;
- keeping abreast of recent developments and cost-effective concepts in environmental technology;
- working with national and international agencies to research these techniques' feasibility, and modifying existing operational methods where necessary;
- interacting with the community; and
- promoting waste-exchange programs among the members.

Through such an association, the polluting member industries would take the institutional responsibilities for constructing, operating, recovering costs, and administering the joint treatment system. This would fit the polluter-pays-principle, as the polluting industries would bear responsibility for the mitigation costs. Treatment facility ownership by an industry association would result in better customer relationships and would encourage adherence to pre-treatment standards and other operating rules, since the beneficiaries are the owners themselves. However, the industry association may lack wastewater management know-how. This could be solved by contracting out facility operations.

Where an industry association establishes a limited liability company, as described in box 4.1, the company rather than the association would assume legal and financial responsibility, and the association's role would be limited to promoting pollution control and environmental concern among area industries.

Build-Operate-Transfer (BOT)

BOT projects are contractual arrangements whereby the contractor constructs, finances, operates, and maintains an infrastructure facility for a

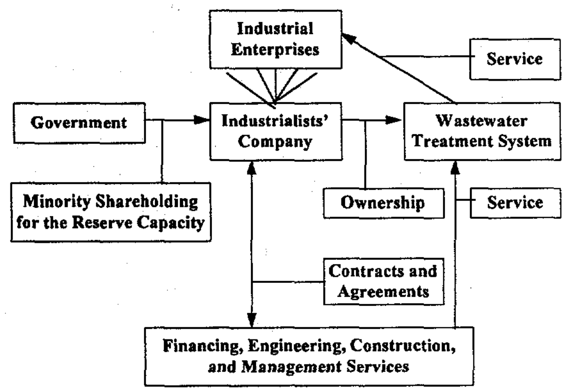
Box 4.1: Proposed Institutional Arrangement for Ja-Ela Ekala

The institutional arrangement suggested by the Ja-Ela Ekala study is a limited liability company established, owned, and managed by the participating area industries. This company would be responsible for implementing and operating the centralized wastewater treatment plant, and would invite consultants, contractors, and equipment suppliers to bid on the various project components, or solicit bids from turn-key contractors.

As owners, the industries would also assume the financing and operational responsibilities and risks. The company would be responsible for meeting effluent standards. It is anticipated that the company would be self-sustaining without subsidies. **This scenario would mean that the waste generators, through the limited liability company, would assume full responsibility.** Of a total investment cost of SL Rs.270 million, the study suggests a 30 percent equity financing by the participating industries and other investors, and 70 percent loan financing. The SL Rs. 80 million share capital would be divided among the participating industries proportionate to each industry's share of the total flow and COD load. A development credit of SL Rs.190 million is assumed to be covered by IDA, onlent to the wastewater treatment company on a project risk, against a mortgage, or a guarantee of the owners.

(SL Rs. million)	Foreign	Local	Total	Percent
Loan Financing	63.0	127.0	190.0	70
Equity		80.0	80.0	30
Total	**63.0**	**207.0**	**270.0**	**100**

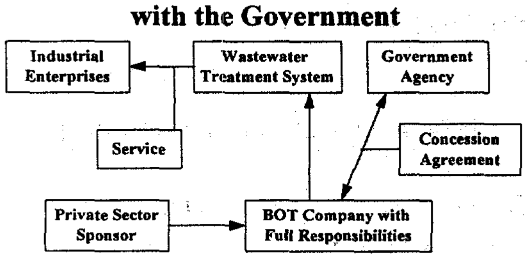
The company would establish cost recovery policies and set tariffs. The participating industries would manage the company through a board while day-to-day management and O&M activities would be undertaken by a professional manager and operating personnel. If the participating industries are reluctant to participate in managing the plant, they might choose to retain an external BOO company or an operating contractor.



Since it would be unfair for the initial participating enterprises to bear the entire system construction costs, including excess capacity reservation, the study suggests that a government agency or the private sector invest in the system, perhaps by becoming minority shareholders. Over time, these investors could sell their shares to industries interested in joining the treatment system. The government might assume the responsibility for the ownership and management of the centralized treatment plant. This option, however, contravenes present GOSL policy. A major government role would be better justified in a more comprehensive wastewater network, larger in scale than this study area alone.

specified period of time, during which the contractor charges the facility users tariffs, fees, and other charges in order to recover capital, operating costs, and a risk-adjusted return on his investment. An advantage of this arrangement over direct government involvement is that the project does not strain government balance sheets. At the end of the contract, the contractor transfers the facility to the ultimate owner, usually a government or other public authority, under the terms of the original agreement.

Figure 4.1: BOT Arrangement with the Government



BOT arrangements usually separate the right to earn revenue under the concession agreement from the ownership of the underlying fixed assets, which normally remain with the owner, generally a public authority. BOT companies running a wastewater treatment facility often require a guarantee from the government for either a minimum volume of wastewater or a financial guarantee if

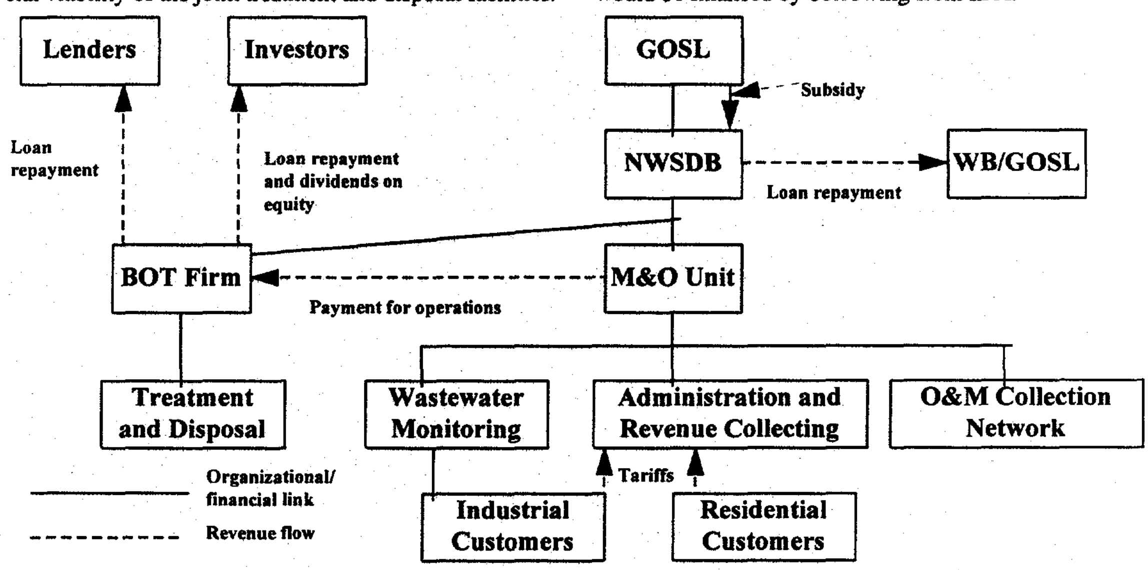
Box 4.2: Proposed Institutional Arrangement for Ratmalana-Moratuwa

The study recommends that the National Water Supply and Drainage Board (NWSDB) operate the wastewater management system, with direct responsibility for the collection system, industrial wastewater monitoring, and standard enforcement, administration, and revenue collection. A private limited (BOO or BOT) company would be responsible for the joint treatment and disposal facilities.

NWSDB would establish a managing and operating (M&O) unit or department that would first finance and oversee construction. NWSDB would tender the work for the wastewater collection system and give the contracts to construction companies. Once the system is in operation, the M&O unit would operate and maintain the collection system, administer revenue collection and finances, monitor industrial wastewater quality and flow, and enforce pretreatment standards. The BOO/BOT firm would be responsible for financing, designing, and constructing the joint wastewater treatment and disposal facilities. In the operation stage, the BOO/BOT firm would be responsible for facilities management, technical operation, maintenance and repair, wastewater effluent quality control, and financial viability of the joint treatment and disposal facilities.

Under this arrangement, the BOO/BOT firm would only receive income from NWSDB, which in turn would be derived from tariffs collected from the system's users. The BOT firm must have government assurances that the agreed payments will be made to them regardless of the amount of tariffs collected. It follows then that the government, through NWSDB, would assume financial responsibility for the overall wastewater management facility.

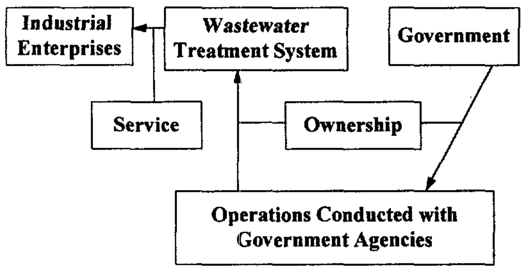
A significant advantage of this institutional framework is that the BOO/BOT company will finance the wastewater treatment and disposal facilities, leaving the government only to find funds for constructing the collection system. For the treatment plant and the outfall, the study suggests BOT 30 percent equity and 70 percent BOT borrowing, possibly from the Private Sector Infrastructure Development Fund, for the treatment and disposal facilities. The study suggests that NWSDB would need contributions from GOSL, either as equity, an outright grant, or a long-term interest-free loan for the full investment cost of the residential collection system, in order to make residential tariffs affordable, while the industrial collection system would be financed by borrowing from IDA.



revenue collection from customers (especially residential customers) is expected to be difficult. BOT contracts are usually signed between a government and a private sector enterprise, for public sector projects. One variation is an arrangement where the private company owns the facility until the end of the contract period (i.e., Build-Own-Operate-Transfer, or BOOT).

Under the BOT approach, one or more private sector sponsors are authorized to create a private project company. The sponsors typically include a major international engineering and construction firm and equipment suppliers, who then act as project builders and suppliers. The project company may include passive equity investors or even a minority equity participation by government.

Figure 4.2: Government Management Option



Build-Own-Operate (BOO)

The BOO concept authorizes a private company to construct, finance, operate, and maintain a specified infrastructure facility for a lengthy period of time. The project company is responsible for system operations and management, without obligation to transfer the fixed assets to an industry association or the government.

BOO arrangements normally are used to privatize public services. As the participating industries are free to establish a private company of their own to administer the wastewater treatment facility, there is no need to contract an external BOT company, which would probably result in higher tariffs.

A major drawback of these arrangements is that developing a BOT, BOO, or BOOT project is complicated, time-consuming, and expensive. In general, expensive legal, financial, and institutional expertise is required to ensure that all parties are protected and that the potential rewards and risks are distributed equitably. A BOT, BOO, or BOOT company's advantages must significantly balance the required expenditure, time, and energy, and they are normally not a suitable model for small-scale projects. In many cases such projects failed because high front-end costs crippled the project before the launch.

Government Ownership and Management

The government, usually local or municipal, and relevant agencies assume responsibility for facility ownership and management, including full responsibility for project design, implementation, operation, management, and financing. Under this model, participating industries tend to remain rather passive.

5
Cost Recovery and Tariff Structure

Establishing an appropriate tariff structure is important to ensure sufficient revenues to cover the costs of centralized or joint wastewater treatment. There are two broad categories of costs to be recovered from customers:

- Capital costs: debt servicing for financing the treatment plant and collection, disposal systems, and connection of each user to the collection system; and
- Operating costs: O&M for collection and treatment facilities, depreciation, and administrative costs.

Ideally, ongoing operations should be self-sustaining, and in theory, all water users should fully pay for both capital and O&M costs in the forms of capital and finance charges, as well as wastewater-based tariffs. This would mean that the general tariff structure should be established in such a way that tariff revenues will cover all costs listed above. Once the level of total tariff revenue necessary for this has been identified, there are several ways in which it can be spread among different types of customers.

The "Polluter-Pays-Principle"

Applying the polluter-pays-principle to revenue collection for centralized industrial wastewter treatment implies that the costs are shared among participating industries proportionately to the system capacity required to manage their specific wastewater. The tariff structure should reflect this.

An ideal tariff structure is based on both volumetric flow and pollution load, ensuring that all partners are treated evenly and there is no cross-subsidy among the industries. Furthermore, this provides individual industries with incentives to reduce pollution, in order to lower the tariff payments. In Europe, for example, a typical tariff formula includes BOD, Kjeldahl-nitrogen, and annual hazardous waste load. A tariff structure based on multiple parameters, like this one, can more accurately implement the polluter-pays-principle, but may be too complex and impractical for the study areas. Multiple parameter methods require complex sampling and analysis in order to determine each customer's charge. Any tariff formula chosen should be simple to apply and easy to enforce. Volumetric flow and BOD measures would be an appropriate set of parameters for wastewater treatment tariffs, since, according to the Ja-Ela Ekala study, at typical activated sludge treatment plants about 60 percent of O&M costs can be attributed to the flow and 40 percent to biological load. However, BOD analyses are often highly erratic, especially in higher concentrations, and unsuitable as a billing basis for individual industries. Instead, the Ja-Ela Ekala and Jakarta studies recommend using COD concentration which, although not directly related to BOD values, reflects final oxygen demand in the recipient water and can be measured more accurately and economically.

Fairly reliable data on pollution loads and flow contribution by each industry tend to be available for organized industrial estates like JIEP. However, for treatment plants serving less well-organized industrial zones or treating a considerable amount of residential wastewater (for example, the proposed treatment plant for Mookervart), setting tariffs by the polluter-pays-principle will be more complicated due to lack of reliable data.

Tariff structures can be simplified by leaving out the pollution load component, such as BOD or

COD measurements, and basing it only on volume. The main advantage of the volumetric tariff is an easier and more reliable verification of the volumetric flows of each enterprise as well as simple calculations. As long as BOD and COD concentrations do not vary substantially among the participating industries, the volumetric tariff would be reasonably fair. For example, a simple volumetric tariff structure would be sufficiently equitable for a common treatment plant serving a cluster of industries with similar production processes and raw materials.

For joint treatment of municipal wastewater, strict application of the polluter-pays-principle is desirable but not always feasible in terms of affordability. For many households in the study areas, tariff rates set for full recovery of investment and O&M costs would be too expensive. Some form of government subsidy for joint treatment of municipal wastewater may be necessary and justifiable on grounds of the greater social and environmental benefit.

Another way to make joint wastewater treatment affordable for residential users is cross-subsidization by industrial participants. For example, the Ratmalana-Moratuwa study proposes a tariff scheme with different flow-based rates for different categories of customers—industrial, commercial, and residential—resulting in industrial customers partially covering the actual costs of treating residential wastewater.

Assumptions

Basic conditions necessary for successful cost recovery through tariffs are as follows:

Box 5.1: Tariff Structures in Practice and Cost Recovery Rates

A common effluent treatment plant for an industrial estate in Odhav, Gujarat, India, uses a tariff structure that divides the participating industries into four categories: 1) unoccupied plot or shed; 2) engineering industry; 3) water-based non-polluting industry; and 4) polluting industry. For these four categories, a fixed monthly charge is levied as given in the table below:

Cost Recovery Mechanism at the Treatment Plant at Odhav, Gujarat (1991)

Classification	Rs. per month
Vacant lot or shed	75
Engineering industry	100
Water-based non-polluting industry	300
Polluting industry	500

This structure attempts to reflect pollution load variations among different types of activities, but fails to include variations within each category. Moreover, it does not take into account volumetric flow, leaving no incentives for enterprises to minmize their wastes. Once an enterprise has been classified, it pays the fixed amount no matter how much or how little effluent it generates. Even at these low charges, the collection rate is quite low, averaging 50 percent.

The tariff structure used at a common effluent treatment plant at Jeedimetla, Andhra Pradesh, is based on flow and COD values. For every 10 cubic meters, a sliding scale with COD values is used, as presented below:

Cost Recovery Mechanism at the Treatment Plant at Jeedimetla, Andhra Pradesh (1991)

COD Concentration of Effluent	Rs. per 10,000 liter tanker or fraction
1~5000	150
5,001~10,000	175
10,001~15,000	200
20,001~35,000	250
Above 35,000	Additional charge of Rs. 25 per tanker for every 1,000 of COD. However, for such tanker loads, specific prior approval must be obtained by the customer from the treatment company.

This system works well because it requires monitoring only one quickly-checked parameter, and it is very easy to enforce. Tariff collection for this treatment plant has been very good, averaging 90 percent. This is mainly due to the fact that the effluents are transported by tankers, permitting strict control over wastewater discharges. Wherever wastewater is collected through a sewer network, tariff collection is more difficult, unless water usage is accurately metered.

Source: Environmental Engineering Consultants. *Report to the World Bank upon Common Effluent Treatment Plants in India*, January 1991.

Table 5.1: Tariff Structure Recommended for the Proposed Wastewater Treatment Plant in Ja-Ela Ekala

Effluent Flow Tariff	Rs. 48/cubic meter (US$0.96/cubic meter)
Effluent COD Tariff	Rs.13/kg (US$0.26/kg)
Annual Subscription	Rs.65,000/year (US$1,300/year)

- **Effective monitoring and enforcement of effluent standards for all industries, with penalties for non-compliance adequate to serve as a deterrent** (i.e., exceeding the cost of participating in the system). These standards should also be applied to discharges from industries outside the project area, providing incentives for these industries to connect to the system, and discouraging industries from relocating outside the serviced area.
- **The government requires all residential, commercial, and institutional organizations to connect when the collection system becomes available.** Full participation will be necessary for the system to effectively reduce water pollution, and full utilization of the system will be necessary to meet revenue requirements for operations and debt servicing.
- **Costs of necessary pre-treatment to be borne by individual industries, in order to encourage waste minimization at source.** Substantial pre-treatment should be reflected in lower tariff charges for centralized treatment.

Examples of Recommended Tariff Structure

Ja-Ela Ekala (volumetric flow plus COD load)

The study recommends the application of the polluter-pays-principle to determine the tariff structure for the centralized wastewater collection and treatment system, relative to each industry's share of the actual flow and COD load. This tariff structure was established based on the revenue level necessary for full recovery of amortized investment cost and O&M costs, and consists of a) a base subscription fee covering administrative and monitoring costs, b) a flow-based component, and c) a COD-based component as given in table 5.1.

Table 5.2: Tariff Structure Recommended for the Proposed Wastewater Treatment Plant in Ratmalana-Moratuwa

Industrial/Commercial	
Flow Tariff	Rs. 47/cubic meter (US$0.94/cubic meter)
Industrial Process Connection Fee (a)	Rs. 15,000 (US$300)
Industrial Domestic Connection Fee (a)	Rs. 37,000 (US$740)
Commercial Connection Fee (a)	Rs. 26,000 (US$520)
Residential Users	
Flow Tariff	Rs. 10/cubic meter (US$0.20/cubic meter)
Connection Finance Charge (b)	Rs. 120/month (US$2.40)

(a) one-time fee to cover actual connection costs .

(b) a monthly surcharge for recovery of amortized costs of residential connection, to continue for at least 15 years.

Ratmalana-Moratuwa (volumetric flow only)

As at Ja-Ela Ekala, the polluter-pays-principle has been applied to determine the tariff structure for industrial and commercial users, but only based on flow. Table 5.2 summarizes the tariff rates recommended by the study. The residential tariff structure was established based on cash-flow analysis including the level of government subsidy necessary for household affordability in the study area.

6
Regulatory Framework

Monitoring and Enforcement of Standards

Two levels of monitoring and enforcement are needed for centralized or joint wastewater management to function effectively: 1) monitoring effluent from individual industries coming into the centralized treatment system, and 2) monitoring effluent after centralized treatment.

For the former, certain standards are needed to protect the centralized treatment system, and to require any necessary pre-treatment. These standards should be set and monitored by the owner or operator of the centralized treatment plant, and compliance should be a precondition included in the service contract for treatment. Some countries or states may have standards for pre-treatment by certain industries. The plant owner or operator could set additional or more stringent standards if necessary to protect the centralized system.

The effluent standards for the final discharge after centralized treatment are usually set by the central or local government. Compliance by the centralized treatment operating company should be monitored by a relevant authority to ensure enforcement of these standards. The effluent standards applicable to the proposed centralized and joint treatment plants for the four study areas are given in table 6.1, which also includes Indian standards for comparison.

Sri Lanka

The legal framework covering environmental issues in Sri Lanka is expressed in the National Environmental Act (NEA), No. 47 (1980), amended by Act No. 56 (1988). This was expanded by the National Environmental (Protection and Quality) Regulations, No. 1 (1990) and National Environmental (Procedure for Approval of Projects) Regulations, No. 1 (1993). These define the projects which need prior approval at the ministry level, and need an Environmental Impact Assessment (EIA) or an Initial Environmental Examination (IEE).

Furthermore, the regulations require that no person can discharge, deposit, or emit waste into the environment without a license from the Central Environmental Authority (CEA). Industry-specific and receptor-specific effluent standards are also given.

Wastewater treatment is not mentioned in the NEA Schedule for projects and undertakings needing prior approval. The closest listed undertaking is constructing waste treatment plants treating toxic or hazardous waste. Because the proposed centralized treatment plant in Ja-Ela Ekala requires pre-treatment at the source to remove toxic pollutants in advance of centralized treatment, it can be interpreted that an EIA or IEE is not legally required for this centralized treatment plant. Individual industries, on the other hand, would need to be individually appraised on their use of toxic or hazardous materials. An environmental license for the centralized treatment plants would still be needed for the Ja-Ela Ekala plant, even if effluent standards are met. The proposed treatment plant in Ratmalana-Moratuwa comes under the Coastal Conservation Act, and an EIA would be required to construct the ocean outfall.

Effluent standards. The NEA provides general standards for discharging domestic and industrial effluents into inland surface waters and marine

Table 6.1: General Standards for Discharge of Effluents into Inland Surface Waters

total mg/l, unless noted otherwise	Sri Lanka (a)	DKI Jakarta (b)	India (c)
COD	250	100	250
BOD	30	75	30
pH (no units)	6.0–8.5	6.0–9.0	5.5–9.0
TSS	50.00	100	100
Total dissolved solids	n.a.	200	2,100
Temperature (Celsius)	40	38	40
Oils and greases	10	5	10
Phenolic compounds (C_6H_5OH)	1	0.50	1
Total chromium (Cr)	0.10	1	2
Copper (Cu)	3	1	3
Lead (Pb)	0.10	0.10	0.10
Nickel (Ni)	3	0.10	3
Zinc (Zn)	5	2	5
Arsenic (As)	0.20	0.10	0.20
Boron (B)	n.a.	1	2
Selenium (Se)	0.05	n.a.	0.05
Ammonical nitrogen (N)	50	5	50
Sulfides (S)	2	0.05	2.80
Sulphates (SO_4)	n.a.	100	1,000
Chlorides (Cl)	n.a.	100	1,000
Cyanides (CN)	0.20	0.05	0.20
Fluoride (F)	2	2	2
Cadmium (Cd)	0.10	0.05	1
Mercury (Hg)	0.0005	0.002	0.01
Radioactive material: Alpha emitters (microcuries/ml)	10^{-7}	follows the BATAN rules	10^{-7}
Radioactive material: Beta emitters (microcuries/ml)	10^{-8}	follows the BATAN rules	10^{-6}

(a) Central Environmental Authority, Sri Lanka. National Environmental Act, No. 47 (1980), as amended by Act No. 56 (1988).
(b) Developed by the Government of DKI Jakarta, based on KEP-03/MENKLH/11/1991, issued by the State Ministry for Population and Environment.
(c) India: Environment (Protection) Rules, 1986

coastal waters, and would apply to treated effluent from the proposed centralized treatment plant in the Ja-Ela Ekala area. However, at present there are no standards for effluent discharged via an ocean outfall, as would be the case for the proposed treatment plant in the Ratmalana-Moratuwa area, which would have a 2-kilometer long ocean outfall. The existing standards for marine coastal waters covers only 300 meters from the low-tide shoreline. It is strongly recommended that suitable effluent standards for discharge into the offshore marine environment be addressed in the EIA, and be adopted by CEA.

The Scheme for the Control of Pollution for Existing Industries (SCOPE), developed in 1992, is a concept aimed at providing interim relief to existing industries in their efforts to meet the standards set in the NEA. It proposes a set of more relaxed standards compared to the NEA, and is to be implemented over a period of five years. However, the study recommends that the proposed plant in the Ja-Ela Ekala area be designed to meet the original effluent standards set under the NEA, rather than the SCOPE standards. The latter are still not lax enough to enable substantial simplification of treatment system design and subsequent cost savings. Even if the proposed plant were built for just enough treatment efficiency to meet SCOPE standards, the limited time span would necessitate upgrading the treatment plant within two or three years. Nevertheless, SCOPE offers a possibility for phased construction of the centralized treatment plant.

Monitoring. Currently there is no legal requirement for monitoring the chemical content of the sludge produced at the joint treatment plants. Legislation concerning definition, handling, and final disposal of solid, liquid, and gaseous hazardous wastes needs comprehensive revision. The issues needing amendment in the context of wastewater treatment either at source or in a centralized system are evaluated in the section on hazardous waste and sludge disposal above.

As for the quality of influents into a centralized treatment facility, the facility operator should conduct a monitoring program to ensure that all serviced industries comply with pre-treatment standards set forth in their service contracts.

Indonesia

The Ministry of Industry, through decree No. 20/M/SK/1/1986, requires that an industrial estate's management assume responsibility to treat the estate's wastewater. In the case of JIEP, wastewater treatment responsibilities are transferred from individual industries to the managing organization P.T. JIEP through transfer of an official document, Tata Tertib Kawasan Industri (TTKI), which specifies existing industries' obligation for connection, pre-treatment, fee payment, etc., for centralized wastewater treatment.

In the Mookervart study area there is no formal framework such as TTKI because it is not an industrial estate. Still, the industries in this area would be obliged to meet the effluent standard given below. The proposed treatment facility for Mookervart would treat municipal wastewater as well. Participation of area households would be subject to Governor Decree No. 45 of 1992, which stipulates that within a sewered area, wastewater must be discharged into the sewer while the wastewater itself must meet certain standards.

Effluent standards applicable nationwide have been issued by the State Ministry for Population and Environment (KEP-03/MENKLH/11/1991). This decree establishes four categories of wastewater standards, depending on the types of receptor (drinking water; fishing; agricultural use; conservation and protection of aquatic life). Based on this, the local government of DKI Jakarta issued its own set of standards applicable to industrial and commercial activities in the area, which will apply to treated effluent from the proposed centralized treatment plant. The Jakarta standards contribute to the general improvement of the quality of area water bodies, but some individual parameters are too lax while others are unrealistically stringent, making full compliance difficult and expensive.

Establishing realistic standards. Some developing countries have adopted stringent standards comparable to those of developed countries and tried to obtain compliance within an unrealistically short period of time. Often overlooked are the enormous costs of upgrading existing wastewater treatment plants or building new facilities. It is strongly recommended that a more realistic approach be adopted in cases where increasingly stringent standards will be phased in over a period of time. SCOPE, as introduced in Sri Lanka, is one such attempt. For Jakarta the study recommends an alternative set of effluent standards more appropriate to the proposed centralized treatment plant

Table 6.2: Effluent Standards Recommended by the Jakarta Study

Parameter (g/cubic meter)	DKI Standards	Proposed Standards 1995	2005	2015
BOD	75	75	50	35
COD	100	200	150	120
TSS	100	100	100	100
NH_4-N	5	10	8	5

than the ambitious standards established by the local DKI Jakarta government (table 6.2). In fact, water pollution in the area is so severe that driving a few industries into compliance with strict standards will make no improvements. What is needed is to get **all** industrial and domestic sources to comply with a more moderate and achievable set of standards.

Monitoring. Industries in the Jakarta area are required by law (PP20) to have their wastewater analyzed by the laboratory of DKI Jakarta (KPPL).

Appendix A
Polluter Inventory

Ja-Ela Ekala, Colombo, Sri Lanka[1]

The study identified a total of 143 industrial establishments in the area, 135 in operation and eight being planned. Of these, 80 (56 percent) use water in their operations, 66 (83 percent) of these businesses generate industrial effluents, and presently only 13 have on-site treatment facilities. Only three have comprehensive treatment systems. The sectoral distribution of the industries and their effluents in the study area is summarized in table A.1.

The figures in table A.1 exclude cleaner effluents, such as cooling water, which are assumed to be segregated from effluents needing further treatment.

To illustrate the use of water in production, the study divided the 135 operating industrial establishments into three categories of water use:

Category 1: dry process; no water used (55 industries);
Category 2: industrial water consumption less than 5 cubic meters per day (55 industries);
Category 3: industrial water consumption greater than 5 cubic meters per day (25 industries).

It became evident that fewer than one-fifth of the industries were using the greatest quantity of water.

The total flow volume of effluents needing treatment in the study area is estimated to be 1,412 cubic meters per day, with total BOD load of 620 kilograms per day. Of this flow, only about 284 cubic meters per day (20 percent) is currently treated by the 13 existing on-site treatment plants. Ekala Industrial Estate (EIE) possesses a central treatment plant, built in 1963, but it only treats domestic wastewater and does not operate properly due to lack of spare parts, pipe blockages, and inadequate revenue.

EIE, which houses 39 operating industries, is equipped with piped water supply and sewerage. There is no piped sewerage for the industries outside EIE. A collection system for the proposed centralized treatment plant would be feasible only if the effluent-generating industries were located reasonably close to each other and their effluent volume big

Table A.1: Types of Industries in Ja-Ela Ekala

	Number of Industries	Total Flow (cubic meters per day)
Food and beverages	14	210
Textile and leather tanneries: wet processing	18	878
Textile and leather tanneries: dry processing	28	1
Chemical	26	134
Mineral Products	6	36
Metal	17	37
Machinery and equipment	10	2
Timber: dry processing	10	0
Paper	3	1
Agriculture and aquaculture	2	113
Others	1	0
Total	**135**	**1412**

enough; in other words only in and around EIE. The study proposes participation by 73 industries, based on their effluent generation levels. 68 industries would have pipe connections to the collection network, and five industries outside the network would transport effluent by tankers.

Ratmalana-Moratuwa, Colombo, Sri Lanka[2]

This study identified 222 industrial establishments in the area. The predominant industries are textiles and garments, chemicals, metal finishing, food, and asbestos products, in addition to a number of small-scale and cottage industries. Currently, liquid wastes from industries are discharged untreated into nearby drainage courses. Domestic wastewater is directed to septic tanks. Washwater is generally discharged directly into roadside drains. The sectoral distribution of industries in the area is summarized in table A.2.

The total flow of industrial effluents, including both process and domestic wastewater, is estimated to be about 8,000 cubic meters per day. The total municipal wastewater flow is estimated to be 7,260 cubic meters per day, and will be included in the joint treatment. Process water is generated from about 100 industries in the study area; over 50 percent of this is generated by the textile manufacturing sector and another 35 percent by the equipment maintenance and repair sector. Of this, more than 90 percent comes from vehicle and equipment washwater. Segregating washwater could reduce this process water by at least 30 percent. Over 90 percent of the total process water flow is generated by only 25 percent of industrial establishments.

Mookervart, Jakarta, Indonesia[3]

The Mookervart study area is characterized by a relatively large number of highly polluting types of industries. Of the 176 industrial establishments in the area, 19 are foods and beverages, 14 are textiles, and 20 are chemical industries. The proportions of industry types found in the area are summarized in table A.3.

Based on the inventory of existing industries, the total flow of industrial effluents in the area was

Table A.2: Types of Industries at Ratmalana-Moratuwa

	Number of Industries
Garments	80
Textiles	20
Metal and equipment	23
Chemical, pharmaceutical, and applied products	17
Food and beverages	17
Equipment maintenance, repair, and technical training centers	16
Printing	10
Plastic	11
Others	28
Total	**222**

Table A.3: Types of Industries at Mookervart

	Number of Industries
Food and beverages	21
Textiles, garments, and leather tanneries	24
Chemical	20
Metal	24
Paper	5
Plastics	30
Pharmaceuticals and cosmetics	2
Printing	8
Electronics	13
Machinery	8
Wood	4
Special material	9
Others	9
Total	**176**

Table A.4: Mookervart—Sources of Effluents

	Top Ten Polluters	Study Area Total (176 Factories)	Share of Top Ten Polluters (%)
Flow (cubic meters per day)	7,290	3,991	54.7
Raw BOD (kilograms per day)	6,346	7,670	82.7
Treatment efficiency	38%	38%	not determined
Net BOD (kilograms per day)	3,991	4,777	83.5

estimated to be 14,501 cubic meters per day, with a BOD load of 7,670 kilograms per day. Existing treatment facilities at a few of the industries reduce the total BOD load by 38 percent to a net BOD load of 4,777 kilograms per day. The study further found that 82 percent of the net BOD load and 50 percent of the total flow are contributed by the ten largest polluters—six food and beverage industries, three textile industries, and a paper mill. Only four of these ten polluters currently have individual treatment facilities. This is summarized in table A.4.

As is apparent from table A.4, Mookervart is a classic example of an industrial area where most of the water pollution is generated by a few large-scale polluters. However, further industrial development in the area is expected to occur among medium-scale industries (20–100 employees) rather than large-scale polluters. Therefore, the total industrial effluent in the area is not expected to increase dramatically. In fact, the study projects that the total BOD load will substantially decrease due to increased individual treatment by current major polluters. Moreover, the Ministry of Industry is discouraging further industrial development in this area.

On the other hand, municipal wastewater is expected to increase significantly. Currently, 75 percent of total wastewater in the area is generated by industry, but by 2015, domestic wastewater is expected to represent over 70 percent of the total flow. This is due to anticipated population growth and sewerage projects due to be implemented in the area, piping more residential wastewater to the proposed joint treatment plant. The study recommends joint treatment of municipal wastewater.

Cipinang, Jakarta, Indonesia[4]

The study area has 122 industrial establishments in operation, and a relatively large share are of highly polluting industries, such as food, dairy, beverages, textiles, and drugs and cosmetics. The sectoral distribution of industries in the area is summarized in table A.5.

The total flow of industrial effluents in the study area is 15,942 cubic meters per day, and the BOD load is 7,956 kilograms per day. The study found that more than half of the industries already have individual treatment facilities which are relatively efficient, reducing the BOD load by 60 percent to 3,192 kilograms per day. The inventory further revealed that the ten largest polluters in the area contribute 84 percent of the net BOD load and 63 percent of the total flow. Of these, eight industries already have individual treatment facilities

Table A.5: Types of Industries in Cipinang

	Number of Industries
Food, dairy, and beverages	22
Textiles, garments, and leather tanneries	13
Chemical	26
Metal	8
Paper	2
Plastics	6
Pharmaceuticals and cosmetics	20
Printing	8
Electronics	7
Machinery	5
Special material	2
Others	3
Total	**122**

on-site, resulting in the average efficiency of 41 percent. This is summarized in table A.6.

Table A.6: Cipinang—Sources of Effluents

	Top Ten Polluters	Study Area Total (122 Factories)	Share of Top Ten Polluters (%)
Flow (cubic meters per day)	10,059	15,942	63.3
Raw BOD (kilograms per day)	4,608	7,956	57.9
Treatment efficiency	41%	60%	not determined
Net BOD (kilograms per day)	2,694	3,192	84.4

Between 1987 and 1991, the number of large-scale industries in Cipinang doubled while medium- and small-scale industries decreased significantly, unlike Mookervart where industrial growth occurred mainly among medium-scale industries. As stated above, most of the large-scale industries already have individual treatment facilities. Therefore, further increases in industrial pollution from growing production capacity is expected to be offset by increased pollution reduction measures at the largest polluting industries. Based on these projections, the study concludes that the future BOD load of industrial effluents in the area will remain fairly constant while the total flow may increase slightly.

Municipal wastewater, which may be connected to the proposed joint treatment system, is expected to increase substantially due to population growth and building additional municipal sewerage.

Based on the inventory of industries, the report concludes that centralized industrial wastewater treatment is not the optimal solution for the Cipinang study area. Most of the total BOD load in the area is generated only by four industries. Moreover, many factories, including the largest polluters, already have individual treatment facilities or their effluents already comply with effluent standards. Building a joint treatment plant just for the remaining industries would be more expensive than investments in individual treatment and upgrading existing treatment facilities.

Jakarta Industrial Estate at Pulogadung (JIEP), Jakarta, Indonesia [5]

JIEP contains 239 industrial establishments, most of which are small- to medium-scale. It has a relatively large share of metal construction and assembling, as well as equipment manufacturing industries which produce limited wastewater, unlike the food, beverage, and textile industries. The sectoral distribution of industries in JIEP is summarized in table A.7.

Despite the fact that a large number of industries operate in JIEP, the total raw BOD load is much lower than in other study areas. This can be explained by the type of industries operating in JIEP; highly-polluting activities such as textile dying, dairy processing, paper mills, and tanneries are relatively less numerous in this study area.

Individual treatment is minimal, and much less

Table A.7: Types of Industries in JIEP

	Number of Industries
Food, dairy, and beverages	18
Textiles, garments, and leather tanneries	18
Chemical	21
Metal	38
Paper	1
Plastics	9
Pharmaceuticals and cosmetics	12
Printing	27
Electronics	15
Mechanical	50
Wood	12
Special material	5
Others	13
Total	**239**

Table A.8: JIEP—Sources of Effluents

	Top Ten Polluters	Study Area Total (239 Factories)	Share of Top Ten Polluters (%)
Flow (cubic meters per day)	975	4,679	20.80
Raw BOD (kilograms per day)	1,414	2,182	64.80
Treatment efficiency	8%	9%	not determined
Net BOD (kilograms per day)	1,301	1,992	65.30

than in Mookervart and Cipinang. Only about 9 percent of the total BOD load is currently removed by existing individual treatment facilities. Unlike Mookervart and Cipinang, where most of the effluent is generated by a few large polluters, JIEP's ten largest polluters contribute only 20 percent of the total flow and 65 percent of the total net BOD load. However, one candy factory contributes one-half of JIEP's total BOD load. This is summarized in table A.8.

The inventory shows that 15 percent of the industries presently registered with JIEP are not yet operational. Moreover, there is excess land area reserved for future industrial development, which will probably add another 20 percent increase in industrial activities. Based on this, industrial effluents are expected to increase substantially in the future. The study projects a doubling of the total flow by 2015. However, total BOD load is projected to decrease substantially due to the expected relocation of the single largest BOD contributor (the candy factory) out of JIEP.

Currently, there are marginal low-income residential areas in JIEP. However, this population is expected to decrease upon further industrial development in JIEP, and be effectively dispersed by the year 2005. Therefore, the study recommends treatment of industrial wastewater only.

Endnotes

1 Soil and Water Ltd. and Enviroplan, Ltd. April 1994. *Feasibility Study for the Establishment of a Joint Wastewater Treatment Plant for Industrial Estate/Industries in Ekala and Ja-Ela.*

2 Associated Engineering and Surath Wickramasinghe Associates. July 1994. *Feasibility Study for the Establishment of a Central Wastewater Treatment Plant for Industrial Estates/Industries at Ratmalana and Moratuwa, Greater Colombo Area.*

3 DHV Consultants BV in association with IWACO, P.T. Waseco Tirta, P.T. Indah Karya, P.T. Bita Bina Semesta. June 1993. *Third Jabotabek Urban Development Project: Environmental Protection Component (A). Joint Waste Water Treatment for Industrial Estates.*

4 DHV Consultants et al., ibid.

5 DHV Consultants et al., ibid.

Appendix B
Cost Summary

Ja-Ela Ekala: Cost Estimates and Financing Plan
Suggested by the Consultant [1] (US$1=Rs.50)

Component	Investment Costs US$ million	O&M Costs US$ per year
Assumed by individual industries		
Flow Metering	0.08	5,600
Pre-treatment Plants	0.664	241,000
Self-monitoring		4,840
Total	**0.744**	**246,600**
Assumed by the BOO company		
Collection and Discharge Network (IDA)	1.729	27,000
Joint Treatment Plant (the BOO company)	2.052	202,300
Land (GOSL)	0.15	n/a
Operator Monitoring		10,280
Total Base Cost	**3.931**	**229,300**
Price Escalation	0.643	
Physical Contingency	0.378	
Total Project Cost	**4.952**	
Financing Cost	0.408	
Net Working Capital	0.04	
GRAND TOTAL	**5.4**	

Ratmalana-Moratuwa: Cost Estimates and Financing Plan
Suggested by the Consultant [2] (US$1=Rs.50)

Component	Investment Costs US$ million	O&M Costs US$ per year
Assumed by NWSDB		
Collection System (IDA)	14.702	169,800
Connections	6.136	0
TOTAL	**20.838**	**169,800**
Assumed by the BOO/BOT company		
Joint Treatment Plant	2.832	153,960
Outfall	3.496	4,600
TOTAL	**6.328**	**158,560**

The report suggests that the centralized treatment plant and ocean outfall could be 30 percent financed by BOT equity, and 70 percent by BOT borrowing, while the collection system could be fully financed by borrowing from IDA, and owned and operated by NWSDB. An additional contribution by GOSL would be needed, comprising US$2.98 million for the full cost of the residential collection system, in order to make charges for residential users affordable. The government contribution might be as equity, an outright grant, or a long-term loan with no interest.

BOT

Component	Equity	Loan	TOTAL
Treatment Plant and Outfall	1.898 (30%)	4.430 (70%)	6.328 million

NWSDB

Component	Subsidy	Loan	TOTAL
Collection and Connection	2.98	17.858	20.838 million

Mookervart: Cost Estimates and Financing Plan
Suggested by the Consultant [3] (US$1=Rp.2,193)

Component		Investment Costs US$ million	O&M Costs US$ per year
Collection System		11.59	439,079
Joint Treatment Plant		5.12	331,053
	Total	**16.71**	**770,132**

JIEP: Cost Estimates and Financing Plan
Suggested by the Consultant [4] (US$1=Rp.2,193)

Component		Investment Costs US$ million	O&M Costs US$ per year
Sewerage		1.542	10,488
Connection		0.057	n/a
Treatment Plant		0.76	20,520
	Total	**2.359**	**31,008**

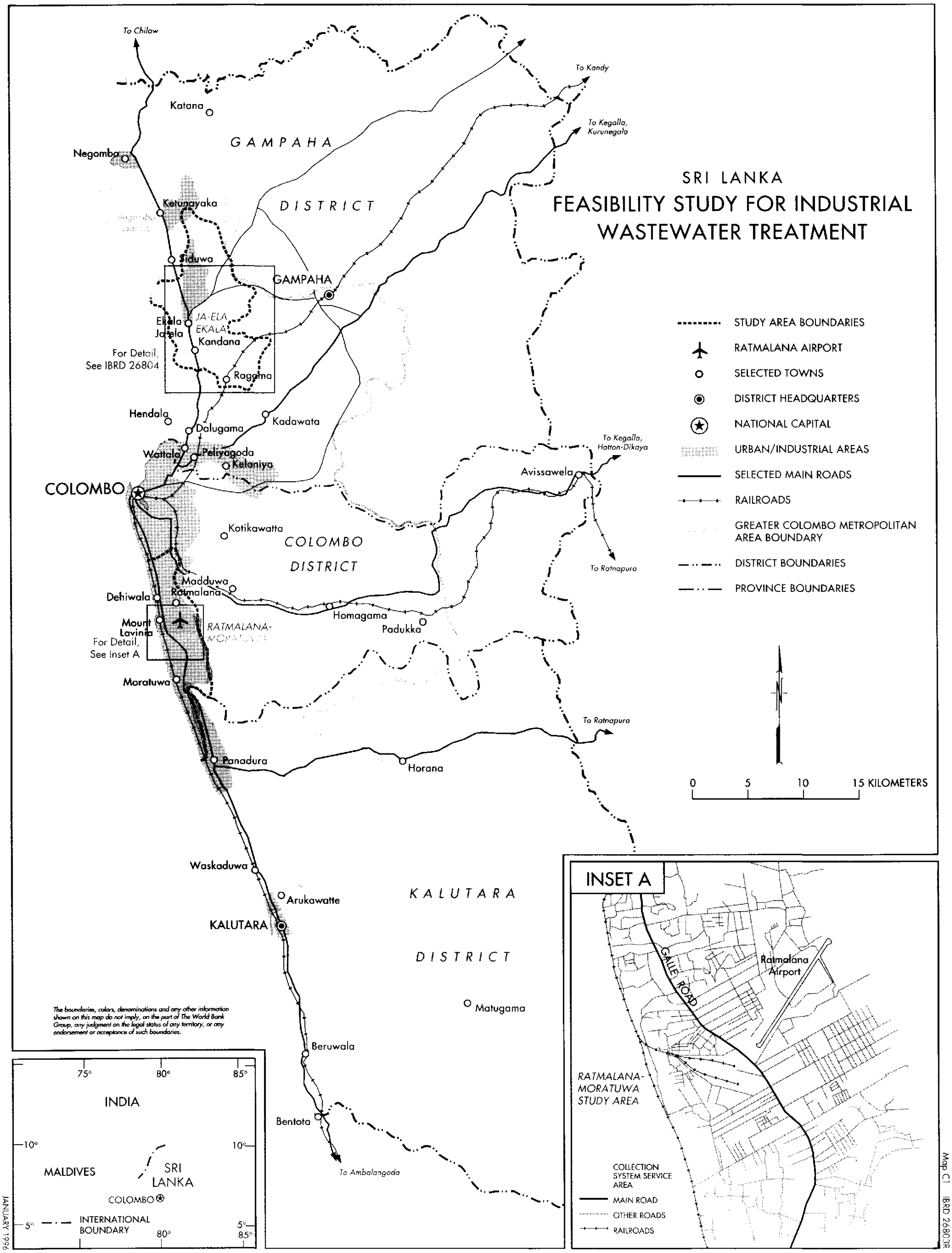
Endnotes

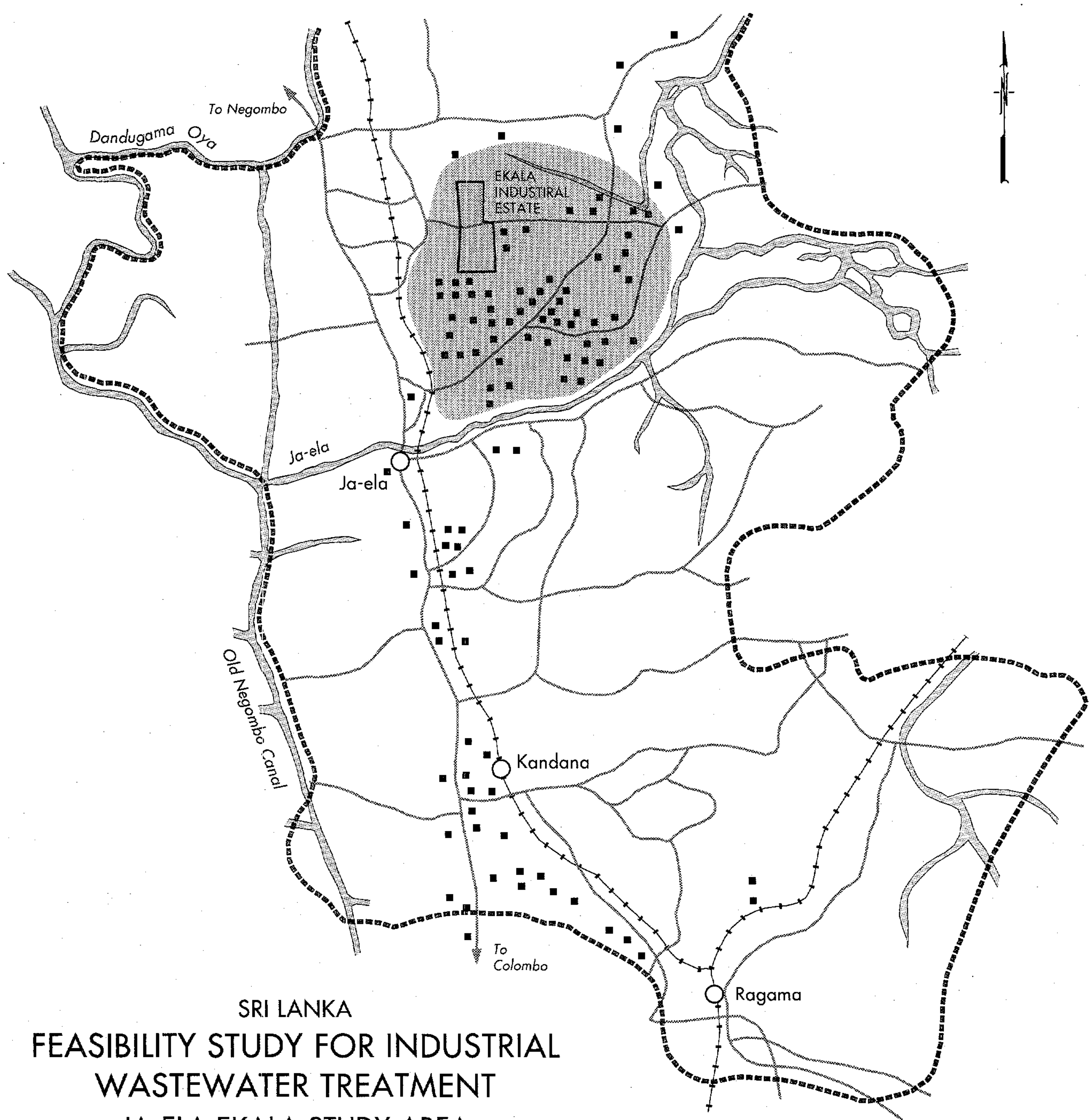
1 Soil and Water Ltd. and Enviroplan Ltd. *Feasibility Study for the Establishment of a Joint Wastewater Treatment Plant for Industrial Estate/Industries in Ekala and Ja-Ela*, April 1994.

2 Associated Engineering and Surath Wickramasinghe Associates. *Feasibility Study for the Establishment of a Central Wastewater Treatment Plant for Industrial Estate/Industries at Ratmalana and Moratuwa, Greater Colombo Area*, July 1994.

3 DHV Consultants BV in association with IWACO, P.T. Waseco Tirta, P.T. Indah Karya, P.T. Bita Bina Semesta. *Third JABOTABEK Urban Development Project: Environmental Protection Component (A), Joint Waste Water Treatment for Industrial Estates*, June 1993.

4 DHV Consultants et al., ibid.


SRI LANKA
FEASIBILITY STUDY FOR INDUSTRIAL WASTEWATER TREATMENT
STUDY AREA BOUNDARIES
RATMALANA AIRPORT
SELECTED TOWNS
DISTRICT HEADQUARTERS
NATIONAL CAPITAL
URBAN/INDUSTRIAL AREAS
SELECTED MAIN ROADS
RAILROADS
GREATER COLOMBO METROPOLITAN AREA BOUNDARY
DISTRICT BOUNDARIES
PROVINCE BOUNDARIES
0 5 10 15 KILOMETERS
To Chilow
To Kandy
To Kegalla, Kurunegala
To Kegalla, Hatton-Dikoya
To Ratnapura
To Ratnapura
To Ambalangoda
GAMPAHA DISTRICT
COLOMBO DISTRICT
KALUTARA DISTRICT
Katana
Negombo
Katunayaka
Siduwa
GAMPAHA
JA-ELA EKALA
Ekala
Ja-ela
Kandana
For Detail, See IBRD 26804
Ragama
Hendala
Dalugama
Kadawata
Wattala
Peliyagoda
Kelaniya
COLOMBO
Avissawela
Kotikawatta
Madduwa
Ratmalana
Dehiwala
Mount Lavinia
For Detail, See Inset A
RATMALANA-MORATUWA
Homagama
Padukka
Moratuwa
Panadura
Horana
Waskaduwa
Arukawatte
KALUTARA
Matugama
Beruwala
Bentota
The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.
75° 80° 85°
INDIA
10° 10°
MALDIVES
SRI LANKA
COLOMBO
5° 5°
80° 85°
INTERNATIONAL BOUNDARY
INSET A
GALLE ROAD
Ratmalana Airport
RATMALANA-MORATUWA STUDY AREA
COLLECTION SYSTEM SERVICE AREA
MAIN ROAD
OTHER ROADS
RAILROADS
JANUARY 1996
Map C1 IBRD 26803R



SRI LANKA

FEASIBILITY STUDY FOR INDUSTRIAL WASTEWATER TREATMENT

JA-ELA EKALA STUDY AREA

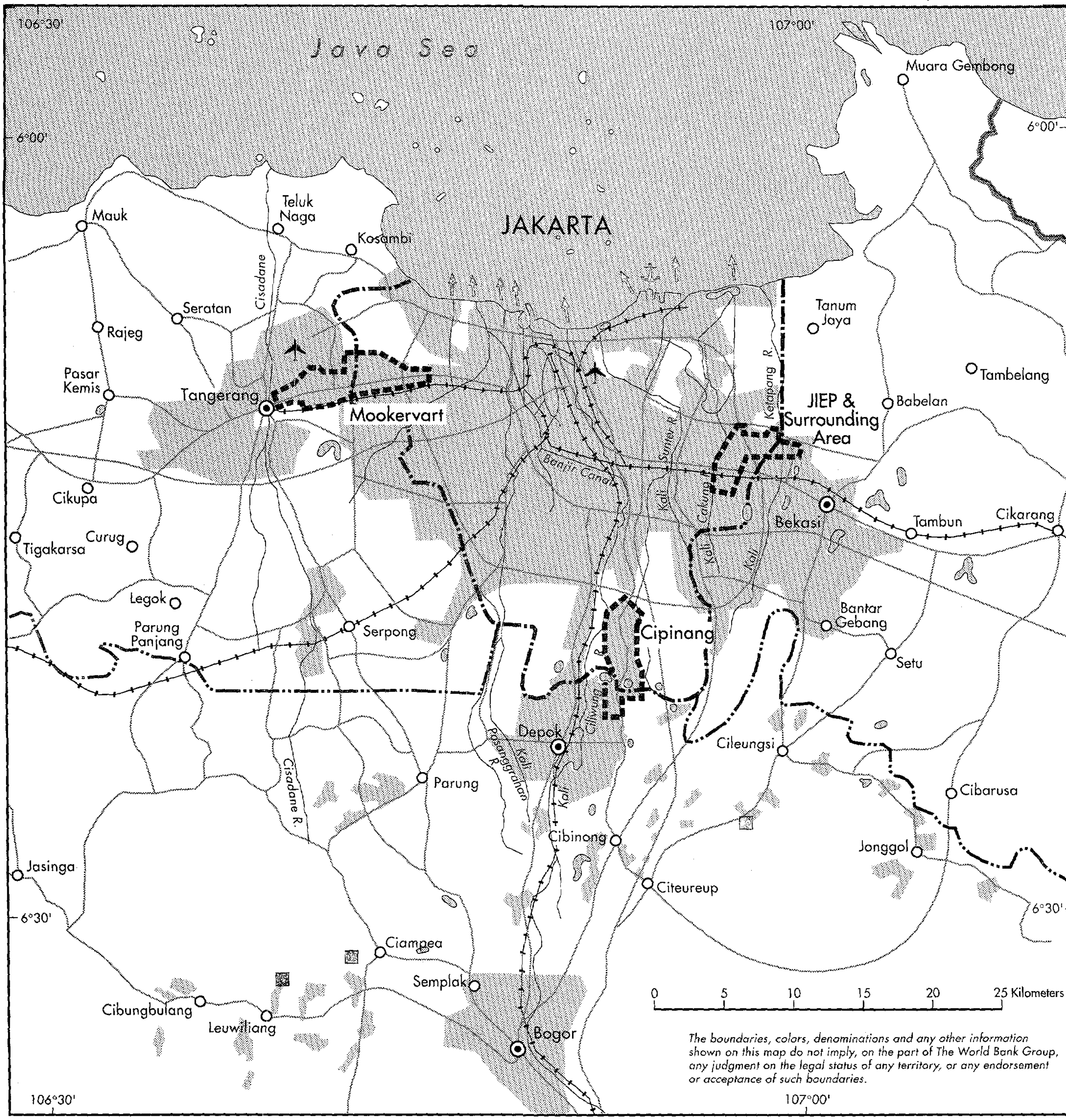
TREATMENT PLANT SITE & PROPOSED IMPROVEMENTS
STUDY AREA BOUNDARY
COLLECTION SYSTEM SERVICE AREA
INDIVIDUAL INDUSTRIAL SITES SERVICED BY COLLECTION SYSTEM
INDIVIDUAL INDUSTRIAL SITES OUTSIDE OF SERVICE AREA
SELECTED TOWNS
ROADS
RAILROADS

0 1 2 3
KILOMETERS

The boundaries, colors, denominations and any other information shown on this map do not imply, on the part of The World Bank Group, any judgment on the legal status of any territory, or any endorsement or acceptance of such boundaries.

JANUARY 1996

Map C3 IBRD 26922R

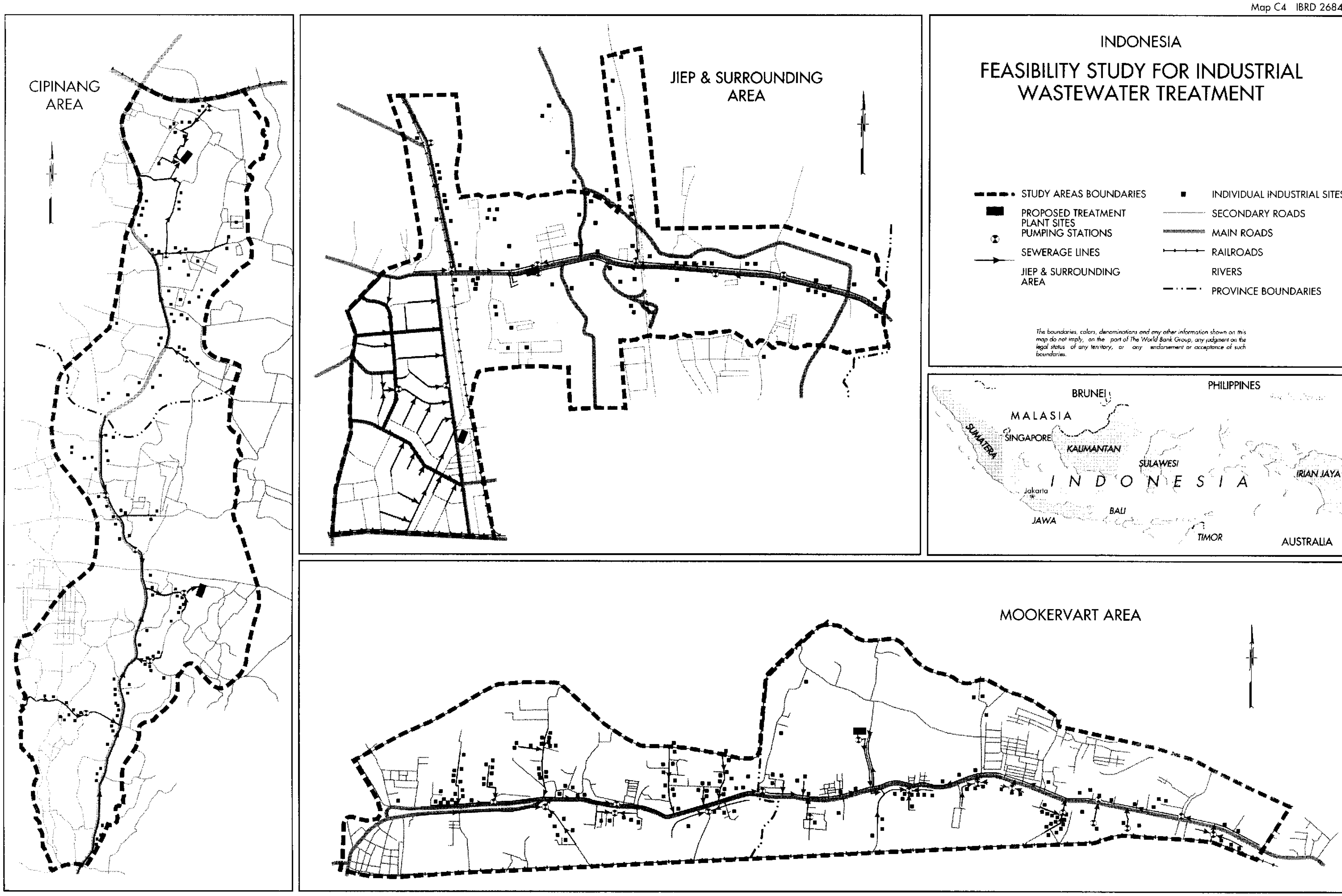


INDONESIA
FEASIBILITY STUDY FOR INDUSTRIAL WASTEWATER TREATMENT

STUDY AREA BOUNDARIES
SELECTED TOWNS
URBAN/INDUSTRIAL AREAS
DRAINAGE OUTFALLS
MAIN ROADS
RAILROADS
AIRPORTS
SELECTED RIVERS
PORT
RESERVOIR
KABUPATEN (REGENCY) HEADQUARTERS
DISTRICT BOUNDARIES
PROVINCE JAKARTA BOUNDARY
JABOTABEK BOUNDARY

JANUARY 1996

Map C4 IBRD 26844R



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