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Demonstration Project of Alternatives to Chlordane And Mirex for Termite Control in China

Environmental Impact Assessment for the Closure of the Liyang Guanghua Chemical Company, Ltd.

Jiangsu Academy of Environmental Science

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This document is a safeguards document prepared for the GEF project *China: Demonstration of Alternatives to Chlordane and Mirex in Termite Control*. The project is a $28 million demonstration of approaches to implement the Stockholm Convention on persistent organic pollutants (POPs) in termite control. There are three safeguards documents prepared for this project.

1. Pest Management Plan (PMP) prepared for the entire project. The PMP was developed according to the requirements of the World Bank's Operational Policy OP 4.09 on Pest Management which mandates the use of integrated pest management (IPM). The project itself is essentially a large-scale implementation of IPM in termite control, since it promotes replacement of the current chemical-based termite control methods with environmentally more sustainable IPM-based method. Majority of project funding – more than $20 million – is allocated directly to IPM activities. The PMP and the project document, therefore, are very closely related, and the principal recommendations and consideration of the PMP are an integral part of the project design.

2. Environmental Impact Assessment (EIA) and Environmental Management Plan (EMP) specific to the component 4 of the project. The component – with the budget of about $2.64 million – demonstrates a closure of a chlordane and mirex manufacturer – Liyang Guanghua Chemical Company Ltd. – in Jiangsu Province. The EIA and EMP were prepared according to Chinese environmental impact assessment regulations and the World Bank's Operational Policy OP 4.01 on Environmental Assessment.

3. Social Assessment (SA) which complements the EIA. The SA was prepared to address the social and economic impacts of the closure of the Liyang Guanghua Chemical Company, Ltd. on the plant work force. The SA was prepared as a matter of best practice, and serves as a basis for the worker compensation and retrenchment program which will be implemented under the project.

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Summary

1. This Environmental Impact Assessment (EIA) addresses the closure Liyang Guanghua Chemical Company in Jiangsu Province, China. It includes demolition of the facilities, disposal of hazardous waste and clean up of the site to a level acceptable for the site's future industrial use.

2. The closure of the Liyang Guanghua Chemical Company is one of the components of the GEF project *China: Alternatives to Chlordane and Mirex in Termite Control.* The project aims to provide China with an opportunity to build knowledge and experience necessary to formulate a national program for phaseout of chlordane and mirex – two of the twelve persistent organic pollutants (POPs) controlled by the Stockholm Convention.

3. Chapter 2 of this EIA provides detailed information about the background of the project. It also give additional details about the component focusing on the closure of the Liyang Guanghua Chemical Company is presented in.

4. Chapter 3 lays out the policy, legal and administrative framework which governs the preparation and implementation of the project and the Liyang Guanghua Closure Component. Four international chemical conventions affect the design of the project: Stockholm Convention, Basel Convention, Rotterdam Convention and the Montreal Protocol. In addition, a number of Chinese laws, regulations and standards, at both national and provincial levels, govern the various activities of the project, including the design and implementation of the closure and clean up of the Liyang Guanghua Chemical Company.

5. Despite a number of applicable laws and regulations, China does not have a standard setting maximum allowable concentration of chlordane or mirex in the environmental media. In the absence of a national or provincial standard, the Stockholm Convention recommended level of 50 ppm was adopted as the clean up level for this project.

6. Chapter 4 provides detailed information about the Liyang Guanghua Chemical Company, chlordane and mirex production as well as geographical, hydrological and climatological information about the plant site. Importantly, the chapter presents results of site investigation and contamination data collected through two phases of site monitoring program. Through site investigation and monitoring, the extend and severity of contamination by the key contaminants –chlordane and mirex – have been determined in the soil, surface water, ground water, and sediments. Concentration of other site contaminants in various environmental media has been measured as well. The site investigation also included the area surrounding the plant, including the nearest residential settlements, to ensure that there is sufficient information to develop a comprehensive clean up plan.

7. Data from the site investigation and monitoring show that the site is moderately contaminated with chlordane and mirex. The contamination exceeding the acceptable

level is contained within the plant compound, and the pattern of contamination is consistent with the normal operation of the plant.

8. Chapter 5 evaluates the risk to human health that the site currently represents. It also confirms that after reducing the contamination to the Stockholm Convention recommended level of 50 ppm, the site will not represent excessive risk to human health. For the risk evaluation in this chapter, the methodology and reference concentrations set by the US EPA were used.

9. Chapter 6 surveys the technological and other alternatives for remediation of the site and disposal of hazardous chlordane and mirex waste. The consideration of alternatives is based largely on international experience, since only limited experience with such disposal is available in China. The information from this chapter serves as a basis for selection of the clean up technology in chapter 8.

10. Chapter 7 assesses potential environmental impacts associated with the plant demolition and site remediation. These impacts include noise, air pollution from heavy machinery, dust from excavation and demolition, borrow pits for backfilling the excavated area, transport and storage of contaminated waste, and pollution associated with final disposal of hazardous materials by incineration of landfilling.

11. Chapter 8 presents the measure for mitigation of the potential environmental impacts identified in chapter 7, and details the site clean up plan and post clean up monitoring. The site clean up relies mainly on excavation of contaminated soil and its final disposal in a hazardous waste landfill. The non-hazardous solid waste will be disposed in a municipal landfill. Contaminated clean up water from washing, rinsing of pesticide containers, etc. will be treated in a licensed industrial wastewater treatment plan capable of handling chlordane and mirex residues.

12. Chapter 9 documents the two round consultation and public participation process that was organized to ensure that the views of general public are adequately reflected in the EIA.

Background of the Demonstration Project

1. Chlordane and mirex are two of the twelve persistent organic pollutants (POPs) controlled by the Stockholm Convention. China, as a signatory to the Stockholm Convention, is obliged to eliminate these chemicals according to the convention requirements. Both chemicals, due to their effectiveness and low cost, have been a backbone of the Chinese termite control industry for decades, despite their carcinogenic, neurological, and physiological impacts on human health, and a broad range of neurological, liver, skin and male reproductive system and immune system disorders that they cause. Similarly to other POPs, chlordane and mirex travel long distances through the global ecosystem, accumulate in the food chain and are highly persistent – their residues have been detected in water, soil, food and beverages, breast milk and human tissues for as long as 12 years after exposure.

Country Situation

2. China is one of the countries with the greatest diversity of termites and most severe termite damage in the world. About 482 species of termites are found in all but six Northern provinces (Heilongjiang, Jilin, Inner Mongolia, Ningxia, Qinghai, and Xinjiang) in China, concentrated mostly south of the Yangtze River. Affecting more than 40% of the total land area in China, termite has caused damages to between 30 and 90% of buildings south of the Yangtze River. In addition, termites have caused damage to historic architecture, dams, bridges and other constructions in China. It is estimated that the direct economic loss caused by termites in China is about 2 to 2.5 billion RMB *yuan* annually. China's explosive growth in new residential construction and general infrastructure development has substantially increased the demand for termite control.

Chlordane and Mirex

3. Since their introduction to China in 1964 and 1979, respectively, chlordane and mirex have become the principal instruments for termite prevention and control, although their use declined in recent years due to regulatory restrictions. Their effectiveness, persistence, low cost and ease of application have lead to their widespread use and contributed to the fact that termite management in China heavily relies on chemical methods. As of December 2004, there were nine chlordane and mirex manufacturers in China, all located in Jiangsu Province. Among the nine manufactures, five produced both chlordane and mirex and four produced only chlordane. From 2000 to 2003, these nine manufacturers produced 450 – 820 tons of chlordane and 9 -31 tons of mirex annually. In practice, chlordane and mirex are mainly used in termite control in residential and other buildings. The use of both termiticides poses significant local and global risks to human health and the environment.

Project description

4. When China ratified the Stockholm Convention in October 2003, China requested the Bank to help in the development of a Demonstration Project of alternatives to chlordane and mirex in termite control. As a consequence, a demonstration project has been developed.

5. The project is a self-standing, full-size GEF operation which is not a part of an existing program. The project is, however, designed to lay a foundation for a nationwide, multi-phase national replication program on the elimination of chlordane and mirex in China. The project thus supports the broad effort of China to comply with the Stockholm Convention, and it is an essential part of a suite of internationally supported interventions. The project further seeks to ensure replicability by including a specific component on promoting and disseminating projects results and lessons to the rest of China. National, provincial and local governmental organizations, institutes and companies involved in this project will also help ensure the dissemination of relevant information. Finally, the project's internet website will make its results widely available, as well as giving access to new information on IPM approach to termite control.

6. The Demonstration Project is design to (i) demonstrate elimination of chlordane and mirex use for termite control in the demonstration provinces through introduction of integrated termite management; and (ii) prepare a national replication program for complete phase-out of chlordane and mirex in China by 2014.

7. Consistent with this design and objective, the key project outputs will include (i) elimination of chlordane and mirex consumption in the demonstration area's building construction sector; (ii) comprehensive policy, regulatory and institutional reforms at the national and provincial level to replace termiticide-based termite management with integrated termite management; (iii) closure and clean-up of the Lyiang Guanghua Chemical Co, Ltd., and corresponding permanent reduction in the national chlordane and mirex production; and (iv) development of a national replication program and production quota system for phaseout of chlordane and mirex in the rest of China. China recommends that the cleanup value of contaminated soil with chlordane and mirex to be 50ppm which is consistent with recommendation from the Basel Convention.

8. The key indicator of project's success will be the use of chlordane and mirex by the termite control professionals in the demonstration area, which should reach zero level by the end of the project.

9. This demonstration project is closely linked with several related and ongoing projects, upon which it either builds or to which it contributes. These include (a) development of a National Implementation Plan (NIP) for the Stockholm Convention, being conducted by SEPA/CIO with the assistance of UNIDO and the GEF, (b) the completed Sino-Italian project titled "POP Pesticides and Draft Strategy on Phaseout in China", (c) the termite study financed by a Canadian Trust Fund, and (d) a toxicity also financed by a Canadian Trust Fund.

10. The NIP includes national strategies and action plans to reduce and eliminate all POPs, building national inventory and capacity building so as to help China in fulfilling its commitment to the Stockholm Convention.

11. The major outputs of the Canadian Termite Study are testing of a small sample of termite treatment chemicals, and development of an initial IPM toolbox for termite control. The output of the Sino-Italian Pesticide project is a preliminary strategic framework for the elimination of all POP pesticides in China. These two projects provide direct inputs into the NIP as well as this demonstration project. The NIP, to be completed in November 2006 will have an initial action plan on elimination of chlordane and mirex based on the Sino-Italian Pesticide Project. One of the major outputs of the demonstration project, to be completed in December 2009, is the National Replication Program which will elaborate and update the initial action plan on chlordane and mirex prepared in the NIP.

12. The toxicity study is to investigate the exposure of DDT and PCBs and their adverse effects with special emphasis on the health of women and children. The initial study result indicates that the tested area in Zhejiang has a high-concentration PCB exposure. PCB geometric concentration levels in women and children in this area are moderately elevated. They are below those found in Arctic Canada (Nunavut) and above those found in southern Canada. The major outputs of the Canadian Toxicity Study are: (a) an evaluation for DDT and PCBs exposure level in the environment, and (b) an evaluation for DDT and PCBs accumulation level in the biological sample.

13. The Demonstration Project selected two provinces as demonstration provinces – Jiangsu and Zhejiang. These two provinces are severely affected by typical termites in China and consume most chlordane and mirex among the provinces which consumes chlordane and mirex. As two of the most developed provinces in China, Jiangsu and Zhejiang have suffered significant economic and social impacts caused by termite damages, and are strongly motivated and experienced in termite control. Organizationally, both provinces have well-established institutions for the management and implementation of termite control activities, and these institutions are supported by qualified research organizations and technical service providers. Finally, both provinces have relatively well-developed termite control.

14. Only the Jiangsu province produces chlordane and mirex in China and there are nine producers. As a demonstration, China has selected the Liyang Guanghua Chemical Company, Ltd. as a demonstration in closing the plant and cleans up its site for future use. Annex 1 lists the remaining eight chlordane and mirex manufacturers in Jiangsu Province.

15. **Closure of the Liyang Guanghua Chemical Company, Ltd.** The objective of this activity is to demonstrate (a) permanent physical closure and dismantling of the Liyang Guanghua Chemical Ltd. which manufactures chlordane and mirex; and (b) clean up the facility's chlordane and mirex contaminated site and disposal of chlordane waste. This activity will provide practical experience with closing down a chlordane and mirex manufacturer and addressing the local environmental and social issues associated with the closure. At the same time, it will achieve permanent reduction of national mirex production by 2 tons, and national chlordane production of chlordane by 190 tons

annually. The reduction of chlordane production exceeds the chlordane consumption reduced through the introduction of the bait system in the demonstration provinces. This activity will have two components as follows.

a. ***Closure and dismantling of Liyang Guanghua Chemical Company.*** This sub-component will fund complete dismantling and removal of all equipment and facilities at Liyang Guanghua Chemical Company, as well as compensation for lost profits directly associated with the closure and workers compensation.

b. ***Clean-up and disposal of chlordane and mirex wastes.*** This sub-component will fund clean up of the contaminated site and dispose of contaminated waste appropriately.

EIA Implementation

16. This EIA report is prepared as required by the Environmental Protection Law of the People's Republic of China. This Law stipulates that "an EIA report must be prepared and submitted for approval for the construction of new projects and the renovation and expansion of existing projects." The compilation of this EIA report also complies with the Environmental Protection Management Methods on Construction Projects [SEPA (1986) No. 003] and the Environment Impact Assessment Law of the People's Republic of China, Notice on Strengthening EIA Management about Construction Projects Loaned by International Financial Organizations (issued by SEPA cooperated with NDRC, MOF and Bank of China, [1993: No.324]).

17. According to the 1993 Notice on Strengthening EIA Management about Construction projects Loaded by International Financial Organizations, a comprehensive EIA is required because implementation of the project will have negative impacts on local ambient environment. However, as far as this Demonstration Project is concerned, the closure of Liyang Chemical Co. aims at cleanup of a contaminated site and is inherently beneficial to the local and global environment.

18. According to the Chinese Technical Guidelines for EIA preparation, the scope of this EIA includes the following issues:

a. Soil quality in the area of the site and its surroundings;
b. Surface water courses in the vicinity of the site in the length of about 1,500 meters;
c. Groundwater in the area enclosed within 0.2 km radius of the project site;
d. Land use in the area – there is no development planned in the area, and in the future, this site will be used for industrial purpose;
e. Fish ponds (for crab farming) within 0.1 km radius of the project site;
f. Ambient air quality in the area of the site and its surroundings;
g. Noise in the area enclosed within 0.3 km radius of the project site; and
h. Vegetation in the area enclosed within 0.3 km radius of the project site; there are no important or sensitive ecosystems in the vicinity of the site.

Main technology and approaches adopted in assessment

19. Four steps and approaches are adopted to conduct the assessment.

a) Based on the analysis of environmental situation and activities of the enterprise, an environmental monitoring plan is developed and a certified monitoring institute is hired to monitor soil, surface, groundwater and sediment. Monitoring data are used to evaluate the pollution status of Chlordane and Mirex as well as some other contaminants in the study area.
b) The risk-based decision making approach is adopted to conduct risk analysis to evaluate the risk that the site represents to human health. The risk analysis methodology of USEPA is applied.
c) Conclusions from monitoring and risk analysis, as well as the cleanup criteria are used to set up the cleanup plan.
d) According to laws, regulations, technical guidelines and standards, environmental management plan (EMP) is developed.

Organization in Charge for Environmental Impact Assessment.

20. Jiangsu Academy for Environmental Sciences (JAES) is responsible for the Environmental Impact Assessment for closure of the Liyang Guanghua Chemical Co. Ltd. under the Demonstration of Alternatives to Chlordane and Mirex in Termite Control Project in China. JAES was founded in 1985 and took the name Jiangsu Institute for Environmental Sciences in 2001. It engages in environmental research, environmental impact assessment and environmental program, environmental engineering, pollution control technology, R&D on environment protection products, promotion of BAT and BEP, and certification of environmental management system etc. JAES has the certificates including Grade A Certificate for Environment Impact Assessment issued by SEPA, Grade B Design Certificate for Environmental Engineering, and the Certificate for ISO 14000 EMS. Jiangsu Key Lab of environmental engineering affiliated to the JAES has the first class testing lab facilities and analytical apparatus.

21. Another Organization involved in the preparation of the Environmental Impact Assessment is the Environmental Monitoring Center of Jiangsu Province. The center has the capability of investigating and monitoring eight categories of pollutants including water, wastewater, ambient air, air emissions, soil, biology, automobile exhausts, indoor air, decorating materials, and also noise and vibration. Its on-line monitoring systems for air are widely distribute in the whole province, forecast daily report on the air qualities of the main cities. It has also set up 36 of on-line monitoring systems for monitoring water qualities in the sensitive area of the province. The center passed the measurement authentication by China Metrology Accreditation (CMA) in Oct.1992, and passed the re-auditing by China National Accreditation of Lab (CNAL) and CMA in Oct. 2002. The certification number of CNAL is NO.L0089.

22. Following the guideline of the CNAL/AC01 (GB/T15481-2000 and ISO/IEC17025: 1999), and Examination Code of Metrology / Checking Accreditation for the Product Quality Test, the *Quality Manual* is developed by the Jiangsu Environmental

Monitoring Center. This *Quality Manual* provides quality control and assurance system for all the monitoring activities of the center, including sampling and analysis.

Policy, Legal and Administration Framework

The Synergy of Four International Chemical Conventions

1. Chemical contamination of the environment shows no respect for territorial borders. For that reason, multilateral environmental agreements (MEAs) provide effective international or regional frameworks to prevent and minimize the impacts of toxic chemicals and hazardous waste in the global commons.

2. Combined, the four MEAs (the Basel Convention, the Rotterdam Convention, the Stockholm Convention, and the Montreal Protocol) address international trade in toxic chemicals, the transport of hazardous waste, the reduction and eventual elimination of releases, use and production of persistent organic pollutants, the environmentally sound remediation of waste stockpiles and the identification of contaminated sites. Most importantly, they help avoid problems in the future. The four MEAs actively promote information exchange and technical capacity building, as well as providing some financial assistance for developing countries or countries with economies in transition.

3. The MEAs is a prime tool for regional environmental cooperation. They are international instruments binding all signatory countries and together, they take measures to remedy, mitigate or otherwise deal with global and or regional environmental concerns. They emphasize on *"efficient use of collective resources - information, financial and expertise; the reduction of duplication and overlaps; emphasis on program and policy coherence; and averting fragmented sectoral initiatives"*.

4. The overarching objective of the different chemicals and hazardous wastes Conventions is the protection of human health and environment from pollution by certain chemicals and hazardous wastes. The scope of the Basel Convention covers a broad range of hazardous wastes, including chemical wastes, subject to transboundary movements. The Convention aims to reduce these movements to a minimum by minimizing the quantity and hazardous nature of the wastes generated and by promoting the treatment and disposal of hazardous wastes as close as possible to their source of generation. The Rotterdam Convention specifically addresses certain hazardous pesticide formulations, subject to international trade. The Stockholm Convention has as its priorities the reduction or elimination of releases of persistent organic pollutants (POPs) from international production, unintentional productions, stockpiles and wastes. The Rotterdam and Stockholm Conventions have provisions to add further chemicals to the treaties. The aim of the Montreal Protocol is to protect the ozone layer by phasing out the production and consumption of ozone-depleting substances.

5. **The Stockholm Convention on Persistent Organic Pollutants (POPs).** The objective of Stockholm Convention on Persistent Organic Pollutants (Stockholm Convention) is to reduce or eliminate release of POPs, and to protect human health and environment. The initial list of 12 POPs includes aldrin, chordane, DDT, dieldrin, dioxins, endrin, furans, heptachlor, hexachlorobenzen, mirex, polychlorinated biophenyls, and toxaphene.

6. The Stockholm Convention includes many agreements, such as:
   a. measures to reduce or eliminate production, use, import/export and releases of POPs.
   b. register of specific exemption;
   c. screening criteria of chemicals specified in Annexes D;
   d. financial resources and mechanisms;
   e. technical assistance;
   f. public information, awareness and education;
   g. research, development and monitoring; etc. Stockholm Convention request the Party should finally phase-out nine pesticides of POPs during a ten-year period from the date on which this Convention has entered into force, as well as manage POPs stockpiles and dispose POPs wastes with environmentally sound manners.

7. It is stipulated in Paragraph 2, Article 6 of the Stockholm Convention that the Conference of the Parties shall cooperate closely with the appropriate bodies of the Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal to, inter alia:
   a. establish levels of destruction and irreversible transformation necessary to ensure that the characteristics of persistent organic pollutants as specified in paragraph 1 of Annex D are not exhibited;
   b. determine what they consider to be the methods that constitute environmentally sound disposal referred to above; and
   c. work to establish, as appropriate, the concentration levels of the chemicals listed in Annexes A, B and C in order to define the low persistent organic pollutant content referred to in paragraph 1

8. **Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal.** Basel Convention on the Control of Trans-boundary Movement of Hazardous Wastes and Their Disposal (Basel Convention) was adopted on 22 March 1989 by the Conference of Plenipotentiaries which was convened at Basel, Switzerland from 20 to 22 March 1989. This convention enters into force in May of 1992. About one hundred countries signed this convention. China signed it on March 22nd, 1990.

9. Basel Convention is intended to prohibit trans-boundary movement of hazardous wastes, especially to developing countries through exportation and consignment. The Convention calls for signatories to minimize hazardous waste generation and encourages on site storage and disposal in environmentally sound

manner. This convention states clearly, in case of wastes have to be transferred across boundaries out of environment concern, the exporting country must inform in advance the recipient country and other related countries of quantity and quality of the wastes. The exporting country must obtain a written approval issued by the Government of the recipient country before conducting hazardous waste trans-boundary operations.

10. In Article 28 of the general technical guidelines for the environmentally sound management of wastes consisting of, containing or contaminated with persistent organic pollutants, it is described that, as stated in article 6, paragraph 2 (c), of the Stockholm Convention, the Stockholm Conference of the Parties shall cooperate closely with the appropriate bodies of the Basel Convention to "work to establish, as appropriate, the concentration levels of the chemicals listed in Annexes A, B and C in order to define the low persistent organic pollutant content referred to in paragraph 1 (d) (ii)." Wastes consisting of, containing or contaminated with POPs above the low POP content should, in accordance with article 6, paragraph 1 (d) (ii), be disposed of in such a way that the POP content is destroyed or irreversibly transformed or otherwise disposed of in an environmentally sound manner when destruction or irreversible transformation does not represent the environmentally preferable option.

11. In Article 29, it is presented that the following provisional definitions for low POP content should be applied to aldrin, chlordane, DDT, dieldrin, endrin, heptachlor, HCB, mirex and toxaphene: 50 mg/kg.

Relevant Regulations on Phase-out of Chlordane and Mirex in China

12. The following is the list of regulations on the Control over Safety of Dangerous Chemicals that will apply to the Demonstration Project:

a. Environment Protection Law of People's Republic of China (December 26, 1989)
b. Solid Waste Pollution Control Law of People's Republic of China (April 1, 1996)
c. Infectious Disease Control Law of People's Republic of China (September 1, 1989;
d. Environmental Impact Assessment Law of People's Republic of China, (October 28, 2002);
e. Construction Project Environmental Protection Regulation, (No. 253 Decree of State Council of People's Republic of China (November 29, 1998);
f. Environmental Impact Assessment Technology Guideline, SEPA (HJ/T2.1-2.3-93);
g. Environmental Impact Assessment Technology Guideline- Acoustic Environment, SEPA (HJ/T2.4—1995);
h. Hazardous Solid Waste Incineration Pollution Control Standard, (GB18484-2001);
i. Hazardous Solid Waste Landfill Pollution Control Standard, (GB18598-2001);
j. Hazardous Solid Waste Storage Pollution Control Standard, (GB18597-2001);

k. Inventory of Hazardous Wastes in China, SEPA (1998);
l. Hazardous Waste Identification Standard, (GB5085-1996);
m. Technological Requirements for the Construction of Hazardous Waste Landfills, SEPA (No. [2004] 75);
n. Hazardous Waste Transportation Manifest (October 1999);
o. Waste Water Integrated Discharge Standards, (GB8978-1996);
p. Ambient Air Quality Standards (GB3095-1996);
q. Surface Water Environment Quality Standards, (GB3838-2002);
r. Ground Water Environment Quality Standards, (GB/T14848-93);
s. Industrial Enterprise Plant Boundary Noise Standards, (GB12348-90);
t. Hygiene Standard for the Design of Industrial Enterprises, (TJ36-79);

13. In addition, guidelines from the World Bank and international conventions apply:

a. Operational Manual of World Bank (January 1999);
b. Operational Directive 4.01: Environment Assessment (and its attachments), the World Bank;
c. Stockholm Convention on Persistent Organic Pollutants; and
d. Basel Convention on the Control of Trans-boundary Movements of Hazardous Wastes and Their Disposal, (1989.3).

Key Provisions of Major Laws, Regulations and Standards

14. **Solid Waste Pollution Control Law.** This Law is the legal basis for hazardous waste treatment in China. Article 3 of the law stipulates that China adopts the principle of reducing the production of solid wastes, and utilizing and disposing of solid wastes to control solid waste pollution. Article 49 of the law stipulates that organizations that collect, store and dispose of hazardous wastes must apply for operational licenses from the environmental protection authority at county or higher levels governments. The State Council issues a specific management rule on such licensing process. It is prohibited to collect, store or dispose of hazardous wastes without obtaining the proper operational license. It is also prohibited to provide hazardous wastes to, or entrust any organizations without an operational license for collection, storage or disposal. Article 12 of the law stipulates that the impacts of solid wastes generated from construction projects on the environment must be assessed. Measures to prevent the environmental pollution must be carried out after being approved by environmental protection authorities according to related procedures. Only after the Environment Impact Assessment (EIA) Report is approved, the feasibility study report or design report of construction projects can be approved for implementation. Article 13 of the law stipulates that solid waste prevention facilities identified in EIA Reports of the construction projects must be designed, constructed and operated simultaneously with main facilities of the project. Solid waste prevention facilities have to be checked and accepted by authorities that approve the

EIA Report of the same construction project before these facilities are being operated. The check and acceptance of solid waste prevention facilities and that of main facilities of the construction project should be conducted simultaneously. These articles provide a legal basis for this environmental impact assessment.

15. **Existing termite control policies.** Since 1987, MOC has established and issued a series of policies and regulations for termite control. Of which, "Regulation on Termite Prevention and Control in Urban Construction", as the MOC No. 72 regulation issued in 1999, is the most significant regulation in termite control in China. This regulation was revised and amended by the MOC No. 130 regulation in 2004. The main rules in both regulations include:

a. In termite affected area, all new buildings and renovations, expansions and decorations of old buildings must have termite prevention treatment;
b. MOC takes charge of the management of termite control in China, and the Departments of Construction of local governments take charge of the management of termite control in the corresponding provinces;
c. Termite control units must have the qualification to do termite control, and the chemicals for termite control must be registered in the Department of Pesticide Management of the Ministry of Agriculture (MOA);
d. The quality assurance term of termite control is 15 years, which starts from the date that house and buildings is transferred to users.
e. Termite control in city area should follow the "prevention as the first priority" principle, use preventive and remedial measures jointly, and implement IPM strategies in termite control as soon as possible; and
f. The government encourages to do research on the control of termites in city area, and promotes the use of new alternatives, techniques, crafts and equipments.

16. In order to strengthen the management of termite control, China has issued many technical standards for termite control in urban areas and dams and dykes, and for termite control studies. Table 3-1 lists standards issued by national agencies and by the Zhejiang and Jiangsu Provinces.

17. In order to reduce the environment pollution and to protect the human health, the Chinese government has issued many policies to eliminate or limit the production and use of chlordane and mirex. Regulations related to the production and use of chlordane and mirex are:

a. *Regulation for Environment Management on the First Import of Chemicals and Import/Export of Toxic Chemicals* (issued by SEPA, Ministry of Foreign Trade and General Agency of Customs in 1994). This regulation aims to strengthen the monitoring and management of the first import of chemicals and the import and export of toxic chemicals included in the List of Toxic Chemicals Banned or Strictly Restricted in China. Chlordane was one of 27

chemicals included in this list. In other words, the import and export of chlordane are strictly controlled in China.

Table 3-1: National, Zhejiang and Jiangsu Termite Control Standards

Category	Issuance Agency and Year	Titles of Standards
Urban Areas	MOC, 1993	Technical Standards for Preventive Engineering of Termite Control in Houses and Buildings
	China Property Management Institute, April 2002	Technical Standards for the Preventive Engineering of Termite Control in Houses and Buildings (Draft)
	Department of Construction of Zhejiang Province, October 1986	Technical Standards for Preventive Engineering of Termite Control in New Houses and Buildings
	Construction Committee of Jiangsu Province, 1993	Operation Rules for Preventive Engineering of Termite Control in Houses and Buildings in Jiangsu Province (draft), and Rules for the Use of Chemicals for Termite Control in Houses and Buildings
	Department of Construction of Zhejinag Province, 1998	Detailed Rules for the Quality Management of Termite Prevention Engineering on Houses and Buildings
	Department of Construction of Zhejinag province, 1999	Measures for the management of chemical application during the termite control in house and buildings
Dams and Dykes	Ministry of Water Conservancy, August 1996	Notice on Further Strengthening Termite Control in Dams and Dykes and Ensuring the Security of Dams and Dykes
	Department of Water Conservancy of Jiangsu Province, 1990	Temporary Measures for Termite Control in Dams and Dykes in Jiangsu Province
Research	GB/T18260-2000 (issued in December 2000, effective in April 2001)	Preventive Termiticides for Wood Treatment: Experimental Methods in Laboratory for the Toxic Effects of Wood Antiseptic Against Termites
	GB2951.38-86 (issued in December 1987, effective in December 1987)	Preventive Termiticides for Cable and Electric Wire Treatment: Experimental Methods in Laboratory for the Cable and Electric Wire Against Termites
	Wuxi Institute of Termite Control, Standard Q/320201NBV101-2001 (effective in 2001)	Experimental Methods and Evaluative Criteria in Laboratory for the Effects of Termiticides against Termites

b. *Regulation for Pesticide Management* (issued by MOA in 1997 and revised in 2001). This regulation aims to strengthen the monitoring and management of

the production, distribution and use of pesticides, to ensure pesticide quality, and to protect human and environmental health. The core measure of this regulation is a pesticide registration system. MOA is in charge of the registration of pesticides and provincial-level Departments of Agriculture provide assistance in pesticide registration. In China, the chlordane and mirex are not registered pesticides.

c. **State Council Order, No. 216 - a**dministrative regulations of the People's Republic of China on Pesticides entered into force on May 8, 1997 and revised in 2001**.**

This is to strengthen the supervision and management of the production, dissemination and use of pesticides, guarantee the quality of pesticides, protect agricultural production and eco-environment and the safety of human and animals. The regulation sets out explicitly the provisions and requirements over the registration, production, dissemination and use of pesticides in PRC. The pesticides referred by the Regulation covers a chemical compound or a substance or a mixture of several substances, and prepared medicines originating from life-form or other natural substances used to prevent, eliminate or control the diseases, pests, weeds and other harmful life-form that endanger agriculture and forestry as well as modulate the growth of plants and insects. The state encourages and supports the research, production, manufacturing and use of safe, high effective and economical pesticides.

d. *No. 6 Regulation "List of Obsolete Production Capability, Techniques, and Products that Need to be Eliminated* (issued by the State Economic and Trade Commission (SETC) in January 1999). This regulation stipulates that the obsolete production capability, techniques, and products included in the appendix of regulation should be shut down and eliminated within stated time limit. Effective on February 1, 1999, this regulation has listed chlordane and its production as one of obsolete products and technologies to be eliminated.

e. *No. 72 Regulation on Termite Prevention and Control in Urban Construction* (issued by MOC in October 1999). As noted earlier, this regulation requires that chemicals used for termite control be registered with the Department of Pesticide Management as pesticides. Because chlordane and mirex are not registered with the Department of Pesticide Management, legally all termite control stations cannot use chlordane to control termite in cities.

The Regulation applies to the management of termite prevention and control in urban houses in termite-stricken areas. The management of termite prevention and control in urban houses refers to the management of termite inspection and control for new buildings, renovated buildings, and old houses. The principle of "prevention first, combined with control and integrated management"should be adhered to and the pesticides approved by the relevant departments of the State could be used in the termite prevention and remedy of urban houses. The termite prevention and control unit should develop

registration system for claiming pesticides. The pesticides should be stored in a special warehouse and controlled by special personnel. The state should encourage the scientific research of termite prevention and remedy of urban houses and popularize the use of new pesticides, new technologies, new methods and new equipments.

f. *Regulation for Safe Management of Hazardous Chemicals* (issued by the State Council in 1987 and revised in March, 2002). This regulation aims to strengthen the safe management of hazardous chemicals and to protect human and environmental health. The regulation has assigned responsibilities to various government agencies to supervise the production, storage, use, sales, transport, and registration of hazardous chemicals.

Article 25 specifies that appropriate measures should be taken to dispose the production facilities, stockpiles and the raw materials in order to root out any potential accident in the case of manufacture companies shutout or bankruptcy. The disposal scheme should be put on records to (1) the local department in charge of supervision and management of hazardous chemical safety under city-level government, (2) local Environmental Projection Bureau and Public Security Bureau.

g. *Environmental Quality Standard of Soil* (GB15618-1995) is a national standard of China, which come into effect on March 1, 1996. There are three classes of standards: the first class standard is for protecting the regional natural environment, maintain the limit-value of environmental quality of soil in natural background; the second class standard is for protecting agriculture, the soil limit-value for human health protection; the third class is the soil critical value for protecting agriculture and forestry as well as natural vegetation growth. There are ten regulated contaminants including cadmium, arsenic, copper, lead, chrome, zinc, nickel, HCH and DDT. There is, however, no standard for Chlordane and Mirex.

Relevant Environment Standards Outside of China

18. So far, only some countries such as USA and Russia had formulated the environmental quality and pollution control standards for chlordane, mirex, endosulfan and hexachlorocyclopentadiene.[1] After reviewing the data and consulting experts, a list of relevant standards applicable in foreign countries is presented as following Table 3-2.

[1] Endosulfan was another product produced at the Liyang Guanghua Chemical Company, Ltd. Hexachlorocyclopentadiene is a raw material for the production of chlordane.

Table 3-2 Summary of Relevant Environmental Standards on Chlordane, Mirex and Others in Foreign Countries

Name of pollutant	Environment Element	Environment Value	Remarks
chlordane	water	□0.55μg/L	Acceptable concentration in drinking water in California, USA (FSTRAC,1990)
		□0.1μg/L	Acceptable concentration in drinking water in New York, USA (CELDS,1992)
		□0.2μg/L	WHO's provision about limit of chemical content in drinking water impacting on human health
		0.19μg/L	Primary target for remediation of tap water in 9 districts, USA (EPA, 2004)
		0.01μg/L	Quality standard for ground water in Virginia, USA (CELDS, 1992)
		2ug/L	MCL value specified by EPA
	water	0.02ng/L (target value) 0.2μg/L (interference value)	Standards for soil remediation and ground water, issued by Holland government in 2000
	Soil	1.6 mg/kg (Residential area) 6.5 mg/kg (Industrial area)	Primary target for remediation of soil directly exposed in 9 districts, USA. (EPA,2004)
		1 mg/kg (intake in soil)	Temporary guideline for polluted soil remediation in Arizona, USA: (Residential area HBGL)
		4 mg/kg (intake in soil)	Temporary guideline for polluted soil remediation in Arizona, USA: (non-residential area HBGL)
		0.00003 mg/kg (target value) 4 mg/kg (interference value)	Standards for soil remediation and ground water, issued by Holland government in 2000
		0.05mg/kg	Sanitary standard for pesticide in soil, Russia
	Disposed as waste	50mg/kg	Basel Convention: guidelines on POPs
Mirex	Water	0.001μg/L	Quality standard for surface water in Pennsylvania, USA (CELDS, 1994)
		0.001μg/L	Quality standard for ground water in Pennsylvania, USA (CELDS, 1994)
		0.037μg/L	Primary target for remediation of tap water in 9 districts, USA (EPA, 2004)
	Soil	0.27mg/kg(Residential area) 0.96 mg/kg(Industrial area)	Primary target for remediation of soil directly exposed in 9 districts, USA (EPA, 2004)

Name of pollutant	Environment Element	Environment Value	Remarks
		0.76 mg/kg(intake in soil)	Temporary guideline for polluted soil remediation in Arizona, USA: (Residential area HBGL)
		2.66 mg/kg(intake in soil)	Temporary guideline for polluted soil remediation in Arizona, USA: (Non-residential area HBGL)
	Disposed as waste	50mg/kg	Basel Convention: guidelines on POPs
Endosulfan	Water	220µg/L	Primary target for remediation of tap water in 9 districts, USA (EPA, 2004)
		0.2µg/L(target value) 5µg/L(interference value)	Standards for soil remediation and ground water, issued by Holland government in 2000
	Soil	700 mg/kg(intake in soil)	Temporary guideline for polluted soil remediation in Arizona, USA: (Residential area HBGL)
		2450 mg/kg(intake in soil)	Temporary guideline for polluted soil remediation in Arizona, USA: (Non-residential area HBGL)
		370 mg/kg(residential area) 3700 mg/kg(industrial area)	Primary target for remediation of soil directly exposed in 9 districts, USA (EPA, 2004)
		0.00001 mg/kg (target value) 4mg/kg (interference value)	Standards for soil remediation and ground water, issued by Holland government in 2000
Hexachloro-cyclopentadiene	Water	220µg/L	Primary target for remediation of tap water in Region 9, USA (EPA, 2004)
	Soil	370 mg/kg (Residential area) 3700 mg/kg (Industrial area)	Primary target for remediation of soil directly exposed in 9 districts, USA (EPA, 2004)

USEPA MCL: Maximum Contaminant Level (MCL): Maximum acceptable pollutant content will be recognized to be applicable environmental criteria.

19. Even some developed countries, which have the very stringent environment standards, such as Denmark and Japan, do not have no standards for soil and groundwater for chlordane, mirex, endosulfan and hexachlorocyclopentadiene.

20. In China, there is no standard for chlordane and mirex available.

Institutional Setup in China for the Management of POP

21. **SEPA.** In charge of China's environmental protection efforts, SEPA is the leading agency for China's negotiation delegation to the Stockholm Convention and serves the focal point for the implementation of the Stockholm Convention in China. The supervision and management of hazardous wastes is one of the major responsibilities of SEPA. Based on the Solid Waste Pollution Control Law, SEPA, working with other ministries, has issued a series of management methods, standards and policies on hazardous wastes. The main departments of SEPA involved in the implementation of Stockholm Convention are its Departments for International Cooperation, Pollution Control, Policy and Law, Science and Standards, Planning and Finance, and Monitoring and Supervision. In particular, the Department of International Cooperation of SEPA is in charge of negotiation and foreign cooperation issues, and the Department of Pollution Control is SEPA's key department in charge of the implementation of the Stockholm Convention, the Basel Convention and the Rotterdam Convention. Specifically, the Solid Waste and Chemical Management Division under the Department of Pollution Control is in charge of the management and control of PCBs pollution in China.

22. **Supporting Institutions Affiliated with SEPA in Hazardous Waste Management.** These institutions include the National Chemical Registration Center, the Solid Waste Import Registration and Management Center, and the China Technology Transfer and Training Center for Hazardous Waste Management and Disposal. The National Chemical Registration Center provides technical supports to SEPA in chemical management. The Center is managed by the Chinese Research Academy of Environmental Science, and supervised by the Solid Waste and Chemical Management Division of the Pollution Control Department of SEPA. In addition to managing the registration of chemicals imported to China for the first time and import and export of hazardous chemicals, the Center is also engaged in improving methods and technologies for chemical management.

23. Since July 1, 2003, SPEA has entrusted the Chinese-Japanese Environmental Protection Publicity and Education Center to control the approval of the import of wastes to be used as raw materials. The Waste Import Registration Center affiliated with the Chinese-Japanese Center is in charge of such approval.

24. Technology Transfer and Training Center for Hazardous Waste Management and Disposal is located in the Solid Waste Control and Resource Research Institute in the Department of Environmental Science and Engineering at Tsinghua University. The Center provides technical support to the negotiation of the Basel Convention and related training activities.

Project Administrative Arrangements

25. **National Leading Group (NLG) for implementation of the Stockholm Convention.** China established the National NIP Development Leading Group in September 2003, with SEPA as the Lead Agency. The NLG provided overall guidance and coordination for the NIP development process at its Project Concept and Project Brief stages. This Group will serve as the National Leading Group for Implementation of the POP Convention after China ratified the Convention on August 13, 2004. It will provide (i) overall guidance to development of the NIP, (ii) review of significant policies related to POPs, and (iii) guidance to implementation of all POP activities. It consists of 11 agencies: State Environmental Protection Administration (SEPA), National Development and Reform Commission (SDRC), Ministry of Foreign Affairs (MOFA), Ministry of Finance (MOF). MOF is the GEF Focal Point in China, Ministry of Commerce (MOCom), Ministry of Science and Technology (MOST), Ministry of Agriculture (MoA), Ministry of Public Health (MOH), Ministry of Construction (MoC), General Administration of Customs (GAC), and State Electricity Regulatory Commission (SERC).

26. SEPA has been designated as the national lead agency for all POPs activities and for implementation of the POPs Convention. All major national and local government, scientific institutions and professional termite control organizations will be involved in project implementation. Roles and responsibilities of key agencies are briefly described as followed:

a. Convention Implementation Office (CIO). SEPA has organized a CIO for overall management of POPs related projects. The CIO is part of SEPA and is responsible for day-to-day compliance with the Stockholm Convention. The CIO has set up a Termite Project team to be in charge of the day to day management and implementation of the proposed demonstration project under the guidance of the CIO, and oversee the provincial PIUs. The project will recruit a Chief Technical Advisor (CTA, an international consultant), a National Technical Advisor (NTA), and various technical experts to assist CIO in project activities.
b. The National Termite Control Center (NTCC) under the Ministry of Construction will oversee policy issues and develops the Operational and Training Manual for use of IPM in termite control.
c. Provincial Steering Group. In each project province, key stakeholders will form a steering group to provide advice to provincial PIU on technical, policy, management and other aspects of project implementation.
d. Local Project Implementation Units in Zhejiang and Jiangsu (local PIUs**).** Zhejiang and Jiangsu provinces will establish project implementation units (PIUs) to conduct day-to-day project management and coordination of provincial level activities in their respective provinces. In Jiangsu, the Jiangsu Environmental Protection Bureau is leading the Jiangsu PIU.

e. The Zhejiang Provincial Institute for Termite Prevention and Control (ZPITPC). The institute is presently responsible for all training provided to termite stations and termite staff in Zhejiang province and for corporation between termite institutes/stations within the province.
f. The Jiangsu Provincial Termite Association. The Association will maintain its present role in the Province. Under the project, it will be responsible for all IPM training to be provided to staff employed by the termite stations in the province. It will continue cooperation between termite institutes and stations within the province.
g. Termite stations in Jiangsu and Zhejiang Provinces**.** The professional termite stations will receive IPM training and implement integrated termite management using bait systems instead of chlordane and mirex. As of 2004, Zhejiang has 90 and Jiangsu has 82 provincial and municipal termite stations, all of which will be involved in this project.
h. Suppliers of bait systems. Contracts to supply bait systems will be awarded based on World Bank procurement rules about six month after the start of the project to allow domestic and international suppliers to register their products with MoA. Bait system will be procured periodically during the implementation period in order to ensure most cost effective supply of bait systems.
i. Hazardous waste management companies**.** Hazardous waste management companies will be selected competitively for the closure of the Liyang Guanghua Chemical Company, cleaning up the production site and disposal of chlordane and mirex contaminated wastes.

Baseline information and site investigation

Basic Information about Liyang

Geographic location

1. Located at south of Changzhou Municipality, Liyang City, Jiangsu Province, is at the intersection of Jiangsu, Zhejiang and Anhui provinces. The city is west to the Taihu Lake, south to the Yangtze River and north to the Tianmu Mountain. It has been known as the center of 'the land of fish and grain' of Jiangsu and Zhejiang Provinces (see Figure 4-1 for details). Geographically, the city is located between 31°1'N and 31°41'N, and between 119°08'E and 119°36'E. Its length from south to north is about 59.06 km, and its width from east to west is 45.14 km. The total area of Liyang City is 1,535 km^2, and the total population is 780,000 (as of 2004).

2. Liyang City has a total of 18 towns and 2 provincial-level development zones (see Figure 4-2 for details). As one of the hundred well-known towns in Jiangsu Province, Licheng Town is the political, economic and cultural center of Liyang city and has a population of 187,000 (as of 2004) and a total area of 123.7 km^2. The famous Beijing-Hangzhou Grand Canal runs through the town.

3. Liyang Guanghua Chemical Company, Ltd. is located in the Liyang Economic and Technology Development Zone. The site is close to Niucheduo Village of Licheng Township, Liyang city, Jiangsu province. It is about 5 km away from the city center. See Figures 4.1 and Figure 4-2 for the geographic location of Liyang City and the Liyang Guanghua Chemical Company, Ltd., and the municipal boundary of Liyang City, respectively.

4. **Economic Information**. In 2004, Liyang City achieved an industrial output of 25.802 billion RMB yuan and a pre-tax profit of 2.257 billion RMB yuan. In 2004, Licheng Town achieved a GDP of 2.11 billion RMB yuan and an industrial output of 4.87 billion RMB yuan.

5. **Geology and Physiognomy.** Topographically, the south, west and north parts of the city are relatively high and hilly but the central and east parts of the city are low and flat. Low hills in the south part of the city are extensions of Tianmu Mountain, with major peaks such as Shimen Peak, Tongguan Peak and Daode Peak. The highest peak is Shimen Peak with an elevation of 506 meters. Low hills at the northwest part of the city are extensions of Maoshan Mountain, with major peaks such as Yiahuan Peak, Wawu Peak, and Zhishan Peak. The highest peak is Yiahuan Peak with an elevation of 410 meters. The Liceng town is almost flat with an elevation of 5-6 meters. Overall, low hill areas account for 65.15% of the total area of the city, and the rest are plain areas.

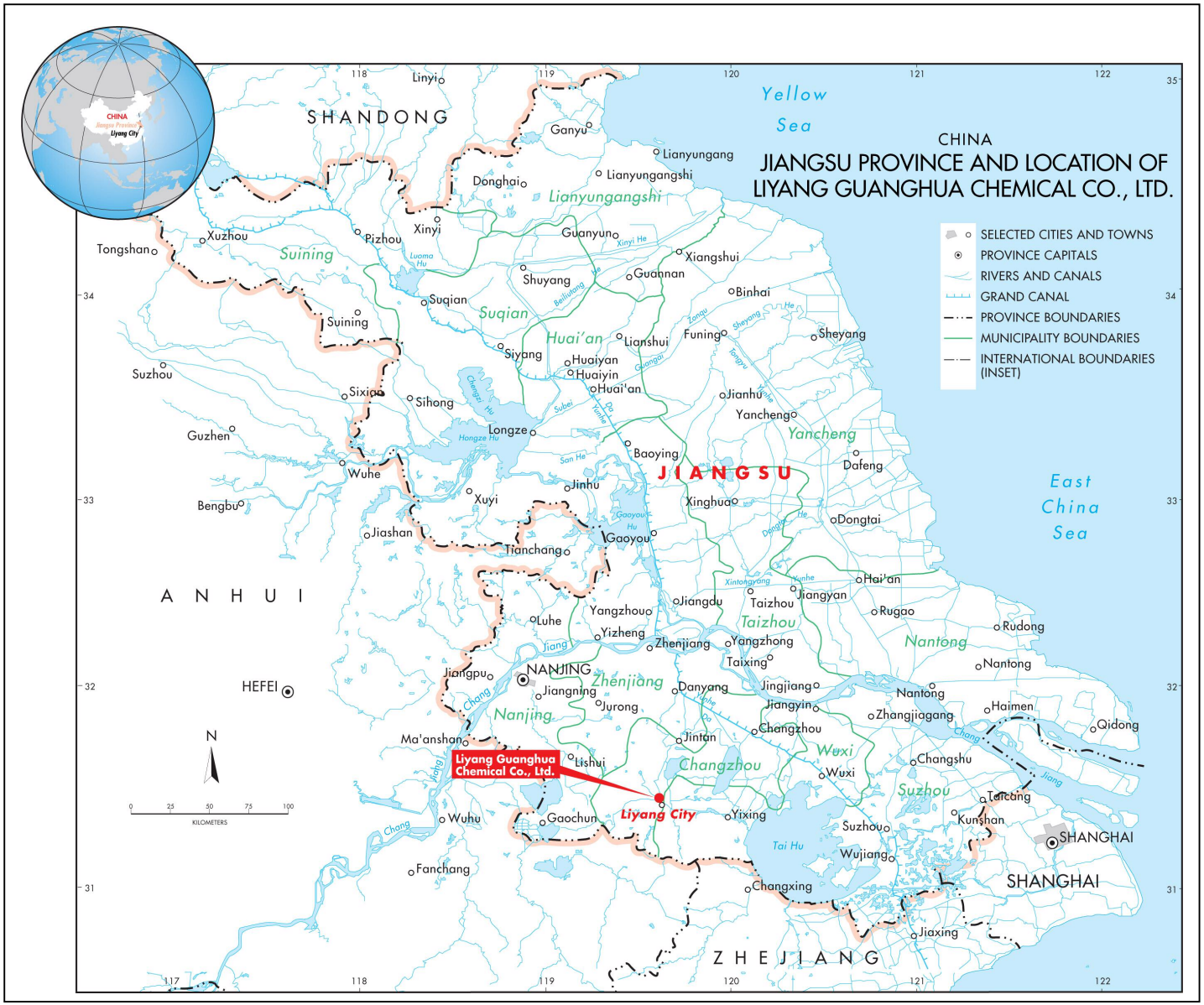


Figure 4-1 Jiangsu Province and Location of Liyang Guanghua Chemical Co., Ltd.

Figure 4-2: Liyang City and the Liyang Guanghua Chemical Co., Ltd

6. Geologically, Liyang areas are alluvial plain in ancient down warped basin. Most area of the Liyang city is covered by a 30 to 50 meters thick layer of lake alluvium sediments from the Quaternary epoch. The top part of this layer has low permeability and water is confined between sands and gravels. Consequently, ground water is not abundant in the area and is mainly supplied by precipitation and surface runoff at the edge of the basin. Soil mechanics of the area determines that bearing pressure of soil foundation is less than 8 ton/m^2 for locations along rivers but 12 to 20 ton/m^2 for other locations, which is suitable for engineering construction. Figure 4-3 shows a satellite image of the Liyang area.

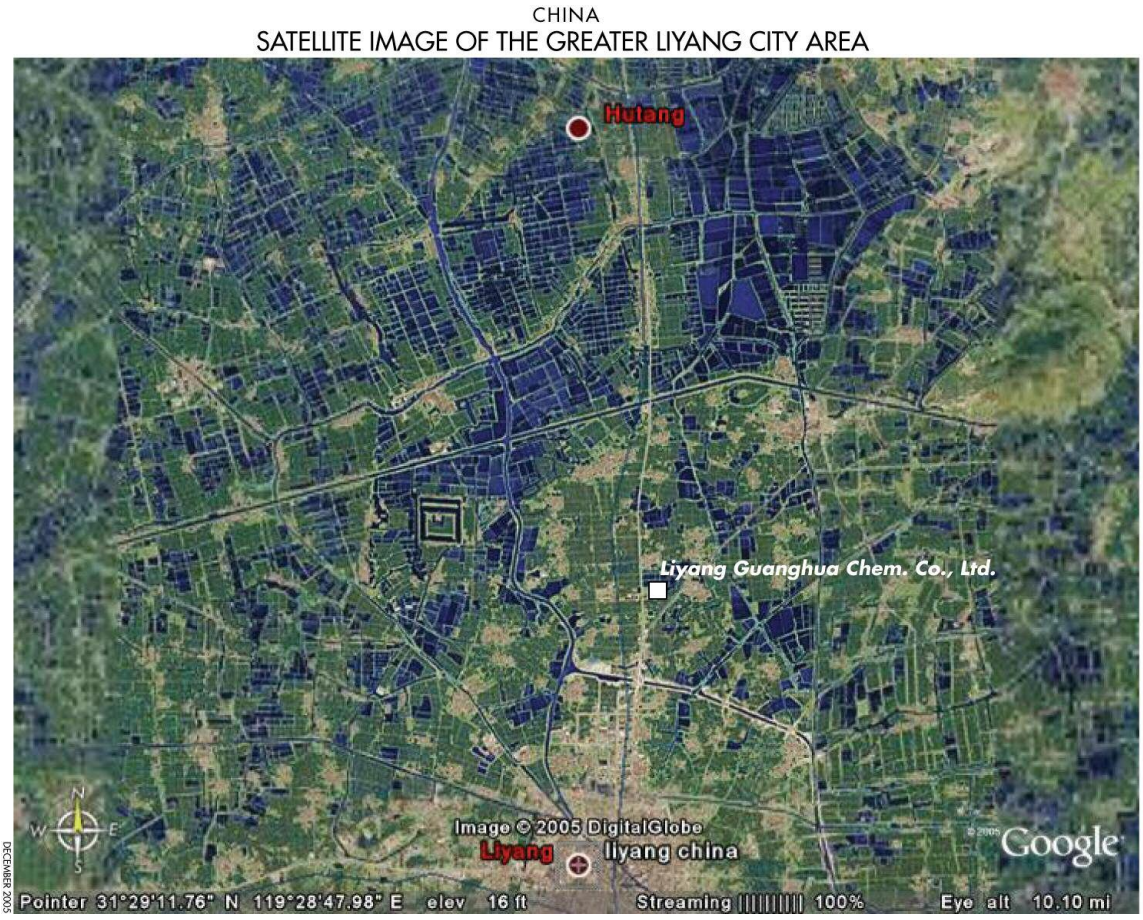


Figure 4-3 Satellite Image of the Greater Liyang City Area

7. **Hydrology**. Liyang is west to the Tai Lake and belongs to the Tai Lake watershed. Liyang City has 125 rivers with a length of 1 kilometer or more. The total length of rivers in Liyang is 614 km, and the annual flow of all rivers is about 0.576 billion m^3. The river network density is about 0.40 km/km^2. Water levels of Liyang rivers vary between 2.50 and 6.0 meters. The highest water level occurs between July and September, and the lowest water level occurs between December and February.

8. **Climate**. Liyang has a sub-tropic monsoon climate, with a clear division of four seasons. It has plentiful rainfall, a short frost season, and an annual average temperature of 15.5□. The average temperatures are 3.2□ in January and 31.1□in July. The average annual precipitation, evaporation and relative humidity are 1152.1 mm, 1558.6 mm and 79%, respectively. The precipitation is 42.2 mm in January and 154.1 mm in July. Average sunlight hours are from 137.6 hours in January to 229 hours in July. The dominant wind is easterly wind, with an annual average wind velocity of 3.1 m/s.

9. **Soil**. Parent soil material in Liyang is mainly sediments (of loess) from rivers and lakes. Some parts of the area do have clay (or subclay) sediments from river plains or sandy sediments from riverbed.

10. **Atmospheric Environment**. In 2004, the air quality within Liyang City is Class II defined by the Air Environmental Quality Standards (GB3095-1996). The annual average concentrations of SO_2, NO_2 and inhalable particles (with a diameter less than 10μm, or PM10) in 2004 were 0.040 mg/m^3, 0.037 mg/m^3 and 0.097 mg/m^3, respectively. Comparing to those of 2003, there is an increase of 0.017 mg/m^3, 0.011 mg/m^3 and 0.002 mg/m^3, respectively, in 2004. The integrated air pollution index of 2004 was 0.82, or the air was lightly polluted. The principal air pollutant was inhalable particles. There was no acid rain event recorded in 2004.

11. **Ecological Environment**. The local ecosystem is classified as mixed deciduous and evergreen forestry. However, the primary vegetation has been severely destroyed, and only some secondary vegetation can be found in Jilong Mountain, Xianren Mountain and some low hills. Such vegetation includes Rhoipteleaceae, camellia, elm, cypress, bamboo, etc. There are also some planted poplar, osier, metasequoia and paulownia.

Liyang Guanghua Chemical Company, Ltd.

12. **Overview**. Liyang Guanghua Chemical Company, Ltd. was established in June 1989 as a collective enterprise. In 2004, the company has a production area of 15064 m^2, 90 employees, and fixed assets of 3 million RMB yuan. Its gross revenue amounted to 80 million RMB yuan with chlordane, mirex and endosulfan as its major products. The sales incomes from chlordane and mirex were 63 million RMB yuan. About 40 workers worked on the chlordane and mirex production facility.

13. Liyang Guanghua Chemical Company, Ltd. is located in the industrial park of the Liyang Economy and Technology Development Zone (LETDZ). The LETDZ was set up in April 1992 and was approved as provincial-level economic zone in November 1993. The LETDZ has an area about 40 km^2, of which around 10 km^2 has been developed. The major industries in the zone are machinery, iron steel, metallurgy and food processing.

14. In 1992, the company built its chlordane and mirex production facilities at the current site. The site was used for agricultural purposes and had no prior industrial activities. From the period from 1992 to 1997, only endosulphane were produced at the site. The chlordane and mirex production line were added in 1997. Its site is at east of Zhen-Guang Highway, south of Zhong River, west of Zhaocun River and north of Wushen canal.

15. In 2004, the company's production facilities consisted of a combined production line for chlordane and mirex, heating boilers, raw material and product warehouses, a laboratory, a wastewater treatment facility and other auxiliary facilities. The production line of chlordane and mirex was built in 1997 with a capacity of 250 t/a, and was expanded with an investment of 0.5 million RMB yuan to a current production capacity of 500t/a. The production and storage facilities of chlordane and mirex cover an area of 1000 m^2. The actual production of chlordane in 2004 was 180 t/a. Mirex was produced on orders. Due to the planned closure, the company stopped its chlordane and mirex production in July 2005.

16. On the same site, the company also had an endosulfan production facility. The endosulfan production line was built in 1992 with a capacity of 300t/a. It was closed in

early 2004 as part of the Montreal Protocol program. Endosulfan production equipments were dismantled. The company has rebuilt its endosulfan production with a non-ODS technology at the Binhai Chemical Industry Park in Yancheng Municipality of Jiangsu Province.

17. **Layout of the Production Facility**. The Liyang facilities cover a total area of 15064 m^2 (176.6×85.3m^2). Table 4-1 provides a detailed overview of production lines, warehouses and other auxiliary facilities. The layout of the Liyang Guanghua Chemical Company, Ltd. is shown in Figure 4-4.

Table 4-1 Production Facilities at the Liyang Site

Names of the Engineering Works		**Designed capacity**	**Remarks**
Major engineering works	Production device of endosulfan (dismantled)	300 t/a	2 workshops, covering an area of 163.3 m^2, the production line closed and dismantled in early 2004
	Production device of chlordane and mirex	500 t/a	Chlordane and mirex share a production device, covering an area of 500 m^2
Warehouses and auxiliary works	Chlordane formulating workshop	/	175 m^2 (25m × 7m) Two separate workshop in one building
	Warehouse		
	Machine maintenance room	/	175 m^2 (25m × 7m) Two separate workshop in one building
	Product warehouse		
	Raw and auxiliary material warehouse	/	503.4 m^2 (29.1m ×17.3m)
	Boiler house	/	82.5 m^2 (7.3m×11.3m)
	Power distribution house	/	Covering an area of 140 m^2
	Analytical lab	/	Covering an area of 80 m^2
	Office	/	Covering an area of 20 m^2
	Toilet	/	Covering an area of 20 m^2
Environmental protection Works	Wastewater treatment facility	4t/d	Biochemical method covering an area of 47 m^2
	Exhaust gas treatment facility [a/]	/	Cl and HCl disposed of with water and alkali absorption methods.

[a/] Exhaust gas treatment facility is part of the production facility. Therefore, it is not shown in the figure separately.

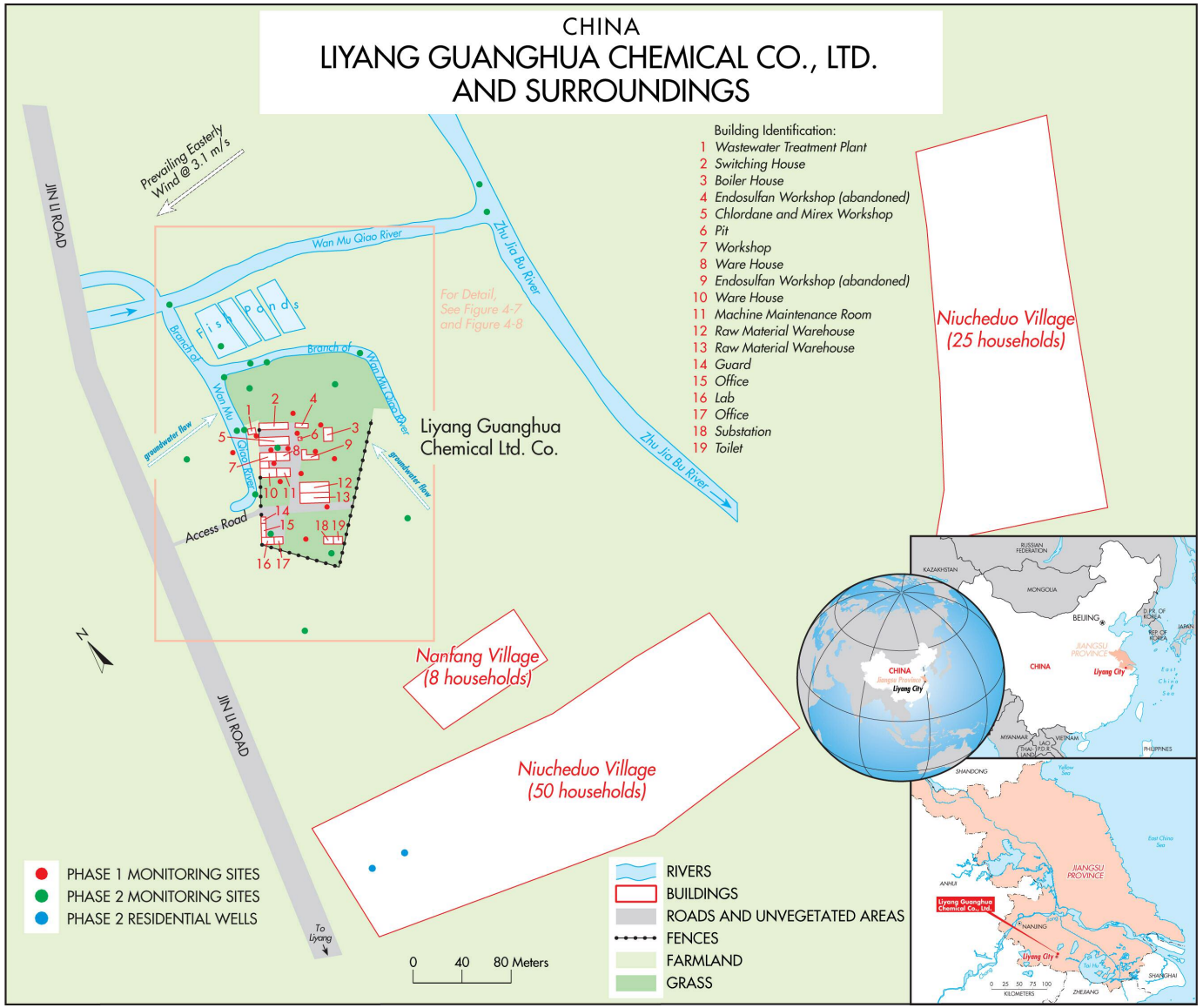


Figure 4-4 Liyang Guanghua Chemical Company, Ltd. and Surroundings

18. **Surrounding Environmental Situation**. According to the master plan of the Liyang City, the LETDZ (the Liyang Economy and Technology Development Zone), where the LGC site is located, has been planned for industrial use. As of 2005, the site of Liyang Guanghua Chemical Company, Ltd. is still surrounded by farmlands. The farm products produced are paddy rice, wheat, cotton and other melons and fruits. There are scattered farmers' houses 300 meters away southwest, 150 meters away south and 600 meters away southeast to the site (see Figure 4-4). Zhen-Guang Highway lies about 75 meters northwest to the site. A small building next to the access road between the main road and the site is used as a workshop run by two people. These two people built the small building without the permission from the government (see Photo 4-1). They lived there to build cement ships. However, it is anticipated that the Liyang City government will request them to vacate the site before the site cleanup activities are carried out.

19. The Liyang Organic Chemical Company Ltd. is located about 300 meters north to the site of the Liyang Guanghua Chemical Company, Ltd. The Liyang Organic Chemical Company is a legally independent company with 18 employees and a production area of 3317 m^2. Its major products are dicyclopentene and water-soluble paint. It has a production capacity of 120 t/a of dicyclopentene.

Photo 4-1: Boat Building Workshop Next to the Liyang Guanghua Site

20. Major surface water bodies surrounding the Liyang Guangha Chemical Co. Ltd. site are Danjin Licao River, Zhong River, Zhaocun River and Wushen Canal (see Figure 4-5). These rivers are not used as drinking water. Water flow direction of the rivers is from west to east or from north to south. These rivers have been used for industrial and agricultural uses. According to the Year 2010 Master Plan**,** Danjin Licao River is classified as Class IV while Zhong River and Zhaocun River are classified as Class III. Based on 2004 monitoring data and the Surface Water Environmental Quality Standards (GB3838-2002), these rivers have a water quality of Class IV to Class V, while some parts of the rivers are worse than Class V. In recent years, the quality of the water bodies within Liyang has decreased due to the discharge of large amount of industrial and municipal wastewater.

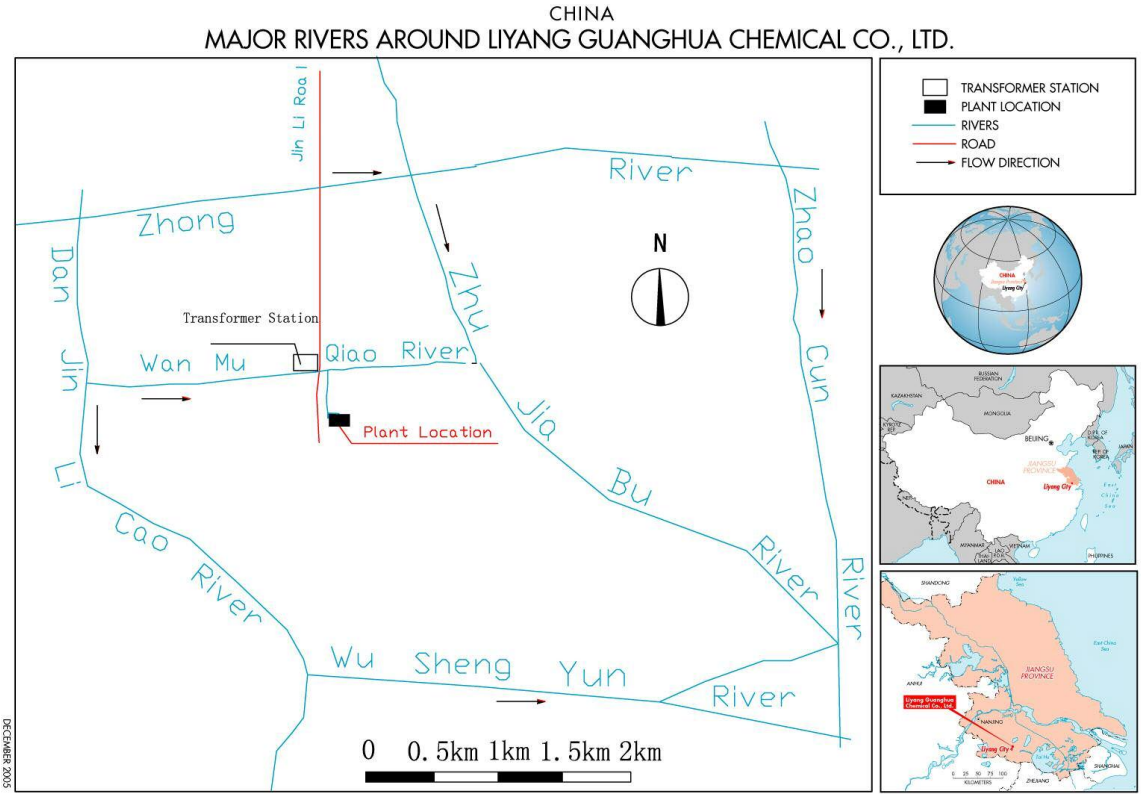


Figure 4-5: Major Rivers Adjacent to the Liyang Guanghua Site

21. The river bodies directly related to the Liyang Guanghua site are Zhujiafu River and Wanmuqiao River, which have received pollutants from the Liyang Guanghua site (See Figures 4-4 and 4-5). Locations and water flow directions of these two rivers are determined through site investigation, interviews, GPS positioning and on-site measurement. Due to serious eutrophication problems, it was reported that these rivers were only used for agricultural irrigation.

22. A branch of the Wanmuqiao River is located along the west boundary of the Liyang Guanghua Chemical Company, Ltd. This branch is the planned water body for the collection of wastewater from neighboring industrial areas (see Photo 4-2).

Photo 4-2: Branch of the Wangmuqiao River at the Liyang Guanghua Site

23. Five fishponds used for crab farming are located 20 meters away to the north boundary of the Liyang Guanghua site (see Figure 4-4).

24. It is informed that Liyang Guanghua Chemical Company, Ltd. used tap water provided by the Liyang Tap Water Company (the water source is the Tianmu Lake) for equipment cleaning, product rinsing and employees' daily uses. However, the company used surface water from the branch of the Wanmuqiao River as cooling water and for cleaning the ground.

25. Domestic water supply for areas around the Liyang Guanghua site is provided by the Liyang Tap Water Company with water taken from the Tianmu Lake. The Tianmu Lake is a designated water source reservoir and is protected for drinking water usage. The water from the lake is of generally good quality (Grade II) and consistent with the requirements for drinking water supply.

26. There are still eight groundwater wells in the surrounding villages. Most of them are not in use anymore because of the availability of tap water supply. The closest wells to the Liyang Guanghua site are located about 150-600 meters south, southwest and southeast to the site. It is noted that few residents do use ground water from some wells and from the rivers for bathing and laundry. According to the site investigation, the flow direction of the ground water is from west to east.

27. Table 4-2 lists all potential environmental risk associated with the Liyang Guanghua site.

Table 4-2 Sensitive Environmental Objects Surrounding the Project site

Objects	Location	Distance to the Site (m)	Scale/use
Residential area of Niucheduo Village	southwest, south	about 300	~ 50 households, 150 people
	South	about 150	~ 8 households, 24 people
Residential area of Southern Village	Southeast	about 600	~ 25 households, 75 people
Workshop next to the access road of the site	South	50	2 people
Branch of the Wanmuqiao River	North	about 20	Water from the river used for irrigation of surrounding farmlands. The river received wastewater from the site.
Fishponds	North	about 25	Four ponds. Used for crab farming
Farmland	East, south, west	Surrounding the site	Used for growing vegetables.
Wells	Southeast, south, southwest	150-600	Eight wells. Not used as drinking water for the residents, livestock, or irrigation.

28. **Health Impacts on Workers**. According to the interviews and on-site survey with the manager and workers of the company, there was no regular medical checking for workers in the factory, and no evidence of any unusual health situation had been observed.

29. **Chemicals Produced or Used on Site**. The Physical and Chemical Properties of the products and major raw and auxiliary material are shown in Tables 4-3 and 4-4. Data are from the Handbook on Safety and Technology of Hazardous Chemicals (Beijing: Chemical Industry Press). Additional information about chlordane, mirex and other chemicals used at the Liyang Guanghua site is provided in Annex 2.

Table 4-3 Physical and Chemical Properties of Products and Major Raw and Auxiliary Material

(Data source: Handbook on Safety and Technology of Hazardous Chemicals, Beijing: Chemical Industry Press)

physical and chemical properties	appearance and properties	freezing point or melting point(C)	boiling point (C)	saturated vapor pressure (kPa)	relative density (water= 1)	combustibility	natural temper-ature (C)	Explos -ion limit (V%)	flash point (C)	type of hazard
Hexachloro-cyclopentadien C_5Cl_6	yellow and amber oil-like liquid, oily stimulating smell	9.6	239	0.012	1.70	strong	/	/	/	Type 6.1
Dicyclopen-tadiene $C_{10}H_{12}$	achromatous crystal	32.5	172	1.33	0.98	weak	503	1.0-10	26	Type 3.3
Tetrachloro-carbon CCl_4	achromatous, rancid liquid, volatile liquid	-22.6	76.8	13.33	1.60	incombustible	/	/	/	Type 6.1
Chloride Cl_2	yellow green, gas with stimulating odor	-101	-3405	506.62	1.47	combustion-supporting	/	/	/	Type 2.3
Chloradane $C_{10}H_6Cl_8$	achromatous or light yellow liquid, its industrial product being amber liquid with a fir odor	/	175	0.27	1.61	generally incombusti-ble, but combustible if exposed to visible fire or high temperature for a long time	/	/	/	Type 6.1
Mirex $C_{10}Cl_{12}$	White and tasteless crystal	/	485	/	/	weak	/	/	/	Type 6.1
1,4-Buty-lene glycol $C_4H_8O_2$	achromatous liquid with no bad smell	12.5	234		1.1	combustible	/	/	/	/
Thionyl-chloride Cl_2OS	light yellow to red, smoking liquid, with strong stimulating odor	-105	78.8	13.3	1.64	incombustible, decomposable into SO_2, chloride and other hazardous smokes if exposed to water or wet air	/	/	/	Type 8.1

Table 4-4 Physical and Chemical Properties of Products and Major Raw and Auxiliary Material

(Data source: Handbook on Safety and Technology of Hazardous Chemicals, Beijing: Chemical Industry Press)

Chemicals	**Solubility**	Toxicity
Hexachloro-cyclopentadien C_5Cl_6	not dissoluble in water, dissoluble in aether, tetrachlorocarbon and many other organic solvents	LD_{50}:584mg/kg(test through the mouth of a grown-up mouse);430 mg/kg(test through the mouth of a young mouse),with obvious stimulation to mucous membrane and skins
Dicyclopentadiene $C_{10}H_{12}$	not dissoluble in water, dissoluble in aether and ethanol	LD_{50}:820mg/L(test through the mouth of a grown-up mouse);0.72 mg/kg(test through the skin of a rabbit).Highly dense steam of this product is stimulating and narcotizing
Tetrachlorocarbon CCl_4	slightly dissoluble in water, dissoluble in many organic solvents	LD_{50}:2350mg/L(test through the mouth of a grown-up mouse);5070 mg/kg(test through the skin of a grown-up mouse). Highly dense tetrachlorocarbon steam is slightly stimulating to mucous membrane, slightly narcotizing to nerve center system, seriously damaging to livers and kidneys.
Chloride Cl_2	dissoluble in water and alkaline liquid	LC_{50}:293ppm/1h(test through absorption by a grown-up mouse) ;stimulating to eyes and mucous membrane of respiratory system, causing excitement of nerves and sudden pause of radioactive heart beats.
Chloradane $C_{10}H_6Cl_8$	not dissoluble in water, dissoluble in many organic solvents	LD_{50}:200mg/kg(test through the mouth of a big mouse);145 mg/kg(test through the mouth of a young mouse),LC_{50}: 100 mg/m 34 hours(test through absorption by a cat);Acutely toxic, possibly causing death within a few hours after poisoning people.
Mirex $C_{10}Cl_{12}$	not dissoluble in water, dissoluble in benzene, dioxane, xylene and tetrachlorocarbon	LD_{50}:312mg/kg (test through the mouth of a grown-up mouse;800 mg/kg(test through the skin of a rabbit),poisoning people if absorbed by skin, etc.
1,4-Butylene glycol $C_4H_8O_2$	dissoluble in water	/
Thionyl chloride Cl_2OS	dissoluble with others in benzene, trichloromethane and tetrachlorocarbon, etc.	LC50: test through absorption by a grown-up mouse: 500ppm/1h;Causing harm to body if absorbed by skin, etc., strongly stimulating to eyes, mucous membrane, skin and upper respiratory duct, able to cause burn

30. **Production Equipment**. Table 4-5 lists major manufacturing equipment used at the Liyang Guanghua Chemical Company, Ltd. Photo 4-3 shows chlordane, mirex, and production facilities, and Photo 4-4 shows abandoned endosulfan production facilities at the Liyang Guanghua Chemical Company, Ltd.

Table 4-5 Major Manufacturing Equipment, Utilities and Storage & Transportation Equipments of this Project

Type		Name of equipment	Specification of equipment	Unit	Number
Production	Chloride And Mirex	Reaction kettle	1000L	set	1
			500 L	set	3
		Decelerator	/	set	1
		Condenser	500 L	set	1
		Glass condenser	/	set	4
		Electrolytic furnace	/	set	2
		Reaction kettle	100 L	set	2
		Horizontal package boiler	1m^3	set	2
	Endosulfan *	Synthetic kettle	500L	set	1
		Water decomposing kettle	500L	set	1
		Cleansing kettle	500L	set	2
		Refined kettle	500L	set	1
		Slicer	500L	set	1
		Condenser	2m^2	set	1
		Centrifugal machine	/	set	1
		Vacuum pump	/	set	3
Environmental protection		Biochemical Treatment equipments	Disposal capacity4t/d	set	1
Storage and transportation		Liquid chloride steel bottle		piece	10
		Packaging material		piece	1800

* The endosulfan equipment has been dismantled but piled up on site.

Photo 4-3: Chlordane and Mirex Production Facilities at the Liyang Guanghua Site

Photo 4-4: Abandoned Endosulfan Production Facilities at the Liyang Guanghua Site

Production Process and Pollution Discharge

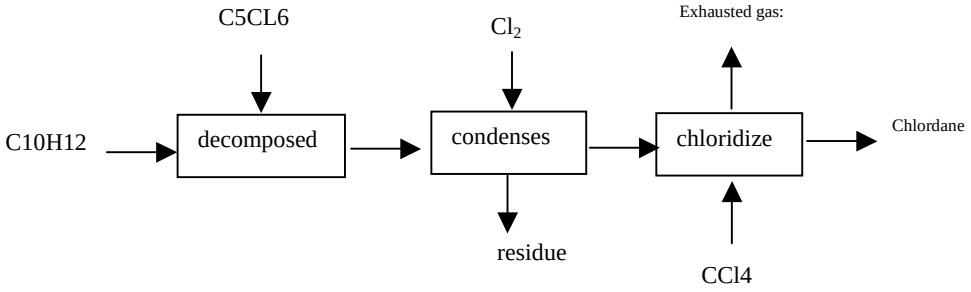
31. **Production of Chlordane**. The raw materials for chlordane are dicyclopentadiene, hexachlorocyclopentadien, chlorine gas and carbontetrachloride. Chlordane is produced through the following two steps:

Step 1: $C_{10}H_{12}$ decomposed under 170℃into cyclopentadiene;

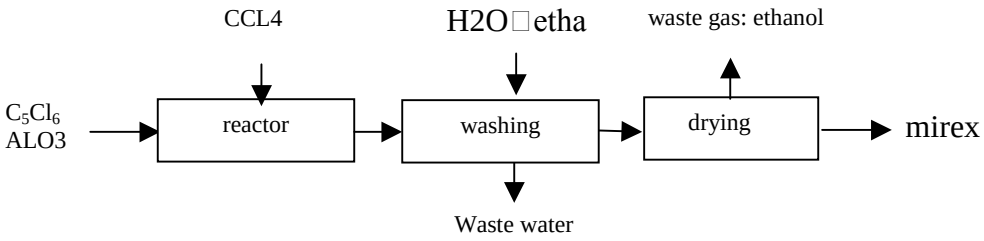
Step 2: C_5Cl_6 condenses with cyclopentadiene under 75□85□ and then chlorinated in CCl_4 under 70□.

32. The process flowchart of chlordane production is shown in Figure 4-6. Wastes from the production are as the following:

a. Exhaust gas. Exhaust gas is absorbed with NaOH to remove excessive Cl_2 before being discharged;
b. Solid wastes: dicyclopolymer waste residue;
c. Wastewater: water for equipment and floor washing is collected and sent to the wastewater treatment facility on site (see Figure 4-4 for the location) for treatment before being discharged into the branch of the Wangmuqiao River next to the site.



(a) Production of Chlordane



(a) Production of Mirex

Figure 4-6: Process Flowchart of Chlordane and Mirex Production

33. **Production of Mirex**. The raw materials for mirex are C_5Cl_6, Al_3Cl, CCl_4 and CH_3-CH_2-OH. Mirex is produced by C_5Cl_6 and cyclopentadiene at the presence of Al_3Cl. Raw mirex is washed with ethanol and water before being dried into the final product. The process flowchart for the production of mirex is shown in Figure 4-6.

34. Wastes from the production are as the following:

a. Exhaust gas: Small quantity of ethanol gas emitted from the drying process is directly discharged into the air;

b. Wastewater: Generated from the washing process. Mirex is recovered from wastewater before being transferred to the on-site wastewater treatment facility.

c. Solid wastes: no solid wastes are produced.

35. **Production of Endosulfan**. The raw materials for production of Endosulfan are: C_5Cl_6, $C_4H_8O_2$ and $SOCl_2$. C_5Cl_6 and $C_4H_8O_2$ react and form endosulfan alcohol after being heated at the presence of catalysts. Next, endosulfan alcohol and $SOCl_2$ will further produce endosulfan liquid under a certain temperature. Finally, endosulfan liquid is cooled, centrifuged and dried to endosulfan final products.

36. Wastes from the production are as the following:

a. Exhaust gas: HCl and Cl_2 are formed during the production process. HCl is absorbed with water to produce hydrochloric acid; Cl_2 is absorbed with NaOH

b. Wastewater: Wastewater is generated from equipment washing and is mainly acid water containing C_5Cl_6. The insoluble C_5Cl_6 is recycled. Alkaline liquid is used to adjust the pH value of wastewater before it is transferred to the on-site wastewater treatment facility for treatment.

c. Solid waste: A small quantity of waste residue is produced during rectification. It is transported for landfill.

37. **Disposal of Wastewater**. During the operation of the Liyang Guanghua Chemical Company, Ltd., wastewater was collected and pre-treated by individual workshops and then sent to the on-site wastewater treatment facility. Effluent was discharged after meeting Class II standards of the Integrated Wastewater Discharge Standards (GB 8978-1996) as shown in Table 4-6. Since there is no discharge standard for chlordane and mirex in China, chlordane and mirex in wastewater were not monitored. Photo 4-5 shows the wastewater treatment facility at the Liyang Guanghua Chemical Company, Ltd.

Table 4-6 Waste Water Discharge Standard (unit:mg/L, except for pH)

Items	Limit	Standard
pH	6-9	□Integrated Wastewater Discharge Standard□(GB8978-1996) Table 4 Class II
COD	150	
SS	150	

38. **Waste Disposal Records and Records of Accident**. Liyang Guanghua Chemical Company provided neither waste disposal records nor accident records. EIA preparers were informed that there was no reported accident such as leaking, overflow in the history of the company.

Photo 4-5: Wastewater Treatment Facility at the Liyang Guanghua Site

39. **Remaining Equipment and Chemicals On Site**. Table 4-7 for equipment and chemicals left on site after the stop of chlordane and mirex production in 2005. Photo 4-6 shows stockpiled chlordane and mirex products on site. Photo 4-7 shows contaminated packaging materials.

Photo 4-6: Stockpiled Chlordane (Left) and Mirex (Right) Products

Table 4-7 Equipment, Chemicals and Wastes Left on the Liyang Guanghua Site

Name		Quantity	Remarks
Facilities and workshops		Production and auxiliary facilities, workshops, public utilities for chlordane, mirex and endosulfan	To be dismantled and disposed of
Chlordane		16t	Stored in the product warehouse
Mirex		2t	
Hexachlorocyclopentadien		6t	Stored in the raw material warehouse
Dicyclopentadiene		5t	
Carbontetrachloride		10t	
Liquid chloride		3t	
Sliced alkaline		2t	
Ethanol		1t	
Packing materials	Plastic cask	approximately 1500 pieces	For hexachlorocyclo-pentadien 200 L capacity
	Iron drum	approximately 300 pieces	For CTC,200L capacity
Dicyclopolymer residue		150t	/
Asbestos contaminated insulation material		1t	Left on steam pipes
Acid organic wastewater		200t	Left in the wastewater treatment facility
Contaminated soil		/	To be determined

Photo 4-7: Contaminated Packaging Materials (1 and 2, chlordane containers; 3, raw material containers; 4, CTC drums)

Photo 4-7 (*continued.*) (5, raw material containers filled with Chlordane; 6, raw material containers)

Environment Monitoring of the Liyang Guanghua Site

40. **Organizational Arrangement for the Monitoring**. On April 1, 2005, the Jiangsu Academy of Environmental Science and Jiangsu Environmental Monitoring Center conducted a site investigation at the Liyang Guanghua facility. The site is relatively flat. After consulting with relevant experts and referring to relative information, JAES developed an Environmental Monitoring Plan. The aim of the Environmental Monitoring Plan was to collect sufficient environmental information through soil and water samples from the site and its surroundings to determine the extent of potential contamination caused by chemicals that were either used as raw-materials or produced on site. This baseline environmental information will determine the extent of site remediation action necessary to meet the requirements of the Stockholm Convention and national environmental standards.

41. Two phases of environmental monitoring were conducted. The first phase monitoring was conducted in May 2005. Based on the analysis of the results of the first phase monitoring, the Environmental Monitoring Plan was revised and the second phase monitoring was conducted in September 2005.

42. **Environmental Monitoring Principles**. National technical criteria adopted are as following:

a. Soil Environment Monitoring Technical Standards (HJ/T166-2004);

b. Ground Water Environment Monitoring Technical Standards (HJ/T164-2004); and

c. Surface Water Environment Monitoring Technical Standards (HJ/T91-2002).

43. **Laboratory Quality Assurance System and Control Measures (QA/QC) for Sampling and Analysis**. Sampling and analyzing of samples have followed the *Quality Manual* developed by Monitoring Center of Jiangsu Province. For detailed discussion on QA/QC, see Annex 3.

First Phase of Environmental Monitoring

44. **Location and Layout of Sampling Points**

45. *Ground water*. The pollution monitoring wells were distributed according to the flow direction of groundwater and positions of pollution sources. The sampling points are numbered from GH1 to Gh14. Figure 4-7 shows groundwater depth and flows at the Liyang Site. Figure 4-8 and Table 4-6 for the detailed locations of sampling points.

46. *Soil***.** Based on the lay-out of the Liyang Guanghua site, it was estimated that the production area of chlordane and mirex would be the most seriously polluted area. Based on technical guidelines for environmental monitoring and experts' advice, Sampling Points 2 to 13 were selected from the potential polluted sources radiating toward the boundary of the site. Monitoring Point 14 was set outside of the site. At all sampling points, i.e. GH1 to GH14 as soil sampling points, cylinder samples were taken. Figure 4-8 and Table 4-6 shows the distribution pattern of sampling points of the first round monitoring.

47. *Surface water*. Two Surface water sampling points are located both in the branch of Wanmuqiao River next to the outlet of the wastewater treatment facility at the Liyang Guanghua site. The sampling points are numbered S1 and S2, respectively. See Figure 4-8 and Table 4-8 for the detailed point location.

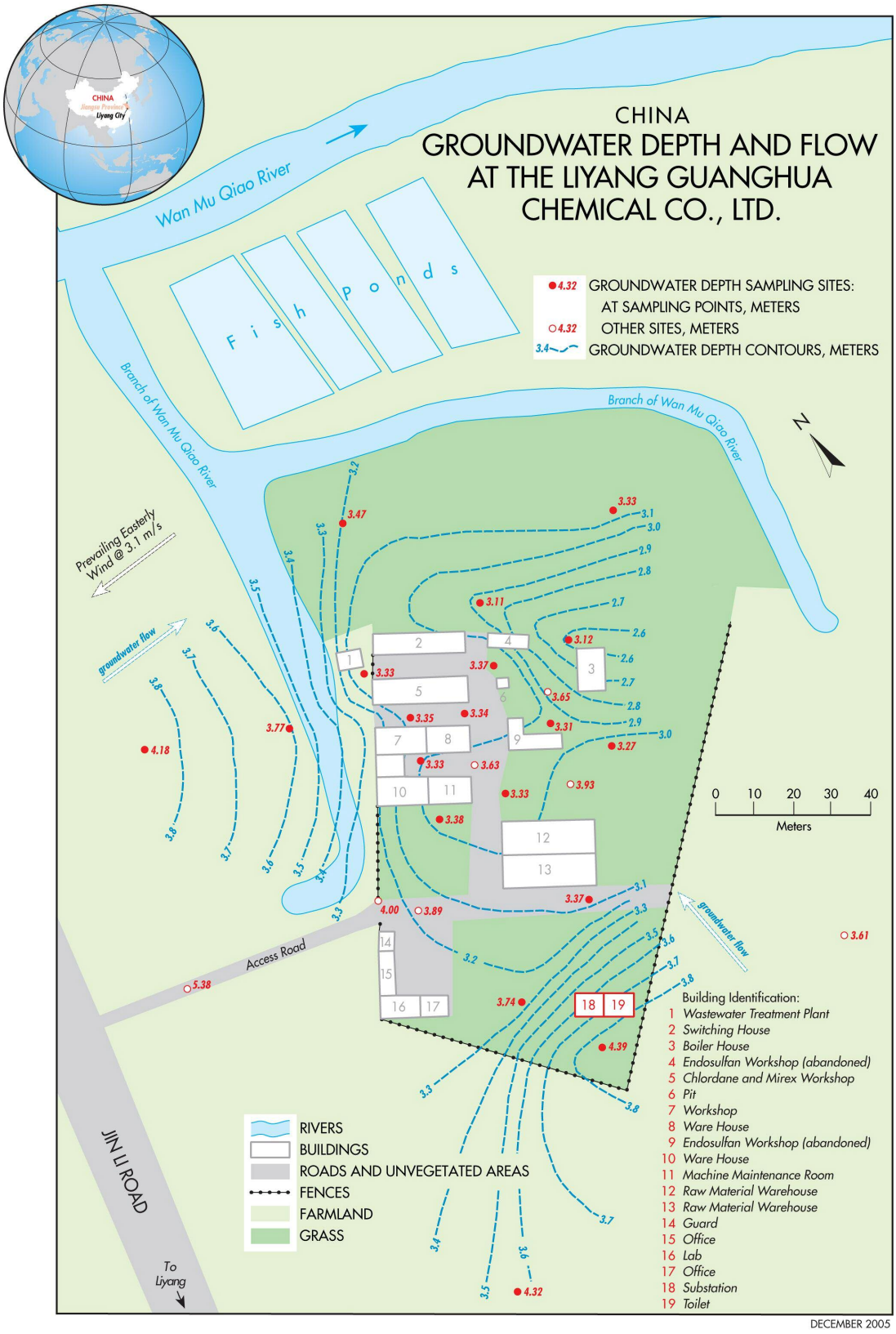


Figure 4-7 Groundwater Depth and Flow at the Liyang Guanghua Site.

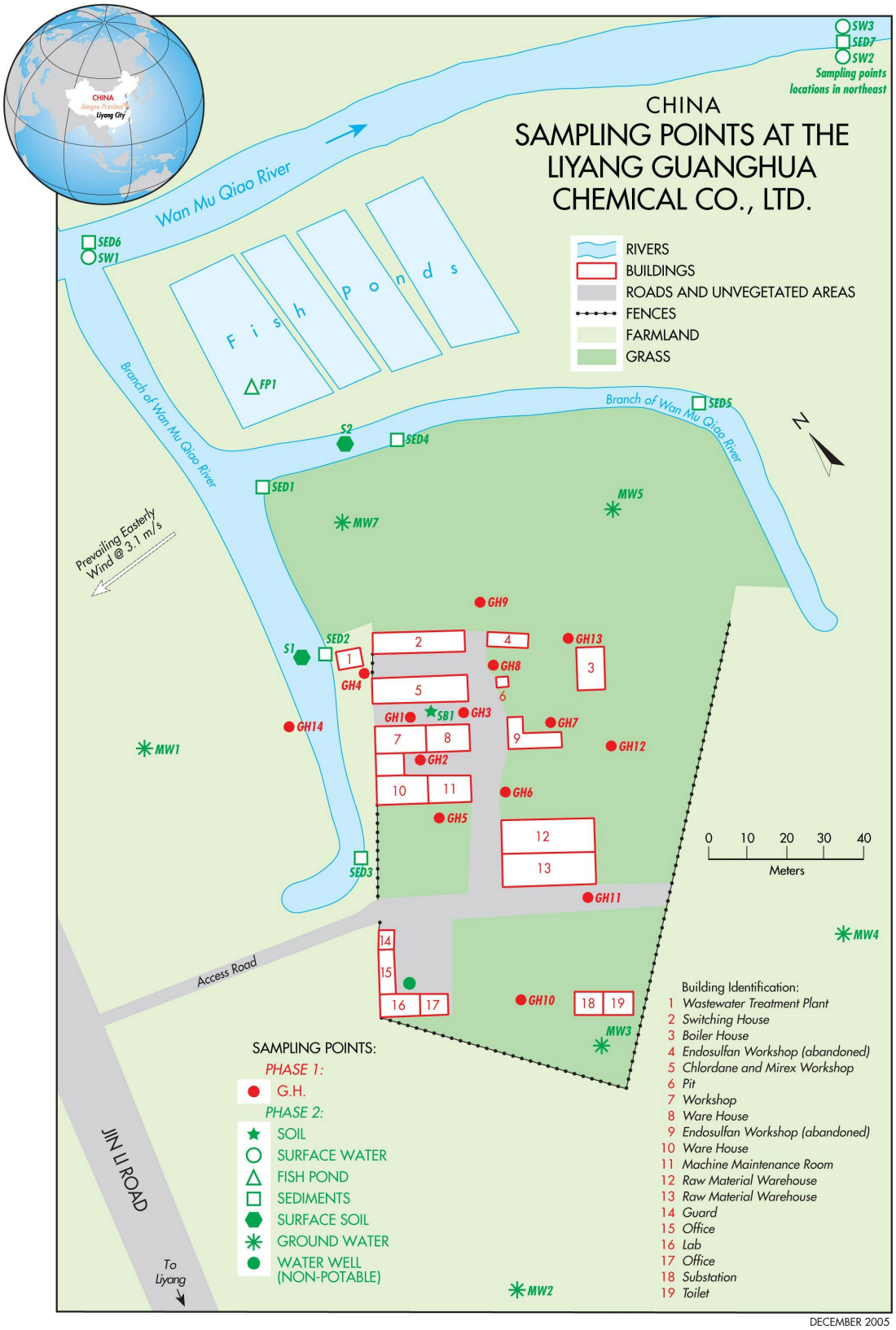


Figure 4-8: Sampling Points at the Liyang Guanghua Chemical Company, Ltd.

Table 4-8 Sampling Plan for Soil and Groundwater (unit: μg/kg)

Sampling points		Depth (m)	Soil Sample Number	Monitoring Factors for soil and ground water			
soil	Ground water			Hexachloro-cyclopentadien (C_5Cl_6)	chlorodane	endosulfan	mirex
GH1		0	1-0	x	x	x	x
		0.1	1-1	x	x	x	x
		0.3	1-2	x	x	x	x
		0.6	1-3	x	x	x	x
		1.0	1-4	x	x	x	x
		1.5	1-5	x	x	x	x
GH2		0.1	2-1	x	x	x	x
		0.3	2-2	x	x	x	x
		0.6	2-3	x	x	x	x
		1.0	2-4	x	x	x	x
		1.5	2-5	x	x	x	x
		2.0	2-6	x	x	x	x
GH3		0.1	3-1	x	x	x	x
		0.3	3-2	x	x	x	x
		0.6	3-3	x	x	x	x
		1.0	3-4	x	x	x	x
		1.5	3-5	x	x	x	x
		2.0	3-6	x	x	x	x
GH4		0.1	4-1	x	x	x	x
		0.3	4-2	x	x	x	x
		0.6	4-3	x	x	x	x
		1.0	4-4	x	x	x	x
		1.5	4-5	x	x	x	x
		2.0	4-6	x	x	x	x
GH5		0.1	5-1	x	x	x	x
		0.3	5-2	x	x	x	x
		0.6	5-3	x	x	x	x
		1.0	5-4	x	x	x	x
GH6		0.1	6-1	x	x	x	x
		0.3	6-2	x	x	x	x
		0.6	6-3	x	x	x	x
		1.0	6-4	x	x	x	x
GH7		0.1	7-1	x	x	x	x
		0.3	7-2	x	x	x	x
		0.6	7-3	x	x	x	x
		1.0	7-4	x	x	x	x
GH8		0.1	8-1	x	x	x	x

Sampling points		Depth (m)	Soil Sample Number	Monitoring Factors for soil and ground water			
soil	Ground water			Hexachloro-cyclopentadien (C_5Cl_6)	chlorodane	endosulfan	mirex
		0.3	8-2	x	x	x	x
		0.6	8-3	x	x	x	x
		1.0	8-4	x	x	x	x
		1.5	8-5	x	x	x	x
		2.0	8-6	x	x	x	x
GH9		0.1	9-1	x	x	x	x
		0.3	9-2	x	x	x	x
		0.6	9-3	x	x	x	x
		1.0	9-4	x	x	x	x
GH10		0.1	10-1	x	x	x	x
		0.3	10-2	x	x	x	x
		0.6	10-3	x	x	x	x
		1.0	10-4	x	x	x	x
GH11		0.1	11-1	x	x	x	x
		0.3	11-2	x	x	x	x
		0.6	11-3	x	x	x	x
		1.0	11-4	x	x	x	x
GH12		0.1	12-1	x	x	x	x
		0.3	12-2	x	x	x	x
		0.6	12-3	x	x	x	x
		1.0	12-4	x	x	x	x
GH13		0.1	13-1	x	x	x	x
		0.3	13-2	x	x	x	x
		0.6	13-3	x	x	x	x
		1.0	13-4	x	x	x	x
GH14		0.1	14-1	x	x	x	x
		0.3	14-2	x	x	x	x
		0.6	14-3	x	x	x	x
		1.0	14-4	x	x	x	x

48. **Monitoring Parameters**. As shown in Table 4-6, the monitoring focused on chlordane, mirex, endosulfan and hexachlorocyclopentadiene (a raw material used in the production of mirex, chlordane and endosulfan).

49. **Sampling Frequency**. Soil and groundwater samples were sampled once a day. Surface water samples were sampled twice a day at each monitoring point.

50. **Sampling Method of Soil and Ground Water**. Fourteen groundwater monitoring wells were drilled according to the sampling location at the site. All boring

equipment was cleaned before boring to prevent cross pollution. All boreholes were drilled with a helical auger, and soil was sampled in an interval of 0.5 m or so in the borehole. The operator wore new gloves in each sampling. Each borehole was supported with packing to prevent the borehole from collapsing. During the sampling, signs of pollution, such as the stratum's structure, color, odor, etc., were recorded during the sampling process. Soil samples were sent to the laboratory for analysis at the same day.

51. The groundwater monitoring wells were built upon soil sampling holes. Each borehole was installed with a PVC pipe. The length of the pipe depends on the depth of the borehole. The PVC pipe consists of one filter tube (the slit width was 0.25mm) and a seamless pipe. The length of filter tube was determined by the depth of groundwater level. In each borehole, the lower end of the filter tube was set at the bottom of the well, and the upper end was 10 cm above the static water surface. Surrounding the filter tube, clean quartz sand with a diameter no less than 0.25mm was backfilled as the filtration bed to a level of 20 cm higher than the filter tube. The space between the quartz and the ground was left hollow.

52. The monitoring wells were washed before sampling. The water pumped out from the wells was five times to the wells' capacity when such water is clean and free of any fine particles.

53. After the well was washed and kept in a static condition for a while, sampling was conducted. Collected samples were added with fixative and sent to the laboratory for analysis immediately. Before sampling, each well's water level, PVC pipe elevation, ground elevation and the location of borehole were recorded.

54. **Selection of Analysis Method**. Usually the analytical procedure for organic pollutants includes sample preparation, pre-concentration and instrument analysis such as GC,HPLC,GC-MS,HPLC-MS etc. GC-ECD method uses ECD as the detector and GC-MS uses MS as the detector. The absolute sensitivity for analyzing organochlorine compounds using GC-ECD is higher than that of GC/MS sometimes; however the detection limit of GC-MS is far below than that of GC-ECD in actual application. The reason is that ECD identify the compounds by the compounds' retention time, while MS method identify the compounds by both the compounds' retention time and the compounds' mass ion segment. Hence, it can differentiate the target compounds from the interference compounds having the same retention time, and improve the quantification accuracy. When highly concentrated (such as 10000 times of concentration), the concentration of many trace components is also enlarged and even higher than the detection limit. This means that when only GC is used, it is more difficult to get baseline separation, and results in two or several compounds appeared at the same retention time. Therefore MS detector is needed to identify target compounds by Selected Ion Mass Spectrum instead of Total Ion Mass Spectrum in order to obtain accurate results. For the reasons above, usually the concentration factor for GC-ECD is only 10-100 times, while the factor for GC-MS can be 10000 times. This makes GC-ECD method have higher detection limit. In actual monitoring, the detection limit of GC-MS is far below than that of GC-ECD. GC-MS is used to ppt level's compound analysis, while GC-ECD is used to ppb level's compound analysis.

55. In environmental monitoring, GC-ECD and GC-FID are widely used to monitor wastewater and exhaust gas. GC-MS is used in many background investigations for ambient air, groundwater and soil, except for those high concentration organic pollutants.

56. For the analysis of mirex and chlordane, GC-ECD or GC-MS can either be selected according to the actual situation. Normally GC-MS can take in place of GC-ECD, but not vice versa. In 2004, the Chinese National Monitoring Center adopted the GC/MS method for analyzing mirex, chlordane etc. in the groundwater. The US EPA8081 and US EPA 8270 developed the GC-ECD method earlier than that of GC-MS method. Although GC-MS method has high sensitivity and more accuracy, method of GC-ECD or GC-FID is often used in monitoring wastewater, waste solid and sediment thanks to the high cost of analysis of GC-MS method.

57. Mirex and chlordane are persistent organic pollutants (POPs), their concentration in the environment are as trace as ppt level. They can be bioaccumulated in advanced organism. The amount of mirex and chlordane in soil is approximately ppt level, but can be biologically accumulated multimillion times in organisms at the top of the food chain. So usually the amount of these compounds for soil investigation is about ppt, ppm or ppb level. In this report, GC-MS method with more accuracy and relatively high resolution has been selected.

58. **Method of Analysis**

- Pretreatment method: EPA 3546 (Microwave Extraction)
- Analysis method of soil: EPA 8270C (Semi-volatile Organic Compounds by GC/MS)
- Analysis method of ground and surface water: EPA 525 (Organic Compounds-LSE/ GC/MS)

59. **Monitoring Results**. For the first phase monitoring, monitoring results of hexachlorocyclopentadiene, endosulfan, chlorodane and mirex in soil, ground water, surface water are shown in Tables 4-9, 4-10, 4-11, 4-12, 4-13 and 4-14 respectively.

Table 0-9 First Phase Monitoring Results of Hexachlorocyclopentadiene in Soil (Unit: mg/kg)

Sampling point	Depth(meter)						
	0.0	0.1	0.3	0.6	1.0	1.5	2.0
GH1	0.00200	8.01000	0.01400	7.12000	0.03500	0.15300	/
GH2	/	0.00260	0.88400	1.33000	0.01640	0.01160	0.00250
GH3	/	0.00004	0.00510	0.06460	0.00680	0.00440	0.00320
GH4	/	0.01150	0.00340	0.00100	0.00160	0.01040	0.00010
GH5	/	0.00040	0.00032	0.00050	0.00092	/	/
GH6	/	0.00071	0.00004	0.00004	0.00004	/	/
GH7	/	0.00517	0.00585	0.00040	0.00005	/	/
GH8	/	0.00236	0.00272	0.00285	0.00227	0.00068	0.00009
GH9	/	0.00258	0.00049	0.00004	0.00181	/	/
GH10	/	0.00677	0.00303	0.01000	0.128	/	/
GH11	/	0.03450	0.04210	0.00438	0.00270	/	/
GH12	/	0.43000	1.72000	2.46000	3.75000	/	/
GH13	/	L	0.00076	0.00002	0.00004	/	/
GH14	/	0.00004	0.00070	0.03340	0.00343	/	/

Note: The detection limit of Hexachlorocyclopentadiene is0.01μg/kg (in 10g soil);
L is the detection limit;
"/" is no sample taken

Table 0-10 First Phase Monitoring Results of Endosulfan in Soil (Unit: mg/kg)

Sampling point	Depth(meter)						
	0.0	0.1	0.3	0.6	1.0	1.5	2.0
GH1	2.510	95.200	3.050	1.160	8.610	16.000	/
GH2	/	1.780	85.400	110.000	3.770	1.950	14.200
GH3	/	2.130	5.260	4.410	28.600	1.880	0.271
GH4	/	3.920	1.320	30.700	7.980	2.890	0.853
GH5	/	0.979	0.531	1.360	0.328	/	/
GH6	/	1.040	9.220	1.160	1.300	/	/
GH7	/	18.600	2.430	5.930	7.180	/	/
GH8	/	19.200	1.960	32.500	32.900	9.480	8.940
GH9	/	0.007	0.180	0.634	0.060	/	/
GH10	/	0.091	1.270	0.200	0.090	/	/
GH11	/	0.709	0.610	0.307	0.225	/	/
GH12	/	160.000	200.000	285.000	232.000	/	/
GH13	/	0.084	0.804	0.317	10.700	/	/
GH14	/	1.280	6.580	0.116	0.495	/	/

Note: The detection limit of Endosulfan is0.02μg/kg (in 10g soil);
"/" is no sample taken

Table 0-11 First Phase Monitoring Results of Chlordane in Soil (Unit: mg/kg)

Sampling point	Depth (meter)						
	0.0	**0.1**	**0.3**	**0.6**	**1.0**	**1.5**	**2.0**
GH1	2.2900	73.6000	12.9000	7.0200	36.5000	8.0300	/
GH2	/	0.4720	18.4000	21.4000	15.600	0.1640	0.6780
GH3	/	0.2650	8.9000	26.3000	1.0400	0.3110	0.7910
GH4	/	12.0000	0.2350	0.6100	0.8300	4.2400	0.8290
GH5	/	0.7560	0.3500	0.1730	0.4180	/	/
GH6	/	0.5860	0.1680	0.2610	0.1870	/	/
GH7	/	0.5200	0.8920	0.1280	0.0996	/	/
GH8	/	0.8220	0.6590	0.8690	0.4500	0.1300	0.2610
GH9	/	0.1570	0.0686	0.1200	0.2860	/	/
GH10	/	0.1030	0.2250	0.0582	3.4100	/	/
GH11	/	0.124	0.0740	0.0801	0.8320	/	/
GH12	/	0.5330	0.7440	3.0100	0.5070	/	/
GH13	/	0.5820	0.0744	0.0544	0.1080	/	/
GH14	/	0.0751	0.4070	0.0217	1.8700	/	/

Note: The detection limit of Chlordane is0.01μg/kg (in 10g soil);
"/" is no sample taken

Table 0-12 First Phase Monitoring Results of Mirex in Soil (Unit: mg/kg)

Sampling point	Depth (meter)						
	0.0	**0.1**	**0.3**	**0.6**	**1.0**	**1.5**	**2.0**
GH1	0.2240	43.4000	0.1770	0.1860	0.5800	0.1470	/
GH2	/	0.1130	0.9830	10.0000	0.2710	0.0204	47.5
GH3	/	0.1230	0.4570	0.7260	0.1450	0.1070	0.0224
GH4	/	0.3230	0.0603	0.3930	0.5080	0.1450	0.0524
GH5	/	0.0823	0.0585	0.3870	0.0776	/	/
GH6	/	0.0175	0.0133	0.0306	0.0375	/	/
GH7	/	0.0017	0.0412	0.0185	0.0145	/	/
GH8	/	0.1230	0.1240	0.0981	0.1550	0.0820	0.1550
GH9	/	0.0138	0.0043	0.0035	0.0115	/	/
GH10	/	0.00921	0.0577	0.0202	0.0106	/	/
GH11	/	0.0524	0.3620	0.6520	0.0764	/	/
GH12	/	0.2670	0.0678	0.0541	0.0243	/	/
GH13	/	0.0123	0.0080	0.0008	0.0286	/	/
GH14	/	0.1260	0.0709	0.0074	0.0598	/	/

Note: The detection limit of Mirex is 0.04μg/kg (in 10g soil);
"/" is no sample taken

Table 0-13 First Phase Monitoring Result - Groundwater (Unit: μg/L)

	Hexachlorocyclopentadiene	Chlordane	Endosulfan	Mirex
GH1	0.38800	4.42000	23.50000	0.02370
GH2	0.69000	0.90800	19.00000	0.00256
GH3	1.23000	1.68000	47.70000	0.06500
GH4	0.63300	0.48000	8.41000	0.13800
GH5	0.84700	7.40000	164.00000	0.06300
GH6	0.89100	0.65200	38.40000	0.00686
GH7	1.63000	2.69000	156.00000	0.00783
GH8	0.30300	9.80000	92.30000	0.02710
GH9	1.23000	0.89600	97.90000	0.00463
GH10	0.46100	0.51800	30.90000	0.00479
GH11	0.93600	2.80000	115.00000	0.00266
GH12	1.24000	2.51000	57.70000	0.01150
GH13	0.40200	0.25500	18.10000	0.01180
GH14	0.56200	0.41300	19.80000	0.00363
Detection limit	0.1ng/L	0.1ng/L	0.2ng/L	0.4ng/L

Table 0-14 First Phase Monitoring Result of Surface Water (Unit: μ g/L)

Sampling point	Hexachloro-cyclopentadiene	Chlordane	Endosulfan	Mirex
S1	0.0786	0.320	4.24	0.0006
S1 parallel	0.0811	0.955	6.49	0.0078
S2	0.0672	0.621	58.1	0.0004
S2 parallel	0.0551	0.826	73.1	0.0004
Detection limit	0.1ng/L	0.1ng/L	0.2ng/L	0.4ng/L

60. **Evaluation of First Phase of Monitoring Results**. The monitoring results of the first phase were evaluated against the Preliminary Remediation Goal (PRG) reference levels developed by the US EPA. The reference levels serve as a concentration, which, if exceeded, merit further consideration and possibly additional site investigation. (For detailed discussion of the PRGs and their use, please see Chapter 5).

61. Endosulfan and hexachlorocyclopentadiene concentrations were below the reference levels. The contamination with these chemicals was sufficiently low that the site did not merit further monitoring or investigation to obtain additional data.

62. Chlordane and mirex concentrations, however, exceeded the reference levels. The detailed comparison of the measured concentrations against PRG reference level and the extent of exceedance of the reference concentration are summarized in the following tables. Figure 4-9 shows concentrations of four different pollutants – hexachlorocyclopentadiene (HEX), endosulfan, chlordane and mirex – at different depths at six sampling points – GH1, GH2, GH3, GH4, GH12 and GH13. These figures show that in general these contaminants have highest concentrations within 1 meter of depth, and their concentrations drop sharply after 1 meter.

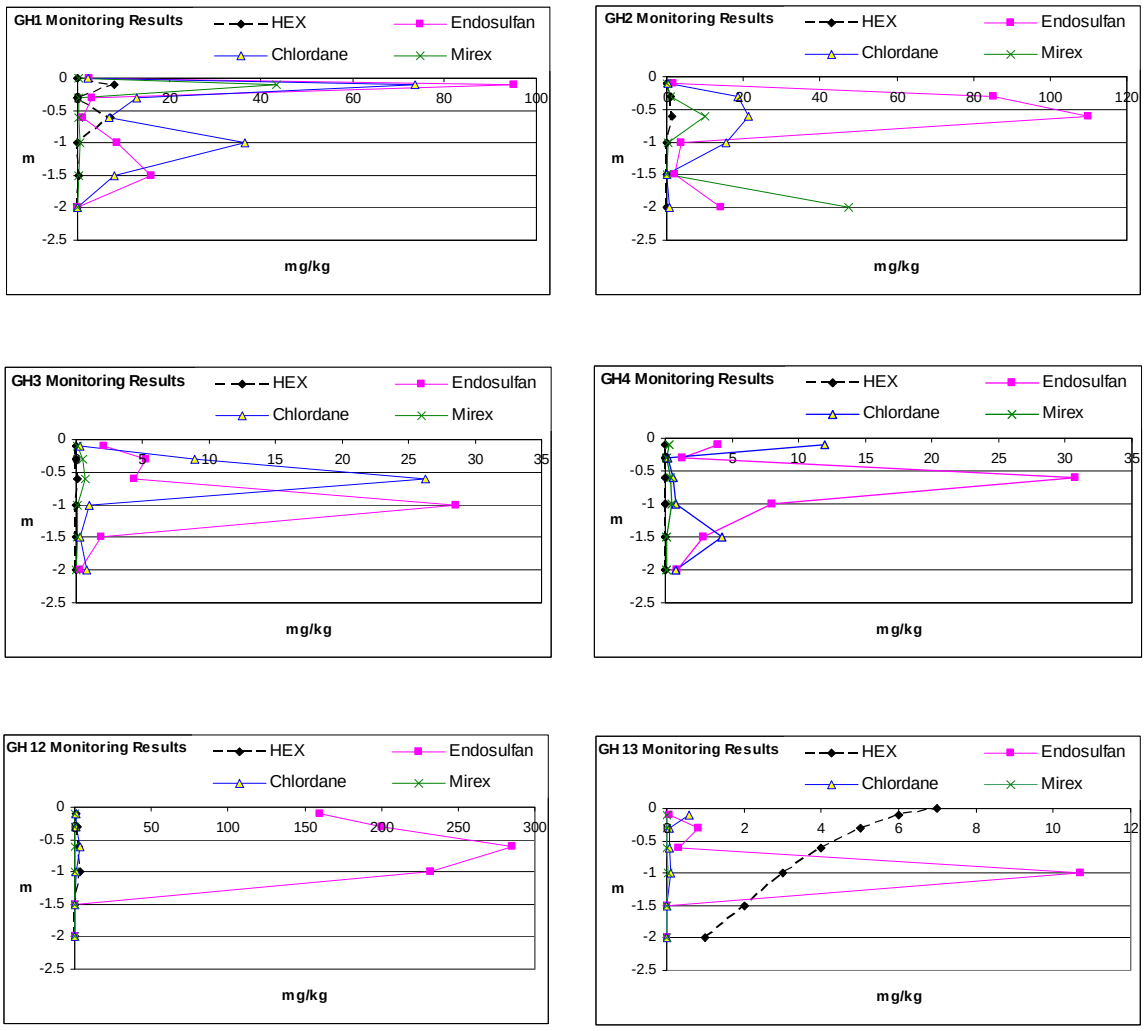


Figure 4-9 Soil Monitoring Results at Six Sampling Points

Table 0-15 Result of assessment on the status of chlordane in soil (Evaluation reference: 6.5mg/kg)

Sampling point	0.0m			0.1m			0.3m			0.6m		
	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	‘Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard
GH1	2.2900	-4.21	0.4	73.6000	67.10	11.3	12.9000	6.40	2.0	7.0200	0.52	1.1
GH2	/	/	/	0.4720	-6.03	0.1	18.4000	11.90	2.8	21.4000	14.90	3.3
GH3	/	/	/	0.2650	-6.24	0.0	8.9000	2.40	1.4	26.3000	19.80	4.0
GH4	/	/	/	12.0000	5.50	1.8	0.2350	-6.27	0.0	0.6100	-5.89	0.1
GH5	/	/	/	0.7560	-5.74	0.1	0.3500	-6.15	0.1	0.1730	-6.33	0.0
GH6	/	/	/	0.5860	-5.91	0.1	0.1680	-6.33	0.0	0.2610	-6.24	0.0
GH7	/	/	/	0.5200	-5.98	0.1	0.8920	-5.61	0.1	0.1280	-6.37	0.0
GH8	/	/	/	0.8220	-5.68	0.1	0.6590	-5.84	0.1	0.8690	-5.63	0.1
GH9	/	/	/	0.1570	-6.34	0.0	0.0686	-6.43	0.0	0.1200	-6.38	0.0
GH10	/	/	/	0.1030	-6.40	0.0	0.2250	-6.28	0.0	0.0582	-6.44	0.0
GH11	/	/	/	0.124	-6.38	0.0	0.0740	-6.43	0.0	0.0801	-6.42	0.0
GH12	/	/	/	0.5330	-5.97	0.1	0.7440	-5.76	0.1	3.0100	-3.49	0.5
GH13	/	/	/	0.5820	-5.92	0.1	0.0744	-6.43	0.0	0.0544	-6.45	0.0
GH14	/	/	/	0.0751	-6.42	0.0	0.4070	-6.09	0.1	0.0217	-6.48	0.0

Table 4-15 (*continued*)

Sampling point	1.0m			1.5m			2.0m		
	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard
GH1	36.5000	30.00	5.6	8.0300	1.53	1.2	/	/	/
GH2	15.600	9.10	2.4	0.1640	-6.34	0.0	0.6780	-5.82	0.1
GH3	1.0400	-5.46	0.2	0.3110	-6.189	0.0	0.7910	-5.709	0.1
GH4	0.8300	-5.67	0.1	4.2400	-2.26	0.7	0.8290	-5.67	0.1
GH5	0.4180	-6.08	0.1	/	/	/	/	/	/
GH6	0.1870	-6.31	0.0	/	/	/	/	/	/
GH7	0.0996	-6.40	0.0	/	/	/	/	/	/
GH8	0.4500	-6.05	0.1	0.1300	-6.37	0.0	0.2610	-6.24	0.0
GH9	0.2860	-6.21	0.0	/	/	/	/	/	/
GH10	3.4100	-3.09	0.5	/	/	/	/	/	/
GH11	0.8320	-5.67	0.1	/	/	/	/	/	/
GH12	0.5070	-5.99	0.1	/	/	/	/	/	/
GH13	0.1080	-6.39	0.0	/	/	/	/	/	/
GH14	1.8700	-4.63	0.3	/	/	/	/	/	/

Note: The amount exceeding standard is the measured value minus the standard value. The value equivalent to standard is the result of the actual concentration divided by the standard value.

Table 0-16 Result of assessment on the status of mirex in soil (Evaluation reference: 0.96mg/kg)

Sampling point	0.0m			0.1m			0.3m			0.6m		
	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	‘Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard
GH1	0.2240	-0.72	0.3	3.4000	42.44	45.2	0.1770	-0.78	0.2	0.1860	-0.77	0.2
GH2	/	/	/	0.1130	-0.85	0.1	0.9830	0.02	1.0	10.0000	9.04	10.4
GH3	/	/	/	0.1230	-0.84	0.1	0.4570	-0.50	0.5	0.7260	-0.23	0.8
GH4	/	/	/	0.3230	-0.64	0.3	0.0603	-0.90	0.1	0.3930	-0.92	0.0
GH5	/	/	/	0.0823	-0.88	0.1	0.0585	-0.90	0.1	0.3870	-0.57	0.4
GH6	/	/	/	0.0175	-0.94	0.0	0.0133	-0.95	0.0	0.0306	-0.93	0.0
GH7	/	/	/	0.0017	-0.96	0.0	0.0412	-0.92	0.0	0.0185	-0.94	0.0
GH8	/	/	/	0.1230	-0.84	0.1	0.1240	-0.84	0.1	0.0981	-0.86	0.1
GH9	/	/	/	0.0138	-0.95	0.0	0.0043	-0.96	0.0	0.0035	-0.96	0.0
GH10	/	/	/	0.00921	-0.95	0.0	0.0577	-0.90	0.1	0.0202	-0.94	0.0
GH11	/	/	/	0.0524	-0.91	0.1	0.3620	-0.60	0.4	0.6520	-0.74	0.2
GH12	/	/	/	0.2670	-0.69	0.3	0.0678	-0.89	0.1	0.0541	-0.91	0.1
GH13	/	/	/	0.0123	-0.95	0.0	0.0080	-0.95	0.0	0.0008	-0.96	0.0
GH14	/	/	/	0.1260	-0.83	0.1	0.0709	-0.89	0.1	0.0074	-0.95	0.0

Table 4-16 (*continued*)

Sampling point	1.0m			1.5m			2.0m		
	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard	Concentra-tion	Amount exceeding standard	Value equivalent to standard
GH1	0.5800	-0.38	0.6	0.1470	-0.81	0.2	/	/	/
GH2	0.2710	-0.69	0.3	0.0204	-0.94	0.0	47.5	-0.91	0.0
GH3	0.1450	-0.82	0.2	0.1070	-0.85	0.1	0.0224	-0.94	0.0
GH4	0.5080	-0.45	0.5	0.1450	-0.82	0.2	0.0524	-0.91	0.1
GH5	0.0776	-0.8	0.1	/	/	/	/	/	/
GH6	0.0375	8	0.0	/	/	/	/	/	/
GH7	0.0145	-0.92	0.0	/	/	/	/	/	/
GH8	0.1550	-0.95	0.2	0.0820	-0.88	0.1	0.1550	-0.81	0.2
GH9	0.0115	-0.81	0.0	/	/	/	/	/	/
GH10	0.0106	-0.95	0.0	/	/	/	/	/	/
GH11	0.0764	-0.94	0.1	/	/	/	/	/	/
GH12	0.0243	-0.88	0.0	/	/	/	/	/	/
GH13	0.0286	-0.94	0.0	/	/	/	/	/	/
GH14	0.0598	-0.93	0.1	/	/	/	/	/	/

Note: The amount exceeding standard is the measured value minus the standard value. The value equivalent to standard is the result of the actual concentration divided by the standard value.

Second Phase Sampling and Monitoring

63. Based on Phase One's findings, a second monitoring phase was designed and carried in September 2005. The aim of Phase Two monitoring was to determine the chlordane and mirex concentrations further away from the source, and to determine the approximate extent of the contaminated area. Additional sampling points were placed at locations of suspected contamination, or in potential sensitive environmental media or landscape features (fishpond, residential wells, groundwater aquifer, sediments, surface waters). Two other chemicals, endosulfan and hexachlorocyclopentadiene, were not monitored in the second phase because their concentrations in the first monitoring phase were lower than the reference level.

64. **Location of Sampling Points.** See Figure 4-8 for locations of sampling points for the second phase monitoring. Table 4-17 lists parameters monitored in the second phase. Mirex in soil (SB1) and surface water (SW1, SW2, SW3) was not sampled as its concentration in the first monitoring phase was generally lower than the reference level.

Table 4-17 Second Phase Sampling Points and Monitored Pollutants

Sampling point	Target	Depth (m)	Pollutants		umber of samples
			Chlordane	Mirex	
SB1	Soil	1.5	x	/	3
		2.0	x	/	
		2.5	x	/	
SW1	Surface water		x	/	3
SW2			x	/	
SW3			x	/	
FP1	Fish pond		x	x	1
SED1	Sediments		x	x	7
SED2			x	x	
SED3			x	x	
SED4			x	x	
SED5			x	x	
SED6			x	x	
SED7			x	x	
MW3	Surface soil		x	x	2
MW7			x	x	
MW1	Ground water		x	x	6
MW2			x	x	
MW3			x	x	
MW4			x	x	
MW5			x	x	
MW7			x	x	
Residential well 1			x	x	2
Residential well 2			x	x	

65. **Monitoring Frequency.** Surface soil, soil, sediments and ground water were sampled once a day. Surface water was sampled twice a day at each point.

66. **Analysis Method.**

Pretreatment method: EPA 3546 (Microwave Extraction)

Analysis method of surface soil, soil and sediments:EPA 8270C (Semi-volatile Organic Compounds by GC/MS)

Analysis method of chlordane and mirex in ground and surface water:EPA 525 (Organic Compounds-LSE/ /cap col GC

67. **Monitoring Results**. The second phase monitoring results for chlordane and mirex in soil, sediments, groundwater and surface water are as follows.

Table 4-18 Second Phase Monitoring Results of Chlordane and Mirex in Soil, Sediments, Groundwater and Surface Water

Samples	Location	Mirex	Chlordane
Sediment	SED1	0.065 mg/kg	0.105 mg/kg
	SED2	0.057 mg/kg	2.09 mg/kg
	SED3	0.014 mg/kg	0.110 mg/kg
	SED4	ND	ND
	SED5	ND	ND
	SED6	ND	ND
	SED7	ND	ND
Surface soil	MW3	0.129mg/kg	0.099 mg/kg
	MW7	ND	ND
soil	SB1-1.5m	/	0.008 mg/kg
	SB1-2.0m	/	1.66 mg/kg
	SB1-2.5m	/	1.92 mg/kg
Surface water	SW1	/	ND
	SW2	/	ND
	SW3	/	ND
Ground water	MW1	ND	ND
	MW2	ND	ND
	MW3	ND	ND
	MW4	ND	ND
	MW5	ND	ND
	MW7	ND	ND
Fish pond	FP1	ND	ND
Drinking well	1	ND	ND
	2	ND	ND

Note: ND is None Detection
"/"is no sample taken

68. **Monitoring Evaluation Results**. The measured concentrations are compared to the US EPA PRG reference levels. Since there are no reference levels developed specifically for sediments, reference levels for soil are used also for evaluation of sediment. Overall, the samples collected during the second phase of monitoring did not exceed the reference levels. In a considerable number of samples, in fact, no presence of chlordane or mirex was detected. This

suggests that the contamination is well contained within the site, especially in the immediate vicinity of the production workshop, and the highest levels are concentrated at sampling points GH1, GH2, GH3 and GH 4. Tables 4-19 and 4-20 show the evaluation results.

Table 4-19 Evaluation of Second Phase Monitoring Results - Mirex

Samples	Sampling Points	Results	Evaluation reference standard	Met the reference standard
Sediments	SED1	0.065 mg/kg	0.96mg/kg	yes
	SED2	0.057 mg/kg		
	SED3	0.014 mg/kg		
	SED4	ND		
	SED5	ND		
	SED6	ND		
	SED7	ND		
Surface soil	MW3	0.129mg/kg	0.96mg/kg*	yes
	MW7	ND		yes
Soil	SB1-1.5m	/	0.96mg/kg	yes
	SB1-2.0m	/		yes
	SB1-2.5m	/		yes
Surface water	SW1	/	0.037μg/L	yes
	SW2	/		yes
	SW3	/		yes
Ground water	MW1	ND	0.037μg/L	yes
	MW2	ND		
	MW3	ND		
	MW4	ND		
	MW5	ND		
	MW7	ND		
Fish pond	FP1	ND	0.037μg/L	yes
Residential well	1	ND	0.037μg/L	yes
	2	ND		

Table 4-20 Evaluation of Second Phase Monitoring Results – Chlordane

Samples	Sampling Points	Results	Evaluation reference standard	Met the reference standard
Sediments	SED1	0.105 mg/kg	6.5mg/kg	yes
	SED2	2.09 mg/kg		
	SED3	0.110 mg/kg		
	SED4	ND		
	SED5	ND		
	SED6	ND		
	SED7	ND		
Surface soil	MW3	0.099 mg/kg	6.5mg/kg	Yes
	MW7	ND		yes
Soil	SB1-1.5m	0.008 mg/kg	6.5mg/kg	yes
	SB1-2.0m	1.66 mg/kg		yes
	SB1-2.5m	1.92 mg/kg		yes
Surface water	SW1	ND	0.19μg/L	yes
	SW2	ND		yes
	SW3	ND		yes
Ground water	MW1	ND	0.19μg/L	yes
	MW2	ND		yes
	MW3	ND		yes
	MW4	ND		yes
	MW5	ND		yes
	MW7	ND		yes
Fish pond	FP1	ND		yes
Residential well	1	ND	0.19μg/L	yes
	2	ND		yes

Pollutants Concentration Gradient Distribution

69. The gradient distribution of pollutant concentration in environmental medium can be obtained by using the Surfer software and actual measured data (see Figure 4-10).

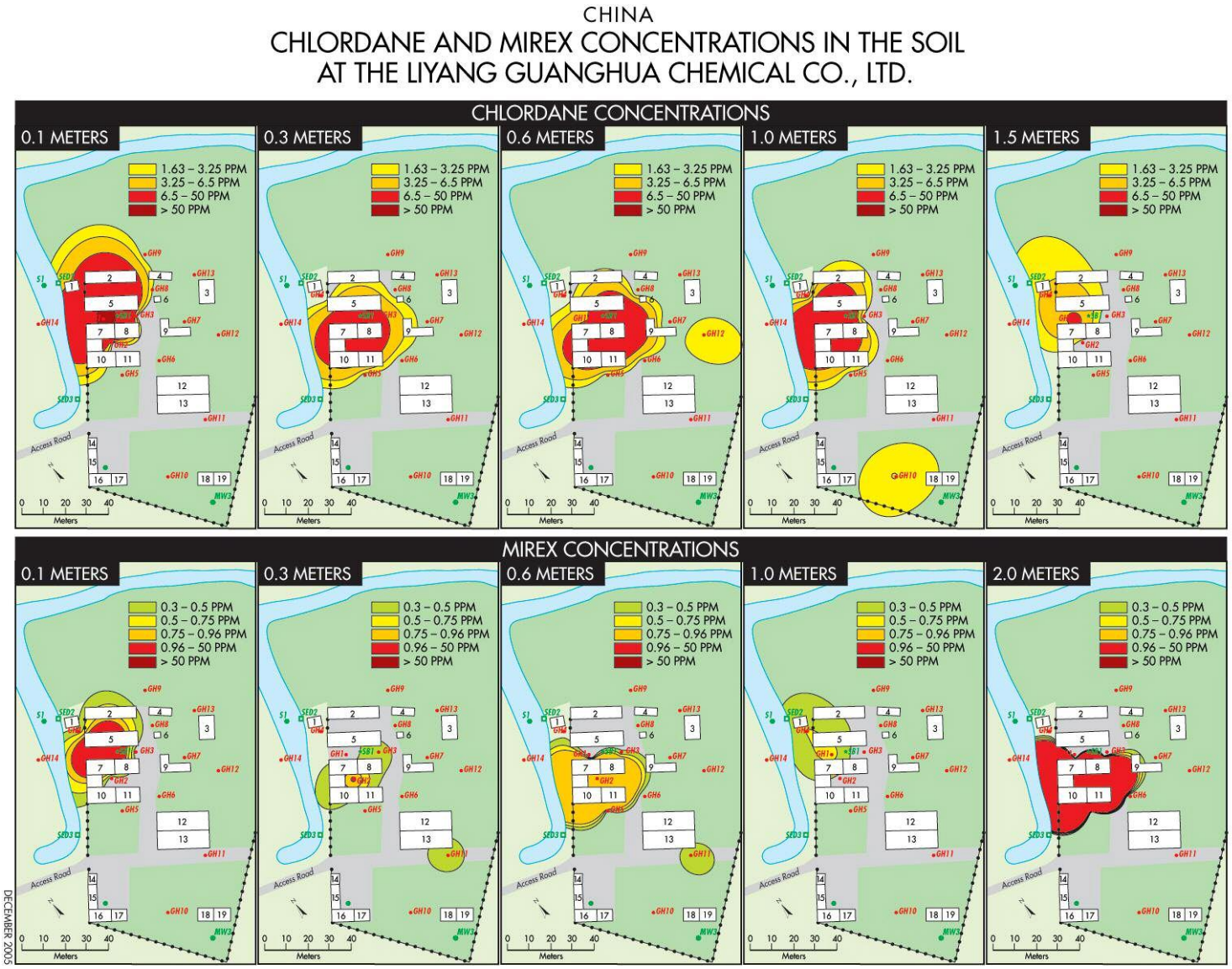


Figure 4-10 Chlordane and Mirex Concentration in Soil

Risk Assessment

Introduction to Risk Assessment

1. Risk assessment is quantitative and qualitative analysis of the risk resulting from a specific occurrence of a contaminant, taking into account the potential harmful effects on human or ecological receptors. In the context of site clean up, it is the evaluation of the risk posed to human health or the environment by the contaminants at the site.

2. Risk assessment serves as a basis for risk management. In the risk management process, the results of the risk assessment are integrated with other considerations, such as economic or legal concerns, to make decisions regarding the need for and practicability of implementing various risk reduction activities.[2]

3. Risk assessment serves also as the basis for risk communications. In the risk communication process, the risk managers use risk assessment results as a basis for communicating risks to interested parties and to the general public.[3]

4. Risk assessment can focus on ecological or human receptors. Ecological risk assessment evaluates the likelihood that adverse ecological effects may occur or are occurring as a result of exposure to one or more stressors. The process is used to systematically evaluate and organize data, information, assumptions, and uncertainties to help understand and predict the relationships between stressors and ecological effects in a way that is useful for environmental decision making. The elements of an ecological risk assessment include planning and scoping, problem formulation, evaluating toxicity, assessing exposures and characterizing risks.[4]

5. Human health risk assessment is the characterization of the potential adverse health effects of human exposures to environmental hazards. It entails planning and scoping, identification of hazards, evaluating toxicity, assessing exposures and characterizing risks.[5] The risk evaluation of the Liyang Guanghua Chemicals site is focusing on risk to human health risk perspective.

6. Toxic contaminants may have two kinds of adverse health effects: cancer or non-cancer (systemic) effects (e.g. birth defects). For carcinogenic chemicals, toxicity is measured as a slope factor of a curve representing the relationship between chemical concentration and cancer risk. For chemicals causing non-cancer effects, toxicity is measured using a hazard quotient (hazard index). It is a ratio of the dose of the chemical to the reference dose representing no adverse health effects.

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[2] http://www.epa.gov/oswer/riskassessment/risk_management.htm
[3] Ibid.
[4] Ibid.
[5] http://www.epa.gov/oswer/riskassessment/basicinfo.htm

7. For a site to constitute risk to human health, three elements must interplay: (i) contaminants, (ii) exposure pathways and (iii) human receptors. First, hazardous chemicals must contaminate the site in sufficient quantities and concentrations to cause health effects. Second, exposure pathways, e.g. inhalation or digestion, must exist through which the contaminants will reach the human receptors. Third, people must be exposed to those contaminants, and the exposure must be sufficient to cause health effects. Thus, risk evaluation considers these three elements to characterize, quantitatively or qualitatively, the risk from the site.

Acceptable Risk

8. To make a decision about "how clean is clean" i.e. what level of clean up is necessary to achieve acceptable protection of human health and environment from the contaminated site, it is necessary to determine what level of risk is considered acceptable. The clean up is then designed to reduce contamination, or implement other measures (e.g., restrict access) to reduce the risk to the acceptable level. Cleaning up a site less than to this level would result in undue risk to some people or the environment. Cleaning up a site more than to the acceptable risk level would result in waste of resources for unnecessary remedial actions.

9. Based on the US EPA practice, and adopted for the Liyang Guangua Chemicals clean up, the following are the generally acceptable risk levels. For carcinogenic health damage, the risk (probability) is considered acceptable if it is in the range between 10^{-4} and 10^{-6} (one in ten thousand and one in a million) or less.

10. For non-carcinogenic (systemic) health damage, the threat is considered acceptable if the exposure to the site does not result in hazard index (HQ) greater than one, that is, if it lead to an uptake of a contaminant greater than the reference uptake associated with no adverse health effects.[6]

11. For most contaminants, setting the clean up level based on the acceptable carcinogenic risk of 10^{-4} to 10^{-6} will also provide adequate protection from non-carcinogenic health effects. For chlordane in industrial soil, this is true only for the risk range of 10^{-5} to 10^{-6}.[7] At the carcinogenic risk level of 10^{-4}, the chlordane concentrations would exceed the level acceptable from the non-carcinogenetic perspective.[8]

12. For interpreting and using results of risk assessment, it is essential to note that the risk-based concentrations of contaminants are "not very precise, and at best, are order-of magnitude estimates or risk."[9] Even among scientists, different opinions exist of toxicity values of various chemicals. For example, for some chemicals, the safe risk-based

[6] The non-cancer health effects of chemical contaminants are evaluated using a ratio of the dose of the chemical to the reference dose representing no adverse health effects. This ratio is referred to as hazard index or hazard quotient (HQ). Contamination levels corresponding to HQ of 1 or less are generally considered acceptable.
[7] Users' Guide and Background Technical Document for US EPA Region 9's Preliminary Remediation Goals (PRG) Table
[8] Ibid.
[9] Ibid.

concentrations calculated by the California Environmental Protection Agency differ from the values calculated by the US EPA by a factor of four or more.

Risk Evaluation Using US EPA PRGs

13. This evaluation of risks of negative health effects from the main contaminants at the site is based on the US EPA Region 9 Preliminary Remediation Goals (PRGs)[10]. PRGs are risk-based tools for evaluating and cleaning up contaminated sites. They are used to facilitate and standardize the risk decision-making process.

14. PRGs are concentrations of different chemicals, derived from standardized equations combining exposure information assumptions with toxicity data that are considered sufficiently protective of humans, including sensitive groups, (children, pregnant women, elderly, etc.) over a lifetime. The PRGs are determined for different environmental media – soil, water and air – for about 600 chemicals.

15. If chemical concentrations at the site are below the PRGs levels no further evaluation of the site is necessary. If chemical concentrations exceed the PRG levels, it does not necessarily designate the site as "dirty" or trigger a response action. Rather, exceeding a PRG suggests that further evaluation of the potential risks that may be posed by site contaminants is appropriate. Such further evaluation may include additional sampling, consideration of ambient levels in the environment, or a reassessment of the assumptions contained in the PRGs (e.g. appropriateness of route-to-route extrapolations, appropriateness of using chronic toxicity values to evaluate childhood exposures, appropriateness of generic exposure factors for a specific site etc.).

16. The PRGs may be used as screening goals (reference levels) or as cleanup goals. As screening goals, they are intended to provide health protection without knowledge of the specific exposure conditions at a site. As cleanup goals, they may be used when the exposure assumptions based on site-specific information match the default exposure assumptions on which the PRGs are based. When used PRGs as cleanup goals, it is preferred to assume maximum beneficial use of a property (that is, residential use) unless a non-residential use (for example, industrial soil PRG) can be justified.

17. PRGs concentrations are based on direct contact pathways for which generally accepted methods, models, and assumptions have been developed (i.e. ingestion, dermal contact, and inhalation) for specific land-use conditions. When using PRGs at a particular site, it is necessary to consider whether the exposure pathways and exposure scenarios at the site are fully accounted for in the PRGs. Based on the reconnaissance of the Liyang Guanghua Chemicals site, the key exposure pathways associated with its industrial use – ingestion, inhalation of particulates and inhalation of volatiles – are fully accounted for in the PRGs. The use of PRG values for industrial land, therefore, is appropriate at the Liyang Guanghua site.

18. PRGs are chemical concentrations that correspond to a fixed level of risk. They correspond either to one-in-one million [10^{-6}] cancer risk or a non-carcinogenic hazard quotient of 1 in soil, air, and water. In most cases, where a chemical causes both cancer

[10] This entire section is a based on the Users' Guide and Background Technical Document for US EPA Region 9's Preliminary Remediation Goals (PRG) Table.

and non-cancer (systemic) effects, the PRG concentrations based on 10^{-6} cancer risk will result in more stringent level of protection. In some cases, the concentrations based on 10^{-5} or 10^{-4} cancer risk (which would be still within the range of acceptable cancer risk) would exceed the concentrations based on the non-cancer risk (i.e., they would result in hazard quotient greater than 1). In those cases, the clean up levels are set only within a limited risk range where non-cancer hazard quotient does not exceed the cancer risk-based concentration. This is the case for one of the main contaminants at Liyang Guanghua Chemicals site – chlordane. For chlordane at the carcinogenic risk level of 10^{-4}, the concentrations would exceed the level acceptable from the non-carcinogenetic perspective. Therefore, for chlordane, the concentrations are acceptable only within the 10^{-5} to 10^{-6} carcinogenic risk range. For example, the province of British Columbia in Canada set the remediation goals of 65ppm for chlordane and 9.6 ppm for mirex. These values are 100 and 10 times the PRG values, respectively, which is consistent with the PRG guidelines.

19. PRGs are calculated for individual chemicals. For sites contaminated with multiple chemicals, the cumulative cancer risk is determined by adding up the risk for each chemical and compared to the acceptable risk. If the site is contaminated with chemicals that cause non-cancer health effects, the hazard index (HI) for each chemical is summed up and compared to the hazard index of 1.

Table 5-1 PRGs for Chlordane and Mirex (October 2004)

Pollutant	**(PRGs)**	
	Industrial soils Carcinogenesis based concentration (mg/kg)	**Industrial soils** Non-Carcinogenesis based concentration (mg/kg)
Chlordane	6.5E+00 ca*	4.0E+02
Mirex	9.6E-01 ca	1.2e+02

ca: PRG is based on cancer risk of 10^{-6}; it may be used within the cancer risk range of 10^{-4} to 10^{-6} to determine the final clean up level.
ca*: PRG is based on cancer risk of 10^{-6} ; it may be used within the cancer risk range of 10^{-5} to 10^{-6} to determine the final clean up level but the concentrations in the cancer risk range of 10^{-4} would exceed the acceptable non-carcinogenic hazard.

Evaluation of the Current Risk from Chlordane and Mirex

20. Chlordane and mirex are the main contaminants of concern at the Liyang Guanghua Chemicals site. They were produced, packaged, transported and loaded, stored and otherwise handled at the site in significant quantities. Between 2000 and 2003, 150-190 tons of chlordane and 2-4 tons of mirex were produced there annually. They have contaminated the site through operational spills associated with production and handling, especially in the immediate vicinity of the production and storage workshops. Although they bind strongly to soil, some portion migrated into the groundwater. The detailed quantitative risk evaluation, therefore, focuses on the risk from chlordane and mirex in soil and groundwater. The risk from chlordane and mirex in other media – air, surface

water, and food – is considered negligible either because of low exposure and low contamination, and is discussed only qualitatively. To illustrate low level of risk from other site contaminants – endosulfan and hexachlorocyclopentadiene – quantitative risk evaluation was carried out for soil and groundwater.

5.4.1 QUALITATIVE EVALUATION

Qualitative Evaluation of Risk from Air

21. Chlordane is highly persistent in soil, where it sorbs strongly and very rapidly to organic particles[11] and clay particles[12]. Although it has low volatility, soil chlordane can vaporize under normal conditions and result in contaminated air and inhalation exposure.[13]

22. Chlordane volatilization into the air is relevant particularly for indoor air contamination of homes that were treated with chlordane. Indoor air exposure to chlordane is listed in the US EPA Hazard Summary for chlordane among sources and potential exposure to chlordane.[14] Outdoor air exposure is not listed among the sources and potential exposures (except for workers who applied chlordane or worked in chlordane treated environment).[15]

23. Chlordane in the atmosphere is partially degraded by sun light, where it reacts with photochemically produced hydroxyl radicals[16]. Its persistence in the air is significantly lower than in the soil. Its calculated half-life in the atmosphere is 2 – 7 days, compared to 4 – 20 years in the soil.[17]

24. In the US, no measured mean chlordane concentrations in ambient air exceeded the allowable concentrations. The measured mean ambient concentrations of chlordane ranged from 1.05 nanograms per cubic meter (ng/m^3) or 0.06 parts per billion (ppb) from 1979-80 in College Station, Texas, to 38.4 ng/m^3 or 2.29 ppb during 1987-88 in Jacksonville, Florida.[18] All of these concentrations were lower than the US EPA calculated concentration of $1ug/m^3$ which corresponds to a generally acceptable 10^{-4} risk of cancer.[19]

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[11] Usarat Pakdeesusuk, Mahmut Pulat and George M. Huddleston III, Environmental Fate Evaluation of DDT, Chlordane and Lindane, 1998; http://www.ces.clemson.edu/ees/lee/organochlorines.html
[12] ATSDR, Public Health Assessment, Agana Power Plant, Mongmong, Guam
[13] ATSDR, Medical Management Guidelines
[14] Hazard Summary, Chlordane, 2000 http://www.epa.gov/ttn/atw/hlthef/chlordan.html
[15] Ibid.
[16] Environmental Defense, Chlordane Scorecard http://www.scorecard.org/chemical-profiles/html/chlordane.html
[17] Environmental Defense, Chlordane Scorecard http://www.scorecard.org/chemical-profiles/text-search.tcl?query_string=chlordane
[18] Environmental Defense, Chlordane Scorecard http://www.scorecard.org/chemical-profiles/html/chlordane.html
[19] Hazard Summary, Chlordane, 2000 http://www.epa.gov/ttn/atw/hlthef/chlordan.html

25. Given the literature data suggesting that in the US the ambient air chlordane concentrations never exceeded allowable levels and short half-life of chlordane in the air, chlordane air emissions from the Liyang Guanghua site were not considered a significant source of exposure of nearby residents, and were not included in the site sampling and testing program. The potential short term exposure of workers involved in site remediation is considered significant, and will be addressed through the use of self-contained personal respirators and other protective measures. The potential long term exposure of the future users of the site will be addressed through removal of the chlordane contaminated soils from the site.

Qualitative Risk Evaluation from Chlordane Residues in Crops

26. The chlordane and mirex production facility was formulating these products exclusively for structural pest management (termite control) as required under the national and local regulations. These formulations are not suitable for agricultural use. In case of accidental drifts to the land surrounding the production facility, the risks of contaminating the food crops will be very limited. Chlordane and mirex figure among the organochlorine compounds with very high hydrophobicity (log K_{ow} exceeding 3), it is assumed that uptake into and movement through the aqueous transport system of plants will be minimal. The level of uptake depends on several factors including clay, organic matter and water content of the soil as well as the root system of the cultivated crops.

27. The site in question is located in a wet area, with heavy clay soils and high organic matter content. The most commonly grown crops are rice and leafy vegetables with shallow root systems. Furthermore the loss of chlordane from plants by normal weathering is extremely rapid. Studies by Klein and Link (1967) showed that of a starting load of 110 ppm, at the end of the seventh day only 7 ppm remained on kale, and only 0.1 ppm remained after 28 days. Crops such as zucchini, pumpkins, and sugar beets have been reported to uptake minimal amounts of chlordane but concentrations levels were in the parts per billions. Therefore, it is possible that chlordane can be cycled via certain crops but it is unlikely this will occur in the land surrounding the contaminated site because of the clay texture of the soil and the cultivated crops in the area.

Qualitative Evaluation of Chlordane Residues in Shellfish

28. In the proximity of the chlordane and mirex production facility, there is a complex of man-made ponds for commercial crab production. The pond is isolated from the natural water ways and the crabs are fed an artificial diet. Crabs are typically harvested after 4-5 months and the pond is completely emptied and cleaned every 4 to 5 years for optimal production. There is no reason to believe that the crab produced in the vicinity would accumulate any levels of chlordane or mirex. Bioaccumulation of these two compounds is only possible through the food chain. Consumption of crabs produced in the area does not present any risk of chlordane poisoning for consumers.

Qualitative Evaluation of Risk from Surface Water

29. As described in more detail in Section 4.2 on aquatic environment in the plant area, the small water courses are minimally utilized due to their serious eutrophication and high background pollution from municipal and industrial sources as well as aquaculture. Because of the high pollution levels, there is no use of the surface waters for swimming, drinking, washing, livestock watering, etc. Therefore, there is no direct exposure of people to the surface waters.

30. PRG tables do not provide reference concentrations for surface water. For comparison purposes, drinking (tap) water reference levels are used (see Table 5-2). For chlordane, all measured concentrations in surface exceeded the PRG reference level for drinking water. The maximum exceedance was by a factor of 5. The risk from exposure to surface waters however is considered negligible, since there is no direct human exposure to these waters, and the drinking water in the area comes from a treated municipal source. Even in a hypothetical scenario of a person drinking only the untreated surface water, the carcinogenic risk from chlordane would not exceed the generally acceptable level.

Table 5-2 Comparison of Chlordane and Mirex in Surface Water to PRG Reference Levels (Unit: ug/L**)**

Sampling point	Chlordane				Mirex			
	Concen -tration	Reference level (PRG) for tap water	Amount Exceeding Standard	Value Equivalent to Standard	Concen-tration	Reference level (PRG) for tap water	Amount Exceeding Standard	Value Equivalent Standard
S1	0.32	0.19	0.13	1.7	0.0006	0.037	-0.0364	0.0
Parallel with S1	0.955	0.19	0.765	5.0	0.0078	0.037	-0.0292	0.0
S2	0.621	0.19	0.431	3.3	ND	0.037	-	-
Parallel with S2	0.826	0.19	0.636	4.3	ND	0.037	-	-

Note: The Amount Exceeding Standard is the measured value minus the standard value. The Value Equivalent to Standard is the result of the actual concentration divided by the standard value. ND means that the contaminant was not detected (its concentration was lower than the detection limit).

31. The highest values for endosulfan and hexachlorocyclopentadiene concentration in surface water were 73.1ug/l and 0.0811ug/l GH7, respectively, and far below the PRG reference values of 220ug/l. The ratios of these values to the PRG reference value are 0.3 and 0.0004 respectively. Similarly, the mirex concentration of surface water at all sampling points was below the reference level. The risk from these chemicals in the surface water is, therefore, considered negligible. For measured concentrations of endosulfan and hexachlorocyclopentadiene, please refer to Table 4-14.

Qualitative Evaluation of Risk from Soil

32. The soils concentrations of the principal contaminants – chlordane and mirex – as well as two other contaminants of interest – endosulfan and hexachlorocyclopentadiene –

were extensively measured at the site. The measured concentrations for chlordane and mirex at some sampling points exceeded the reference levels. For these chemicals, a quantitative risk assessment was carried out (see next section on quantitative risk assessment) to quantitatively determine the risk they represent. The comparison of the measured concentrations against the reference levels is discussed below.

33. The concentrations obtained from the site sampling were compared to two reference levels. First, they were compared against the PRG reference level. Second, they were compared against the Stockholm Convention level of 50 ppm, which was adopted as a clean up target for this project.

Chlordane and Mirex

34. For chlordane, comparing with the PRG reference level of 6.5mg/kg (See Table 5-1), the concentration at the following sampling points is noteworthy.

(i) At the sampling point GH1, except in the surface layer, soil concentrations at all other depths are above the PRG level. The maximum concentration is 11.3 times the PRG.

(ii) At the sampling point GH2, the concentration in the depth between 0.3 and 1.0 meters exceeds the PRG. The maximum concentration is 3.3 times the PRG value. At other depths at this sampling point, the measured concentration does not exceed the PRG value.

(iii) At the sampling point GH3, only the concentration at depths of 0.3m and 0.6m exceed the PRG reference value. At the sampling point GH4, the layer at 0.1m away from the surface is over standard, others not exceeding the standard.

(iv) At all other sampling points – GH5, GH6, GH7, GH8, GH9, GH10, GH11, GH12, GH13 and GH14 – the measured concentrations are below the PRG reference value.

35. Comparing chlordane concentrations with the adopted Stockholm Convention based clean up target of 50ppm, only the concentration at the depth of 0.1meters at the sampling point GH1 exceeds the target. For all chlordane sampling results, please see Table 4-11.

36. For mirex, comparing against the PRG level of 0.96mg/kg, all measured concentrations are below the reference level, except at the depth of 0.1 meter at sampling point GH3 and 0.3 and 0.6 meter at sampling point GH2. The maximum exceedance of the measured concentration over the reference level is 45.2 times.

37. Comparing mirex concentrations at the site with the Stockholm Convention based clean up target of 50ppm, no sampling point exceeds the standard. For detailed sampling results, please see Table 4-12.

38. Given the exceedance of PRG reference values for chlordane and mirex, and the quantity of chemicals in soil, risk from soil is considered significant and is further evaluated quantitatively – please see section on quantitative risk evaluation.

Endosulfan and Hexachlorocyclopentadiene

39. The highest values for endosulfan and hexachlorocyclopentadiene contents in soil are 285mg/kg at 0.6m of GH12 and 8.01mg/kg at 0.1m of GH1, respectively. The ratios of these values to the 3700mg/kg specified in PRGs of US Region 9 are 0.08 and 0.002 respectively which are far below the reference value. Nonetheless, a quantitative risk assessment was carried out to illustrate the extremely low levels of risk from these non-POPs chemicals.

Qualitative Evaluation of Risk from Ground Water

Chlordane and Mirex

40. Comparing the measured concentration of chlordane and mirex to the PRG reference level for tap water it is found that:

(1) The chlordane concentration in ground water at all sampling points exceeds the reference level. The maximum exceedance was 51.6 times the reference level;

(2) The mirex concentration was below the reference level at the sampling points except GH3, GH4 and GH5. The maximum exceedance of the reference value was 3.7 times.

Table 5-3 Comparison of Chlordane and Mirex in Ground Water to PRG Reference Levels (Unit: ug/L)

Sampling point	Chlordane				Mirex			
	Concentra-tion	Evaluation reference	Amount exceeding standard	value equivalent standard	Concentra-tion	Evaluation reference	Amount exceeding standard	value equivalent standard
GH1	4.42	0.19	4.23	23.3	0.0237	0.037	-0.0133	0.6
GH2	0.908	0.19	0.718	4.8	0.00256	0.037	-0.03444	0.1
GH3	1.68	0.19	1.49	8.8	0.065	0.037	0.028	1.8
GH4	0.48	0.19	0.29	2.5	0.138	0.037	0.101	3.7
GH5	7.4	0.19	7.21	38.9	0.063	0.037	0.026	1.7
GH6	0.652	0.19	0.462	3.4	0.00686	0.037	-0.03014	0.2
GH7	2.69	0.19	2.5	14.2	0.00783	0.037	-0.02917	0.2
GH8	9.8	0.19	9.61	51.6	0.0271	0.037	-0.0099	0.7
GH9	0.896	0.19	0.706	4.7	0.00463	0.037	-0.03237	0.1
GH10	0.518	0.19	0.328	2.7	0.00479	0.037	-0.03221	0.1
GH11	2.8	0.19	2.61	14.7	0.00266	0.037	-0.03434	0.1
GH12	2.51	0.19	2.32	13.2	0.0115	0.037	-0.0255	0.3
GH13	0.255	0.19	0.065	1.3	0.0118	0.037	-0.0252	0.3
GH14	0.413	0.19	0.223	2.2	0.00363	0.037	-0.03337	0.1

Note: The amount exceeding standard is the measured value minus the standard value. The value equivalent to standard is the result of the actual concentration divided by the standard value.

41. Similarly to soil, because of the elevated groundwater concentrations of chlordane and mirex, a further quantitative risk evaluation was carried out.

Endosulfan and Hexachlorocyclopentadiene

42. The highest values for endosulfan and hexachlorocyclopentadiene contents in the ground water respectively at GH9 and GH7 are far below the reference value of 220ug/l. The ratios of these values to the standard value are 0.007 and 0.45 respectively. Given the low concentrations, no further quantitative evaluation was carried out.

Qualitative Evaluation of Risk from Sediment

43. The sediment in the dead-ended branch of the Wanmuqiao River adjacent to the plant was suspected of high concentration of chlordane and mirex. This was because the river branch was a recipient of the effluent from the plant's wastewater treatment facility, and was located in the proximity of the production area where the highest soils concentrations of chlordane and mirex were measured. Also, river courses adjacent to the production facilities are generally known to for occasional use as dumps for liquid and solid waste from the facilities. (It must be noted, however, the there is no evidence that there any such dumping occurred at Liyang Guanghua Chemical Company).

44. The measured concentrations of chlordane and mirex in sediment, however, did not confirm this hypothesis. The highest chlordane concentration of 2.09 mg/kg was measured at sampling point SED 2, located at the discharge point of the wastewater treatment plant. Concentrations of about 0.1 mg/kg were measured at sampling points SED 1 and SED 3 within about 50 meters from the discharge point. No detectable concentrations were measured at other sampling points.

45. The sampling results suggest that the contamination of the sediment is minimal when compared to the chlordane PRG soil reference of 6.5 mg/kg. The spatial pattern of chlordane concentrations in sediment suggest that the chlordane containing sediment is contained in the vicinity of the discharge point, and did not migrate out of the dead-ended Wanmuqiao River branch. This patter is consistent with the field observations that the branch has no measurable water flow, and is filled with stagnant water and overgrowing with weeds.

46. The highest measured mirex concentration in sediment was o.965 mg/kg, well below the PRG soils reference level of 0.96 mg/kg. Mirex distribution in sediment followed similar spatial pattern as chlordane. Again, no mirex was detected in sediment outside the dead-ended Wanmuqiao River branch.

47. Given the low concentrations of chlordane and mirex in sediment, and no possibility of human exposure to sediment which is permanently under several feet of water, the risk from chlordane and mirex in sediment is considered negligible. Since sediment with chlordane and mirex traces is contained in the dead-ended Wanmuqiao River branch, and the area does not have any sensitive aquatic life that would require protection from low levels of chlordane and mirex in the sediment, no further evaluation is considered necessary.

5.4.2 QUANTITATIVE EVALUATION

Quantitative Evaluation of Risk from Chlordane and Mirex Contamination in Soil

48. Soil is the main environmental medium polluted with chlordane and mirex. The actual concentrations of chlordane and mirex in soil were determined by the sampling at fourteen sampling points at different depths during the first phase of site monitoring. Complementary sampling at three additional sampling points was carried out during the second phase of site monitoring. The measured concentrations are summarized in Tables 4-18 and 4-19. The cancer risk associated with maximum and average value for each sampling point was calculated using the PRG guidelines and PRG values (see Table 5-1). According to the guidelines, the cancer risk was determined as a ratio of actual concentration to the PRG multiplied by 10^{-6}.

49. For example, the chlordane concentration of 73.6 mg/kg – the highest measured concentration of chlordane at the entire site (measured at depth of 10 cm at sampling point GH1 located between the production and storage workshops) – corresponds to cancer risk of 1.13E-05, calculated as 73.61mg/kg ÷ 6.5 mg/kg x 10^{-6} .

50. The mirex concentration of 43.4 mg/kg – again the highest measured concentration at the site (measured at the same sampling point as the maximum chlordane concentration) – corresponds to cancer risk of 4.52E-05, calculated as 43.4 mg/kg ÷ 0.96 mg/kg x 10^{-6}**.** Table 5-4 shows cancer risk for maximum and average concentration at each sampling point.

51. The cumulative cancer risk from combined chlordane and mirex carcinogenesis is a sum of the individual risks. For the sampling point with the highest measured concentration of both chlordane and mirex (sampling point GH1 at 10 cm depth), the cumulative cancer risk is 5.65E-05, calculated as 1.13E-05 + 4.52E-05. Table 5-4 shows cancer risk corresponding to the combined chlordane and mirex contamination for other sampling points.

Table 0-4 Risk Caused by Chlordane and Mirex in Soil

Sampling position	Chlordane(ppm)					Mirex(ppm)					Associated risk	
	Maximum value	Average value	PRG	Maximum risk	Average risk	Maximum value	Average value	PRG	Maximum risk	Average risk	Maximum risk	Average risk
GH1	73.60	23.39	6.5	1.13E-05	3.60E-06	43.40	7.46	0.96	4.52E-05	7.77E-06	5.65E-05	1.14E-05
GH2	21.40	9.45	6.5	3.29E-06	1.45E-06	10.00	1.91	0.96	1.04E-05	1.99E-06	1.37E-05	3.44E-06
GH3	26.30	6.27	6.5	4.05E-06	9.64E-07	0.73	0.26	0.96	7.56E-07	2.74E-07	4.80E-06	1.24E-06
GH4	12.00	3.12	6.5	1.85E-06	4.81E-07	0.51	0.19	0.96	5.29E-07	1.96E-07	2.38E-06	6.76E-07
GH5	0.76	0.42	6.5	1.16E-07	6.53E-08	0.39	0.15	0.96	4.03E-07	1.58E-07	5.19E-07	2.23E-07
GH6	0.59	0.30	6.5	9.02E-08	4.62E-08	0.04	0.02	0.96	3.91E-08	2.58E-08	1.29E-07	7.20E-08
GH7	0.89	0.41	6.5	1.37E-07	6.31E-08	0.04	0.02	0.96	4.29E-08	1.98E-08	1.80E-07	8.28E-08
GH8	0.87	0.53	6.5	1.34E-07	8.18E-08	0.16	0.12	0.96	1.61E-07	1.28E-07	2.95E-07	2.10E-07
GH9	0.29	0.16	6.5	4.40E-08	2.43E-08	0.01	0.01	0.96	1.44E-08	8.64E-09	5.84E-08	3.29E-08
GH10	3.41	0.95	6.5	5.25E-07	1.46E-07	0.06	0.02	0.96	6.01E-08	2.54E-08	5.85E-07	1.71E-07
GH11	0.83	0.28	6.5	1.28E-07	4.27E-08	0.36	0.18	0.96	3.77E-07	1.86E-07	5.05E-07	2.29E-07
GH12	3.01	1.20	6.5	4.63E-07	1.84E-07	0.27	0.10	0.96	2.78E-07	1.08E-07	7.41E-07	2.92E-07
GH13	0.58	0.20	6.5	8.95E-08	3.15E-08	0.01	0.01	0.96	1.28E-08	5.72E-09	1.02E-07	3.72E-08
GH14	1.87	0.59	6.5	2.88E-07	9.13E-08	0.13	0.07	0.96	1.31E-07	6.88E-08	4.19E-07	1.60E-07

52. The calculation shows that the highest level or cancer risk from chlordane and mirex at the site is 5.65E-05. This risk is one order of magnitude smaller than the upper bound of acceptable cancer risk of 10E-04. Thus, remediation of the site would not be necessary. However, since according to PRG guidelines, chlordane concentrations exceeding 65 mg/kg may fall within the range that represents an unacceptable non-carcinogenic health threat, and the highest chlordane concentration is 73.6 mg/kg, it is conservative to remediate the site to reduce the chlordane concentrations to levels below 65 mg/kg.[20]

Quantitative Hazard Evaluation from Hexachlorocyclopentadiene and Endosulfan in Soil

53. Although hexachlorocyclopentadiene and endosulfan were measured in soil in concentrations below the reference levels, a quantitative evaluation is carried out to illustrate the extremely low hazard that the residues of these chemical represent at the site.

54. The PRGs for both hexachlorocyclopentadiene and endosulfan are based on non-carcinogenic health effects. According to the US EPA User Guide for the PRG table, for non-cancer hazard estimates, the measured concentration is divided by its respective non-cancer PRG designated as "nc" in the PRG table. For cumulative hazard estimate from multiple contaminants, the ratios are then and summed up. The cumulative ratio represents a non-carcinogenic hazard index (HI). A hazard index of 1 or less is generally considered “safe”. A ratio greater than 1 suggests a need for further evaluation.

55. For the hexachlorocyclopentadiene and endosulfan concentrations at the site the HI is calculated in Table 5-5. The highest cumulative HI is 7.77E-02, which is far below the acceptable value of 1. This confirms that even cumulative hazard from combined impacts of hexachlorocyclopentadiene and endosulfan is well below the generally acceptable level.

Table 0-5 Hazard Index of Hexachlorocyclopentadiene and Endosulfan in Soil
(Unit: mg/kg)

Sampling point	Depth	Hexachlorocy-clopentadiene	PRG (tape water)	HQ	Endosulfan	PRG (tape water)	HQ	Accumulative HI
GH1	0.0	0.00203	3700	5.49E-07	2.510	3700	6.78E-04	6.79E-04
	0.1	8.01000	3700	2.16E-03	95.200	3700	2.57E-02	2.79E-02
	0.3	0.01380	3700	3.73E-06	3.050	3700	8.24E-04	8.28E-04
	0.6	7.12000	3700	1.92E-03	1.160	3700	3.14E-04	2.24E-03
	1.0	0.03510	3700	9.49E-06	8.610	3700	2.33E-03	2.34E-03
	1.5	0.15300	3700	4.14E-05	16.000	3700	4.32E-03	4.37E-03
GH2	0.1	0.00260	3700	7.03E-07	1.780	3700	4.81E-04	4.82E-04

[20] According to an InterCalc table that supplements the PRG guidelines, the hazard index for chlordane at industrial sites for all combined soil exposure routes (inhalation, dermal contact and ingestion) equals to one only at 400 mg/kg. This level would be exceeded in the 6.5 mg/kg carcinogenic reference level was multiplied by 100, corresponding to 10E-04 carcinogenic risk. Conservatively, therefore, only level of 65 mg/kg, corresponding to multiplication by 10 (and carcinogenic risk of 10E-05), is accepted for this evaluation.

Sampling point	Depth	Hexachlorocy-clopentadiene	PRG (tape water)	HQ	Endosulfan	PRG (tape water)	HQ	Accumulative HI
	0.3	0.88400	3700	2.39E-04	85.400	3700	2.31E-02	2.33E-02
	0.6	1.33000	3700	3.59E-04	110.000	3700	2.97E-02	3.01E-02
	1.0	0.01640	3700	4.43E-06	3.770	3700	1.02E-03	1.02E-03
	1.5	0.01160	3700	3.14E-06	1.950	3700	5.27E-04	5.30E-04
	2.0	0.00245	3700	6.62E-07	14.200	3700	3.84E-03	3.84E-03
GH3	0.1	0.00004	3700	1.08E-08	2.130	3700	5.76E-04	5.76E-04
	0.3	0.00514	3700	1.39E-06	5.260	3700	1.42E-03	1.42E-03
	0.6	0.06460	3700	1.75E-05	4.410	3700	1.19E-03	1.21E-03
	1.0	0.00679	3700	1.84E-06	28.600	3700	7.73E-03	7.73E-03
	1.5	0.00443	3700	1.20E-06	1.880	3700	5.08E-04	5.09E-04
	2.0	0.00317	3700	8.57E-07	0.271	3700	7.32E-05	7.41E-05
GH4	0.1	0.01150	3700	3.11E-06	3.920	3700	1.06E-03	1.06E-03
	0.3	0.00342	3700	9.24E-07	1.320	3700	3.57E-04	3.58E-04
	0.6	0.00102	3700	2.76E-07	30.700	3700	8.30E-03	8.30E-03
	1.0	0.00157	3700	4.24E-07	7.980	3700	2.16E-03	2.16E-03
	1.5	0.01040	3700	2.81E-06	2.890	3700	7.81E-04	7.84E-04
	2.0	0.00010	3700	2.70E-08	0.853	3700	2.31E-04	2.31E-04
GH5	0.1	0.00004	3700	1.08E-08	0.979	3700	2.65E-04	2.65E-04
	0.3	0.00032	3700	8.65E-08	0.531	3700	1.44E-04	1.44E-04
	0.6	0.00005	3700	1.35E-08	1.360	3700	3.68E-04	3.68E-04
	1.0	0.00092	3700	2.49E-07	0.328	3700	8.86E-05	8.89E-05
GH6	0.1	0.00071	3700	1.92E-07	1.040	3700	2.81E-04	2.81E-04
	0.3	0.00004	3700	1.08E-08	9.220	3700	2.49E-03	2.49E-03
	0.6	0.00004	3700	1.08E-08	1.160	3700	3.14E-04	3.14E-04
	1.0	0.00004	3700	1.08E-08	1.300	3700	3.51E-04	3.51E-04
GH7	0.1	0.00517	3700	1.40E-06	18.600	3700	5.03E-03	5.03E-03
	0.3	0.00585	3700	1.58E-06	2.430	3700	6.57E-04	6.58E-04
	0.6	0.00040	3700	1.08E-07	5.930	3700	1.60E-03	1.60E-03
	1.0	0.00005	3700	1.35E-08	7.180	3700	1.94E-03	1.94E-03
GH8	0.1	0.00236	3700	6.38E-07	19.200	3700	5.19E-03	5.19E-03
	0.3	0.00272	3700	7.35E-07	1.960	3700	5.30E-04	5.30E-04
	0.6	0.00285	3700	7.70E-07	32.500	3700	8.78E-03	8.78E-03
	1.0	0.00227	3700	6.14E-07	32.900	3700	8.89E-03	8.89E-03
	1.5	0.00068	3700	1.84E-07	9.480	3700	2.56E-03	2.56E-03
	2.0	0.00009	3700	2.43E-08	8.940	3700	2.42E-03	2.42E-03
GH9	0.1	0.00258	3700	6.97E-07	0.070	3700	1.89E-05	1.96E-05
	0.3	0.00049	3700	1.32E-07	0.180	3700	4.86E-05	4.88E-05
	0.6	0.00004	3700	1.08E-08	0.634	3700	1.71E-04	1.71E-04
	1.0	0.00181	3700	4.89E-07	0.060	3700	1.61E-05	1.66E-05
GH10	0.1	0.00677	3700	1.83E-06	0.091	3700	2.46E-05	2.65E-05
	0.3	0.00303	3700	8.19E-07	1.270	3700	3.43E-04	3.44E-04
	0.6	0.01000	3700	2.70E-06	0.200	3700	5.41E-05	5.68E-05
	1.0	0.12800	3700	3.46E-05	0.090	3700	2.43E-05	5.89E-05
GH11	0.1	0.03450	3700	9.32E-06	0.709	3700	1.92E-04	2.01E-04
	0.3	0.04210	3700	1.14E-05	0.610	3700	1.65E-04	1.76E-04
	0.6	0.00438	3700	1.18E-06	0.307	3700	8.30E-05	8.42E-05
	1.0	0.00270	3700	7.30E-07	0.652	3700	1.76E-04	1.77E-04
GH12	0.1	0.43000	3700	1.16E-04	160.000	3700	4.32E-02	4.34E-02
	0.3	1.72000	3700	4.65E-04	200.000	3700	5.41E-02	5.45E-02
	0.6	2.46000	3700	6.65E-04	285.000	3700	7.70E-02	7.77E-02
	1.0	3.75000	3700	1.01E-03	232.000	3700	6.27E-02	6.37E-02
GH13	0.1	0.00001	3700	2.70E-09	0.084	3700	2.27E-05	2.27E-05
	0.3	0.00076	3700	2.05E-07	0.804	3700	2.17E-04	2.18E-04
	0.6	0.00002	3700	5.41E-09	0.317	3700	8.57E-05	8.57E-05
	1.0	0.00004	3700	1.08E-08	10.700	3700	2.89E-03	2.89E-03
GH14	0.1	0.00004	3700	1.08E-08	1.280	3700	3.46E-04	3.46E-04
	0.3	0.00070	3700	1.89E-07	6.580	3700	1.78E-03	1.78E-03
	0.6	0.03340	3700	9.03E-06	0.116	3700	3.14E-05	4.04E-05
	1.0	0.00343	3700	9.27E-07	0.495	3700	1.34E-04	1.35E-04

Risk from Chlordane and Mirex in Groundwater

56. The results from the second phase of site sampling confirm that there is no detectable concentration of chlordane or mirex in the residential wells nearest to the contaminated site. The residential well sampling data are consistent with the overall spatial pattern of the chlordane and mirex in soils, surface water and groundwater. The pattern suggests that the contamination is localized around the production and storage workshop, and has not migrated significantly outside of that area.

57. Since no chlordane and mirex contamination was detected in the residential well, and since the wells are not use as sources of water for drinking or domestic use, there is no risk. However, the data from the first phase of sampling show that the groundwater at the contains some chlordane and mirex, even though both chemicals have only minimum solubility in water, and literature typically considers them simply insoluble (see table 2-3 for solubility properties). The measured concentrations of chlordane and mirex at the site are summarized in table 3-7. The highest concentration of chlordane was measured at sampling point GH8. It was 9.8 ug/L. The highest concentration of mirex was measured at sampling point GH4. It was 0.138ug/L.

58. Since it may be possible that, overtime, some contaminated groundwater would migrate into the residential wells, the risk evaluation, evaluates a hypothetical worst-case scenario that (i) contaminated ground water with unreduced chlordane and mirex concentrations would reach the wells and (ii) there would be some limited use of well water for domestic purposes due to breakdown of the central municipal water supply.

59. The risk from the worst-case scenario is calculated using an ASTM E1739-95 formula.

The exposure (dose) of the pollutants is calculated as follows.

$E = (C \times CR \times EF \times ED) / (BW \times AT)$

E: exposure (available, potential dose) (mg/kg-day)
C: mean concentration of chemical (mg/kg, mg/L)
CR: rate of contacts contaminated medium (assuming 2L/day)
EF: Exposure frequency, assuming 350 days per year
ED: Exposure duration, assuming 30 years
BW: mean body weight, assuming 60kg, adjusted to typical adult weight in China from the 70 kg adult weight
AT: period, when C is constant (day) assuming 70years x 365days = 25550 days

The exposure (dose) for chlordane in the groundwater than is:

$E_{chlordane} = (C(9.80\ ug/L) \times CR\ (2L/day) \times EF\ (350\ days/year) \times ED\ (30\ years)) / (BW\ (60\ kg) \times AT\ (25500\ days)) = 1.34 \times 10^{-4}$ mg/kg-day

The exposure (dose) for mirex in the groundwater then is:

E_{mirex} = (C(0.138 ug/L)×CR (2L/day)×EF (350 days/year)×ED (30 years)) / (BW (60 kg)×AT (25500 days)) = 1.89×10^{-6} mg/kg-day

The actual health risk associated with such exposure is determined by the following formula:

Risk = E ×SF

Risk: a unit less probability (*e.g.*, 1E-05) of an individual developing cancer;
SF: Slope factor, expressed in $(mg/kg\text{-}d)^{-1}$。 or toxicity expressed as a carcinogenic slope factor. The Integrated Risk Information (IRIS) database give the toxicity of chlordane and mirex expressed as a carcinogenic slope factor SF. The values are 0.35 $(mg/kg.day)^{-1}$ for chlordane and 1.8 $(mg/kg.day)^{-1}$ for mirex.

Therefore, risk for chlordane from groundwater is:

$$Risk_{chlordane} = E_{chlordane}\ (1.34\times 10^{-4}\ mg/kg.day) \times SF(0.35(mg/kg.day)^{-1}) = 4.7\times 10^{-5}$$

Risk for mirex from groundwater is:

$$Risk_{mirex} = E_{mirex}\ (1.89\times 10^{-6}\ mg/kg.day) \times SF(1.8\ (mg/kg.day)^{-1}) = 3.4\times 10^{-6}$$

Potential health affected persons for chlordane = Risk $(4.7\times 10^{-5})\times$ Number of people (239)
= 0.0117

Potential health affected persons for mirex = Risk $(3.4\times 10^{-6})\times$ Number of people (239)
= 0.000847

Based on the formula and calculation shown above, the actual health risk R would be as shown in Table 5-6.

Table 5-6 Health Risk Resulting from Groundwater Pollution

Actual exposure concentration (μg/L)		Exposure (dose) mg/kg.day	SF $(mg/kg.day)^{-1}$	Actual Health Risk	Potential Health Affected Persons
Chlordane	9.80	1.34×10^{-4}	0.35	4.7×10^{-5}	0.0117
Mirex	0.138	1.89×10^{-6}	1.8	3.4×10^{-6}	0.000847

60. Table 3-16 also shows the calculated values for the overall public health impact expressed as Potential Health Affected Persons = Actual Health Risk × Exposed Persons.

61. Based on the site reconnaissance, the factory is about 150m from the nearest residential settlement of Nichuedo village with 8 households. Altogether, there are 83 households with 249 residents in the nearby residential settlements of Nichuedo and Nanafang (see Table 2-2 for more detailed description).

62. According to the risk assessment result, if the groundwater polluted by chlordane and mirex is used as drinking water, the resultant potential health risk calculated based on the worst situations is 4.7×10^{-5} and 3.4×10^{-6} respectively, which are within the range of risk levels of 10^{-4} and 10^{-6}. Therefore, there is no significant risk for individuals of the study area. Taking all 249 people into account, the overall risk loss will be 0.0117 person-death and 0.000847 person-death for chlordane and mirex, respectively. This is much less than 1 person-death threshold considered significant by both risk scholars and decision-makers.

63. It is important to reiterate that the above calculation of risk from groundwater is based on the worst case scenario, assuming exposure that, based on the available information, does not exist, and is unlikely exist in the future. As long as the exposure to the groundwater as drinking water remains as it is now, there is no health risk from chlordane and mirex in groundwater to the nearby residents and site users. Given the fact that chlordane and mirex bind very rapidly and strongly to clay and organic matter in soil, and that they are practically insoluble in water, it is unlikely that their movement through groundwater represents a significant route of their migration in the environment. Generally, these chemicals have low potential for causing significant ground or surface water contamination.[21]

Hazard from Hexachlorocyclopentadiene and Endosulfan in Groundwater

64. Hexachlorocyclopentadiene and endosulfan were also detected in the groundwater samples, albeit at low concentrations. (See Table 4-13 for sampling results). To illustrate the negligible health impact they would have if the groundwater was used for drinking, the hazard they represent is quantified in Table 5-7. Since hexachlorocyclopentadiene and endosulfan are non-carcinogens, the PRG calculation for non-carcinogenic substance is used to estimate the hazard index (see the section on hexachlorocyclopentadiene and endosulfan in soil for more details). For groundwater, the highest cumulative HI is 0.749, which is below the value of 1, indicating that no unacceptable risk from Hexachlorocyclopentadiene and Endosulfan in groundwater exists.

Table 5-7 Hazard Index of Hexachlorocyclopentadiene and Endosulfan in Groundwater (concentration unit: ug/l)

Sampling point	Hexachloro-cyclopentadiene	PRG (tape water)	HQ	Endosulfan	PRG (tape water)	HG	Accumulative HI
GH1	0.388	220	0.002	23.5	220	0.107	0.109
GH2	0.690	220	0.003	19.0	220	0.086	0.090
GH3	1.230	220	0.006	47.7	220	0.217	0.222

[21] Usarat Pakdeesusuk, Mahmut Pulat and George M. Huddleston III, Environmental Fate Evaluation of DDT, Chlordane and Lindane, 1998; http://www.ces.clemson.edu/ees/lee/organochlorines.html

GH4	0.633	220	0.003	8.4	220	0.038	0.041
GH5	0.847	220	0.004	164.0	220	0.745	0.749
GH6	0.891	220	0.004	38.4	220	0.175	0.179
GH7	1.630	220	0.007	156.0	220	0.709	0.717
GH8	0.303	220	0.001	92.3	220	0.420	0.421
GH9	1.230	220	0.006	97.9	220	0.445	0.451
GH10	0.461	220	0.002	30.9	220	0.140	0.143
GH11	0.936	220	0.004	115.0	220	0.523	0.527
GH12	1.240	220	0.006	57.7	220	0.262	0.268
GH13	0.402	220	0.002	18.1	220	0.082	0.084
GH14	0.562	220	0.003	19.8	220	0.090	0.093

Evaluation of Post-Cleanup Risk From Chlordane and Mirex

65. Based on the guidance from Stockholm and Basel Conventions, China adopted 50 ppm as a target clean up level for chlordane and mirex at Liyang Guanghua Chemicals site. The analysis below shows that cleaning up the site to the 50 ppm level will render the site sufficiently clean to pose no unacceptable risk of damage to human health (concentration of other contaminants at the site are already below the reference levels, hence the clean up decision is based on chlordane and mirex). The analysis is based on the PRG methodology introduced earlier.

66. According to PRG guidelines for cancer risk estimates (both chlordane and mirex are carcinogens), the site-specific concentration is divided by the PRG reference levels for cancer evaluation and multiplied by 10^{-6} to estimate chemical-specific risk for a reasonable maximum exposure. For multiple pollutants, add the risk for each chemical.

Therefore:

$$\text{RISK} = \text{actual concentration} / \text{PRG} \times 10^{-6}$$

So:

$$\text{Log (risk)} = \log (\text{actual concentration/PRG}) - 6$$

Negative logarithm of risk (- Log (risk)) = 6 - log (actual concentration/PRG)

If actual concentration equals to PRG, then negative logarithm of risk will be 6.

67. For chlordane, if the concentration is 50 ppm and PRG is 6.5ppm, therefore, actual concentration divided by PRG (50/6.5) will be 7.69. Log (7.69) equals to 0.89. Then the negative logarithm of risk will be 5.11. That means that the 50ppm concentration of chlordane will cause the risk of $10^{-5.11}$ or 7.69×10^{-6}. This is well within the range of generally acceptable cancer risk of 10^{-4} and 10^{-6}.

68. For mirex, if the concentration is 50 ppm and PRG is 0.96ppm, therefore, actual concentration divided by PRG (50/0.96) will be 52.08. Log (52.08) equals to 1.72. Then the negative logarithm of risk will be 4.28. That means that 50ppm concentration of mirex will represent the risk of $10^{-4.28}$ or 5.21×10^{-5}. This again is well within the range of generally acceptable cancer risk of 10^{-4} and 10^{-6}.

69. The relationship between the chemical concentration and risk for chlordane and mirex is shown in Figures 5.1 and 5.2.

70. In Figure 5.1 and Figure 5.2, the points with 50ppm chlordane and mirex are marked.

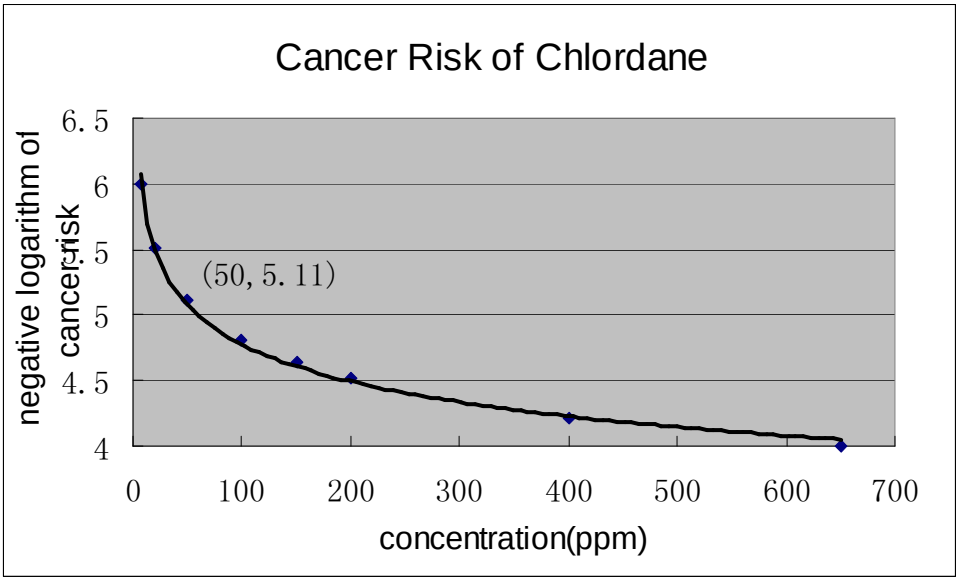

Figure 5-1 Carcinogenic risk of chlordane

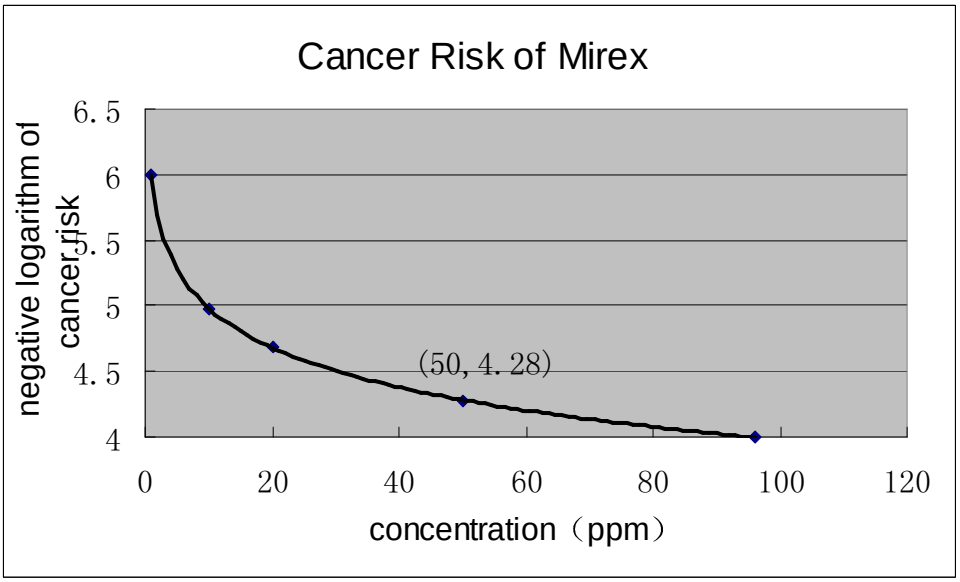

Figure 5-2 Carcinogenic risk of mirex

71. The combined carcinogenic risk from both chlordane and mirex at 50 ppm level is a sum of the individual risks of the two chemicals. It is $10^{-4.22}$ (6.02×10^{-5}). Again, this is well within the range of generally acceptable cancer risk. The non-carcinogenic hazard

index (HI) corresponding to the combined chlordane and mirex exposure from the site is a cumulative value from individual HI for chlordane and mirex. The cumulative HI for chlordane and mirex at 50 ppm concentration is 0.541, which again is well below the threshold value of 1. As shown in the calculations above, the 50 ppm clean up level sets adequate protection against combined health impact of chlordane and mirex in soil, either from the carcinogenic or non-carcinogenic perspective. As in other risk calculations in this document, the standard exposure assumptions used to develop PRG values are considered valid also for Liyang Guanghua Chemicals site.

72. For detailed technical guidance on calculating risk, please refer to *Users' Guide and Background Technical Document for US EPA Region 9's Preliminary Remediation Goals (PRG) Table.* The carcinogenic and non-carcinogenic concentrations for chlordane and mirex in soil used for the calculation can be found in the *Region 9 2004 PRG Table.* The documents are available online at www.epa.gov/region09/waste/sfund/.

Remediation Alternatives

1. Challenges exist in conducting remediation at the site, and China in general, due to the current lack of (1) any jurisdictional environmental quality standards or preliminary remediation goals (PRGs) and (2) experience in POP site remediation. As part of the demonstration project, there is a particular need to establish a process for assessing the most appropriate technology and remedial options at this site, which will serve as a model for future activities of this nature.

2. Given the baseline information presented in the previous sections, the principal contaminant of concern is chlordane, and the main medium is contaminated soils. In addition, the project requires dismantling and disposal of the production line, disposal of raw materials and obsolete stocks, contaminated packaging materials, asbestos contaminated insulation materials, 200 tons of wastewater and sludge stored in the water treatment facility. The following discussions on available cleanup technologies are extracted from a report prepared for the project with actual case studies.[22]

General description of Available Technologies

3. Traditional methods of treating soils contaminated with halogenated semi-volatile organic pesticides include thermal processes (e.g., incineration, thermal desorption), chemical processes (e.g., dechlorination), and excavation and off-site disposal in a landfill. The USEPA Treatment Technologies for Site Cleanup: Annual Status Report (Eleventh Edition) lists 100 Superfund Remedial Action projects that involved organic pesticides and herbicides from fiscal year 1982 to 2002 (USEPA, 2004a). Soil remedial technologies employed at these sites (number of sites involved) were as follows:

- incineration (36),
- bioremediation (25),
- solidification/stabilization (14),
- thermal desorption (9),
- soil vapor extraction (3),
- physical separation (3),
- in-situ thermal treatment (3),
- chemical treatment (2),
- soil washing (2),
- flushing (1),
- phytoremediation (1), and
- solvent extraction (1).

3. Pesticides at Superfund sites were treated most often by incineration followed by bioremediation and thermal desorption; the relatively high number of bioremediation projects may be attributed to its use for non-chlorinated pesticides. The use of

[22] Royal Roads University, 2005. Case Study on POPs Alternatives for Termite Control: Remedial Options for Chlorinated Pesticides Contaminants at the Liyang Guanghua Chemical Plant.

bioremediation to treat contamination by more persistent chlorinated pesticides is emerging and is discussed later in this report.

4. Groundwater may be treated in situ or ex situ. In situ technologies that have been employed for groundwater contaminated with chlorinated pesticides and herbicides include air sparging, treatment walls, chemical treatment and bioremediation. In situ remedial technologies used for chlorinated pesticides and herbicides in groundwater from fiscal year 1982 – 2001 at USEPA Superfund sites included the following:

- ③ air sparging (5),
- ③ bioremediation (7),
- ③ chemical treatment (1),
- ③ multiphase extraction (1),
- ③ permeable reactive barrier (2) and
- ③ phytoremediation (1).

5. Ex situ groundwater remediation involved pump and treat, using technologies such as activated carbon adsorption, UV oxidation, high energy destruction and bioremediation.

6. The remediation of chlordane, mirex and other possible contaminants at the Liyang Guaghua Chemical Plant using the main technologies for soil and groundwater listed in the previous paragraphs is presented in this report. The application of each remedial option to the site is evaluated using the following criteria:

- ③ *Ability to Meet Remedial Objectives* – the suitability for the remedial option to reduce contaminants to acceptable levels that is protective of human and environmental health is considered.
- ③ *Proven Technology* – the track record of the technology with respect to its use at other sites in China is considered. Factors considered include whether the technology has been used at a real site, or whether pilot studies have been conducted in the field or laboratory with the demonstrated ability to be scaled-up to field use.
- ③ *Potential for Toxic Residual Compounds* – some remedial options may potentially produce intermediate and/or residual compounds with toxicity equal to or even greater than the targeted contaminant.
- ③ *Logistics* – the suitability and availability of the technology including the number of commercial suppliers that can design, construct, deliver and maintain the technology in China; availability of a suitable work area, e.g., if excavation and stockpiling is required, would there be a suitable location on-site for setting up the stockpile area?
- ③ *Potential Impact to Tenants, Visitors, Other Site Users and Other Receptors During Implementation* – site works during the implementation of some remedial alternative may pose the risk of adverse environmental impacts, in addition to the existing contaminants on-site. For example, contaminated water generated during remedial activities may impact surface water adjacent to the site.

- *Public and Land Owner Acceptability* – will the approach be acceptable to the public? In particular, the "not in my backyard (NIMBY) syndrome" for the disposal of contaminated materials is considered here.
- *Implementation Timeline* – the time required to conduct the cleanup using the technology is considered.
- *Environmental Risks and Uncertainties* – potential risks include accidental spills, excavation slope failure, and encountering larger volumes or higher concentrations of waste than anticipated during the prior characterization, and/or generating large quantities of groundwater.
- *Relative Cost* – if more than one remedial technology is feasible, capital costs for construction and implementation of the different technologies may be a major factor in the decision of a remedial option. Costs include planning construction, implementation, operation, maintenance and/or monitoring.

7. Each of these factors are discussed under "advantages" and "limitations" for each technology and a brief overview of the applicability of the technology to the site and specific requirements are provided. Searches were conducted using "EPA REACH IT" (http://www.epareachit.org/), the US EPA Innovative Technologies databases (http://cfpub.epa.gov/asr/search.cfm), Science Direct (http://www.sciencedirect.com/) and other sources for case examples of each technology.

8. The most effective technology and cleanup strategy (or combination of strategies) will be that which provides the best balance amongst the criteria listed above, as well as others. In some cases, greater weighting may be placed on one criterion (e.g., costs, regulatory acceptance) over others.

Natural Attenuation

9. **Description of the Technology**. Soil and water has physical, chemical and biological characteristics that can enable volatilization, adsorption, chemical and photochemical reactions and biodegradation processes, to reduce contaminants to acceptable levels. Natural attenuation or intrinsic remediation is a risk-based management process that relies on these existing natural conditions to provide remediation. In order to consider this option, the site should be well characterized. Using site specific properties; such as contaminant concentrations and volumes, groundwater plume depths and flow rates, and soil properties such as organic matter, pH and moisture content; modeling is conducted to predict degradation rates, pathways and potential contaminant concentrations in receptors. The modeling is conducted to demonstrate that natural process occurring at the site will eventually reduce the contaminants to acceptable levels and that there will be minimal risk to receptors if the contaminants are left in place. A long term monitoring program is instituted to confirm that degradation is occurring at rates consistent with meeting the cleanup objectives.

10. Natural attenuation is usually applied to fuel hydrocarbons, volatile organic compounds (VOCs, e.g., carbon tetrachloride), Semi-Volatile Organic Compounds (SVOC, e.g., cyclopentadienes) and some pesticides (AFCEE, 2005; FTTR, 2005a).

11. Volatilization from soil is a major loss mechanism for chlordane; the rate depends on parameters such as the soil organic content, water content, temperature, and relative humidity as well as adsorption to soil. In general, sandy soils and soils with small amounts of organic matter retain chlordane less than soils with high clay and/or organic content, or moisture. Soil moisture is the most important factor. Chlordane does not degrade rapidly in water and no information is available on whether chlordane undergoes photochemical reactions in the aquatic environment (ATSDR, 1994).

12. Mirex can undergo photodecomposition in water to yield photomirex with the rate increasing with increasing dissolved organic matter (ATSDR, 1995). Photolysis, aerobic and anaerobic biodegradation of mirex in soils is very slow (ASTDR, 1995). Endosulfan released to soil will most likely be subjected to photolysis (on soil surfaces), hydrolysis (under alkaline conditions), or biodegradation (ATSDR, 2000).

13. **Advantages of Monitored Natural Attenuation**

- ③ The overall relative cost is generally lower than active remediation;
- ③ There will be less generation and handling of contaminated materials;
- ③ Technical requirements for the implementation will be available in China;
- ③ Potential impact of remedial activities on-site users, visitors, and other ecological features will be minimal; and
- ③ It can be used with other remedial technologies or as a follow up to other intrusive remedial measures

14. **Limitations of Monitored Natural Attenuation**

- ③ The application of monitored natural attenuation for this project will require that there is a framework in place for the robust assessment of its performance. This will require additional site data to model site-specific, natural attenuation potential;
- ③ The long term effectiveness of natural attenuation for chlordane and mirex is unknown and a risk assessment will be required;
- ③ Site physical and chemical conditions may change with time resulting in remobilization of stabilized contaminants (the stability of current in-place contaminants at the site is also not known);
- ③ The contaminants may migrate into the adjacent river before they are degraded;
- ③ Intermediate degradation products may be more mobile and more toxic than the parent materials. For example photo-isomerization of chlordane can occur in the environment leading to photoisomers that are more toxic than chlordane; and mirex has been shown to produce intermediate compounds, e.g., kepone, which are persistent;
- ③ Longer time frames (years) will be required to achieve remediation objectives, compared to active remediation. The site will not be available for reuse until contaminant levels are reduced.
- ③ Long term monitoring is required, with associated costs; and
- ③ It may not be acceptable to the public on the basis of perceived exposure and extensive consultations may be needed in order to gain public acceptance.

15. **Applicability in China.** The natural attenuation of chlorinated pesticides such as chlordane and mirex is very slow, especially in cooler climates, and the applicability of this to the Liyang Guaghua Chemical Plant may not be practical at this point due to data limitations. It may be suitable after removal of the highly contaminated substrate. The application of monitored natural attenuation to the residual contaminants will require the establishment of a framework for the robust assessment of its performance. This framework will need to include suitable strategies for monitoring the degradation of chlordane, mirex, and other contaminants in situ and predicting the potential for natural attenuation. Contingency plans will also be needed in case the contaminants do not behave as predicted by the model. Data requirements include:

- ③ Soil and groundwater quality data including volume and distribution of chlordane, mirex and other contaminants;
- ③ Physical characteristics of soil and geochemical data to assess the potential for the degradation of the contaminants including soil pH, total organic carbon (TOC), redox potential (E_h). For example, very high or very low pH levels will limit microbial diversity and biodegradation, while sorption of the pesticides will be greater in soils with a higher TOC. Since evaporation is the major route of removal from soils and sediments, sorption can significantly reduce pesticide degradability;
- ③ Location of potential receptors including groundwater wells and potential surface water discharge points;
- ③ A risk assessment to indicate the measures are protective of human and environmental health; and
- ③ Determination of the monitoring requirements to validate that degradation of the contaminants is occurring including suitable monitoring locations, frequency, and surrogate data as part of a risk management plan.

Bioremediation

16. **Description of the Technology.** Bioremediation uses microorganisms to degrade organic contaminants and convert them to biomass, intermediate products, and byproducts such as carbon dioxide, methane, and inorganic salts. It is suitable for soil, sediment, sludge, wastewater and groundwater. The key environmental conditions that affect biodegradation include pH, soil moisture content, temperature, and nutrient concentration. In *Enhanced Bioremediation*, the degradation process is accelerated by providing nutrients, microorganisms, and oxygen. Treatabilty studies, which determine the biodegradability of the contaminants, identify intermediates and byproducts, and disclose ways to enhance the process, are usually required to determine the feasibility of application.

17. Enhanced bioremediation can be conducted in situ or ex situ using either aerobic or anaerobic processes. In enhanced aerobic bioremediation, nutrients, electron acceptors (usually oxygen) and microorganisms are introduced to accelerate the natural biodegradation process. Oxygen is introduced by either air sparging, circulating hydrogen

peroxide or by using solid phase peroxide. For anaerobic bioremediation, nitrate (the electron acceptor) is circulated throughout the contaminated media to enhance degradation. In ex-situ bioremediation, contaminated soils are excavated while groundwater is pumped out of the aquifer, mixed with amendments and placed in a treatment cell. Water is treated in bioreactors while soils are placed in cells that have leachate collection systems and some form of aeration. Moisture, heat, nutrients, oxygen, and pH are monitored and controlled to enhance biodegradation. Ex-situ bioremediation technologies include bioreactors, biofilters, land farming and some composting methods; while in-situ bioremediation technologies include bioventing, biosparging, biostimulation and liquid delivery systems. A basic summary and current status of the use of bioremediation to treat pesticide contaminated media has been provided by Frazar[23] (2000). Additional details on bioremediation and its application may also be obtained from the Federal Remediation Technologies Roundtable (FRTR)[24].

18. Bioremediation techniques have been successfully used to remediate soils, sludges, and ground water contaminated with petroleum hydrocarbons, solvents, pesticides, wood preservatives, and other organic chemicals. They are especially effective for remediating low level residual contamination after source removal (FRTR, 2005b). The application of bioremediation to organochlorine remediation is, however, limited to a few laboratory studies or bench scale experiments.

19. Various studies have shown the biodegradability of endosulfan by a wide variety of soil microorganisms including fungi (28 species) and soil bacteria (15 species). Endosulfan sulfate was the major product of fungal metabolism, whereas bacterial transformation produced endosulfan diol (ATSDR, 2000). Its half-life is dependent on the type of isomer and has been reported to be up to 60 and 800 days, for the α- and β-isomers respectively. Only a few microorganisms capable of degrading chlordane have been isolated and the literature indicates that chlordane can persist in soils for more than 20 years (ATSDR, 1994). Degradation of mirex in soil may occur by anaerobic biodegradation with an estimated half-life of 10 years (ASTDR, 1995). The lignin degrading white rot fungi, *Phanerochaete chrysosporium*, was found to extensively degrade chlordane by Kennedy et al. (1990) suggesting it may also be useful for degrading chemical constituents such as chlordane, lindane, and DDT.

20. **Advantages of Bioremediation**

- ③ The overall cost is generally lower than active remediation, especially if conducted in situ;
- ③ There is less generation and handling of contaminated materials if the remediation is conducted in-situ;
- ③ Low technological requirements;
- ③ It can be used with other remedial technologies or as a follow up to other intrusive remedial measures after the removal of highly contaminated materials.

21. **Limitations of Bioremediation**

[23] http://clu-in.org/download/studentpapers/frazar.pdf
[24] http://www.frtr.gov/matrix2/section4/4_2.html

- ③ Bioremediation of pesticide-contaminated soils/groundwater is still in the developmental phase.
- ③ Before any full-scale bioremediation project can begin, treatability studies must be conducted;
- ③ Byproducts of contaminant transformation are sometimes hard to predict;
- ③ Compared to active remediation, a longer time frame may be needed to achieve remediation objectives due to the persistence of chlordane and mirex;
- ③ Cleanup objectives may not be attained if the soil matrix prohibits contaminant-microorganism contact;
- ③ High concentrations of chlorinated organics may be toxic to the microorganisms;
- ③ Additional site data on the soil environment including soil characteristics, pH, and TOC is needed;
- ③ The circulation of water-based solutions through the soil during enhanced in-situ bioremediation may increase contaminant mobility;
- ③ In-situ enhanced bioremediation may not be suitable for clay, highly layered, or heterogeneous subsurface environments because of oxygen (or other electron acceptor) transfer limitations.
- ③ Preferential flow paths may be generated for the injected fluids which will severely decrease contact between the fluids, organisms and contaminants throughout the contaminated zones.

22. **Applicability of Bioremediation.** There is considerable experience around the world on using bioremediation for treating volatile and semi-volatile organic contaminants in general; however, the application of bioremediation to chlorinated pesticides is limited. Therefore, this EIA will not suggest the use of this technology at the Liyang site.

Incineration

23. **Description of the Technology.** This technology uses high temperatures (870 to 1200°C) and oxidizing atmospheres to destroy waste by converting organic or biological materials to H_2O and CO_2 and other inorganic gases. It is used to treat soils, sediments, sludge, and other solid and liquid wastes. It is not applicable to groundwater. Normally the heat required is generated from the combustion of the organic material contained in the waste or by adding supplemental fuel. Organic substances commonly destroyed by incineration include alcohols, ketones, xylene, methyl ethyl ketone (MEK) and ethyl acetate. It is a proven technology for the destruction of organochlorine wastes - including PCBs and pesticides such as DDT and chlordane - in soil, sediment and sludge. Off gases require treatment to remove particulates and neutralize and remove acid gases (HCl, NOx, and SOx). The US EPA regulations for incineration require the destruction and removal efficiency to exceed 99.99% for principal organic hazardous wastes and 99.9999% for PCBs and dioxins (FRTR, 2005d). Combustion residuals (ash) can be disposed of in a landfill if they meet safety regulations, otherwise they must be treated. Incineration may be conducted on-site using a transportable unit or waste may be transported off-site to a central facility.

24. Hazardous waste incinerators may be classified into the following, based on the type of combustion chamber:

- Rotary kiln – primary chamber is a slightly-inclined, rotary cylinder lined with refractory materials that serves as the combustion chamber and operates at temperatures up to 980°C. Waste leaving the kiln is passed through an after-burner to complete the process followed by a quench, and an air pollution control system;
- Fixed-hearth incinerators – may contain single multiple hearths in which the combustion occurs;
- Fluidized bed incinerators – a bed of granular solid is suspended in air above the waste to remove hazardous gas and ash products;
- Plasma incinerators – extremely hot plasma is generated by injecting ionized air through an electric arc; and
- Infrared systems – intense IR radiation is generated by passing electric current through silicon carbide heating elements.

25. **Advantages of Incineration**

- Incineration is a proven technology that has frequently been used to remediate organochlorine compounds;
- It provides a nearly complete destruction of contaminants;
- Treatment duration is short- to long-term depending on the volume of contaminated materials;
- Applicable to a wide variety of media; and
- Incineration may be conducted on-site, yielding transport cost savings.

26. **Limitations of Incineration**

- High costs – Internationally, treatment costs for soils contaminated with PCBs or dioxins cost $1,650 to $6,600 USD per metric ton ($1,500 to $6,000 per ton) to incinerate" (FRTR, 2005d).
- Metals if present, can react with other elements in the feed stream, such as chlorine or sulfur, forming more volatile and toxic compounds than the original material;
- Emission controls are needed to prevent the release of pollutants such as dioxins, furans, NOx, SOx and particulates;
- Complex supporting infrastructure are needed, including analytical laboratories for emission monitoring; and,
- Potential public concerns with emissions. Some community groups have opposed the operation of hazardous waste incinerators in their communities. .

27. **Applicability.** Incineration is the recommended technology for the destruction of chlordane by dissolving it in a flammable solvent and incinerating it under controlled conditions (ATSDR, 1994). Incineration is also the recommended method for the disposal of mirex (ATSDR, 1995) and endosulfan (ATSDR, 2000). The disposal of obsolete stockpile of pesticides at the site including chlordane and mirex could be achieved through incineration. Therefore, highly contaminated soils at the Liyang site may be treated by this technology.

28. As noted, the cost per unit for destruction is extremely high for incineration and it may not be the preferred choice on the basis of economics. In addition to identifying soil contaminants and their concentrations, other information on soil properties, including soil moisture content and classification, and particle size distribution will be required. Soil particle size data allows an accurate estimation of the dust loading in the system for proper design of the air pollution control equipment. A test burn will need to be conducted to determine performance and cost, followed by a detailed cost analysis. The incinerators need to be operated efficiently in order to ensure destruction and removal efficiency of over 99.9999%. Failure to ensure proper design can potentially result in the production of dioxins and furans that can lead to severe health and environmental concerns.

Thermal Desorption

29. **Description of the Technology.** Thermal desorption involves volatilization of the contaminants and water by heating them to temperatures between 90 to 560 °C. A carrier gas or vacuum system is then used to transport the volatilized water and organics to a gas treatment system to remove particulates and contaminants. Particulates are removed by conventional particulate removal equipment, such as wet scrubbers or fabric filters. Contaminants are removed through condensation followed by carbon adsorption, or they are destroyed in a secondary combustion chamber or a catalytic oxidizer. Based on the operating temperature of the desorber, thermal desorption processes can be categorized into two groups: high temperature thermal desorption (HTTD) and low temperature thermal desorption (LTTD). In HTTD, the waste is heated to temperatures between 320 and 560 ^{O}C, whereas the wastes are heated to between 90 and 320 ^{O}C for LTTD. LTTD has the advantage of retaining most of the soil's physical properties and, as such, can be re-used on-site after remediation. The targets of this technology include a range of semi-volatile organic, PAH, PCBs, and organochlorine pesticide contaminated soils, sediments and sludges. It is not considered suitable for liquids (FRTR, 2005f).

30. **Advantages**

- It provides a nearly complete destruction of contaminants;
- Duration is short- to long-term depending on the volume of contaminated materials;
- May be conducted on-site yielding transport cost savings; and
- Soil can be reused on site for low temperature thermal desorption.

31. **Limitations**

- ③ Soils and sediments with high moisture content may require dewatering (drying) to achieve suitable feedstock moisture content levels;
- ③ Heavy metals in the feedstock may produce solid residual that requires further treatment;
- ③ High organic matter content soils increase reaction time as a result of binding of contaminants;
- ③ Clays and silty soils may cause poor performance of the thermal desorption technology, as a result of caking and strong binding of contaminants;

- ③ If operating conditions are not optimal, excessive particulate and volatile air emissions can occur; and
- ③ High capital and high operation and maintenance costs.

32. **Applicability.** As of 2005, there is no information about the availability and applicability of this technology in China. The GEF supported China PCB Management and Disposal Demonstration Project will purchase one thermal desorption unit and use it for the clean-up of contaminated soil with low PCB concentration (50-500ppm) after 2007. This unit may be available for the clean-up of the contaminated soil at the Liyang site.

33. The costs of thermal desorption may be less than that of incineration since it has lower energy requirements. This technology will be a suitable candidate for the remediation of chlordane contaminated soils. Apart from contaminant concentrations, information on other soil properties including soil moisture content, classification, and particle size distribution will also be required. Soil particle size data is again needed to determine dust loading in the system, which is essential for air pollution control equipment parameters. A test burn will also be needed to determine performance and costs, followed by a detailed cost analysis. The furnace will need to be operated efficiently in order to ensure destruction and removal efficiency of over 99.9999%. Failure to ensure proper design can potentially result in the production of dioxins and furans that can lead to severe health and environmental concerns.

Vitrification

34. **Description of the Technology.** Vitrification, also known as glassification is a high temperature process of immobilizing waste that produces a glass-like solid. It can be used to treat media contaminated with organic, inorganic or radioactive materials. The waste is combined with glass constituents such as silicon dioxide (SiO_2), sodium carbonate (Na_2CO_3), calcium oxide (CaO) or borax (B_2O_3). An electric current is then used to heat (melt) and vitrify the contaminated material. The organic contaminants in the soil being treated are pyrolized (decomposed) and are generally reduced to simple gases. Inorganic contaminants are incorporated into the molten soil which solidifies into a glass-like solid. Gases are collected through a stainless steel hood placed over the treatment area and subsequently treated. It can be conducted in-situ or ex-situ.

35. **Advantages of Vitrification**

- ③ It can be conducted in situ thereby minimizing waste handling;
- ③ It can deal with multiple contaminants at the same time;
- ③ It provides complete destruction of organic contaminants;
- ③ It is a proven technology.

36. **Limitations of Vitrification**

- ③ It is very energy intensive (temperatures of up to 1300°C are required) and consequently expensive;
- ③ Accessibility to sufficient power supply is needed;

- ③ Environmental conditions may affect the long-term immobilization of some contaminants;
- ③ Treatability studies are generally required;
- ③ Larger particles, such as coarse gravel or cobbles are undesirable for vitrification, while smaller particles may limit the effectiveness by slowing vapor release;
- ③ Long-term effectiveness has not been demonstrated for some contaminants; and
- ③ Off-gases for organic contaminants require treatment;
- ③ Use or disposal of the resultant slag is required; and
- ③ Regulatory and public acceptance is low.

37. **Applicability.** This technology is not recommended for remediation at the Liyang Guaghua Chemical Plant for the following reasons:

- ③ There is little experience worldwide on the use of vitrication to the destruction of organochlorine contaminants (including chlordane, mirex and endosulfan);
- ③ Specialized equipment required may not be currently available in China;
- ③ High energy requirements;
- ③ Possibility exists of releasing toxic off gases such as dioxins and furans; and
- ③ Long term stability has not been demonstrated for some contaminants.

Pyrolysis

38. **Description of the Technology.** In pyrolysis the organic contaminant is heated in an oxygen deficient atmosphere leading to decomposition. The organic materials are transformed into gaseous components, small quantities of liquid and a solid residue containing fixed carbon and ash. The gases require treatment and this can be accomplished in a secondary combustion chamber, flared, or partially condensed. Particles are also generated and may be treated using conventional particulate removal equipment such as fabric filters or wet scrubbers. The equipment used is similar to that of incineration (i.e., rotary kiln, rotary hearth, fluidized bed), with the exception that lower temperatures and less oxygen are required for combustion. The target contaminant groups for pyrolysis are semi-volatile organics and pesticides (FRTR, 2005g).

39. **Advantages of Pyrolysis**

- ③ Equipment similar to that of incineration and so may be available in China;
- ③ Complete destruction of waste
- ③ Medium time frame

40. **Limitations**

- ③ Pyrolysis is an emerging technology with limited data for its application to chlordane, mirex and endosulfan;
- ③ There are specific feed size and materials handling requirements that impact applicability or cost at specific sites;
- ③ The technology requires drying of the soil to achieve a low soil moisture content (< 1%), otherwise high moisture content increases treatment costs; and
- ③ Treated media containing heavy metals may require stabilization prior to final disposal (FRTR, 2005).

41. **Applicability.** No case examples on the use of pyrolysis for chlordane and mirex remediation are noted in the remedial literature. Therefore, this EIA will not recommend this technology for the remediation of the Liyang site.

Chemical Treatment

42. **Description of the Technology.** In chemical treatment methods, a chemical reaction is used to convert the contaminants into innocuous substances. Methods available for chlorinated organic compounds include Base Catalyzed Decomposition (BCD), Glycolate/Alkaline Polyethylene Glycol (APEG), Gas Phase Chemical Reduction (GPCR) and Chemical Oxidation.

43. *Base Catalyzed Decomposition (BCD).* The BCD process involves treatment of the contaminated liquid, soil or sediment in a reactor with fuel oil, alkali metal hydroxide (e.g., sodium hydroxide) and a proprietary catalyst. The mixture is heated to above 300 °C in a reactor. The reagents produce atomic hydrogen which decomposes the contaminants yielding carbon and inorganic salts. The carbon and salts are separated from the oil by gravity or centrifugation. The oil and catalyst is recovered and reused in other treatments (UNEP, 2005).

44. *Glycolate/Alkaline Polyethylene Glycol (APEG).* In the APEG process an alkaline polyethylene glycol (APEG) reagent (e.g., potassium polyethylene glycol) is mixed with the contaminated soils and heated in a treatment vessel. The reaction between the APEG reagent and halogenated compounds renders the halogenated compounds non-toxic through the replacement of halogen molecules (e.g. chlorine) by polyethylene glycol molecules. Treatment of the wastewater generated by the process may include chemical oxidation, biodegradation, carbon adsorption, or precipitation (Environment Canada, 2005).

45. *Gas Phase Chemical Reduction (GPCR).* This involves the gas phase chemical reduction of organic compounds by hydrogen at temperatures of over 850°C. Chlorinated hydrocarbons, such as PCBs, HCB, dioxins, furans and other POPs, are chemically reduced to methane and hydrogen chloride. GPCR is capable of treating waste with high POP concentrations including aqueous and oily liquids, soils, sediments, transformers and capacitors (UNEP, 2005). Gases leaving the reactor are scrubbed to remove water, heat, acid and carbon dioxide. Scruuber residue and particulate is disposed off-site.

46. **Advantages of Chemical Treatment**

- ③ The BCD process has the advantages of not requiring very high temperatures, high pressure, or energetic reagents;
- ③ BCD can be used as a final treatment step other processes such as thermal desorption;
- ③ Air emissions are relatively minor for BCD; and
- ③ The technologies are amenable to small-scale applications.

47. **Limitations of Chemical Treatment**

- ③ High capital and high operation and maintenance costs;

- ③ High clay and moisture content will increase treatment costs;
- ③ The APEG technology is generally not cost-effective for large waste volumes;
- ③ Concentrations of chlorinated organics greater than 5% require large volumes of reagent;
- ③ With the BCD process, capture and treatment of residuals (volatilized contaminants captured, dust, and other condensates) may be difficult, especially when the soil contains high levels of fines and moisture; and
- ③ Use of hydrogen in GPCR requires suitable controls and safeguards.

48. **Applicability of Chemical Treatment.** While the costs of these technologies may be slightly lower than that of incineration, they require proprietary technology and equipment that are currently not available in China in addition to the limitations listed above. They are not recommended for adoption for this project.

Excavation and Disposal in a Secure Landfill

49. **Description of the Technology.** This is not a treatment system per se; the contaminants are relocated to a safer site where contaminant migration into the surrounding ecosystem is curtailed. The contaminated material is excavated and transported to a permitted hazardous waste landfill for disposal. The landfill is equipped with a cover and specialized liners to prevent infiltration and contaminant migration, and monitoring systems are installed to ensure system integrity. Excavation and off-site disposal is applicable to a full range of contaminants, including organochlorine pesticides. There area a number of different categories of secure landfills in operation in Canada and the US designed to accept specified waste by regulations. The construction, operation, maintenance and monitoring of these landfills are heavily regulated. Before waste is accepted into the landfill, it generally undergoes a leaching test such as the Toxic Characteristics Leaching Protocol (TCLP – US EPA SW 846 Method 1311; http://www.epa.gov/epaoswer/hazwaste/test/pdfs/1311.pdf). The TCLP is designed to test the mobility of the contaminants present in the waste. The waste is leached with an extraction fluid designed to mimic leachate generated in a landfill followed by chemical analysis of the leachate. Analyte concentrations in the leachate are compared to the regulatory levels. If the values exceed the regulatory limits, the waste is designated as toxic. Treatment of leachable waste (e.g., by stabilization) is required before its placement into designated landfill.

50. **Advantages of Excavation and Disposal in a Landfill**

- ③ The main advantages is the contaminant is removed in a short time frame;
- ③ Low technology requirements; and
- ③ Public acceptance is generally high.

51. **Limitations of Excavation and Disposal in a Landfill**

- ③ Fugitive emissions may be generated during excavation;
- ③ Overall costs can be high due to transportation costs and landfill tipping fees;
- ③ Transport of the soil through populated areas may affect community acceptability;
- ③ Contaminants are not treated but simply moved from one location to the other;

- ③ Potential exists for the migration of contaminants from the secure landfill (without careful monitoring and controls); and
- ③ Long term monitoring of the landfill is required;
- ③ Regulatory acceptance is low because treatment of contaminant is preferred.

52. **Applicability of Excavation and Disposal in a Secure Landfill.** This technology is very cost effective and ready available in China. Therefore, this EIA recommends this technology for the Liyang site. Additional data requirements for this option will be the TCLP (toxic characteristics leaching procedure) or an equivalent test for leaching properties depending on the concentration of contaminants.

Pump and Treat

53. **Description of the Technology.** The main objective of groundwater pumping is to remove contaminated water from an aquifer and prevent contaminant migration through groundwater. Following a detailed site characterization and risk analysis a decision will be made as to whether pumping is necessary. If pumping is chosen the criteria for well design, pumping system and treatment method is then determined. Factors that need to be considered in designing the pumping system include hydraulic conductivity, the extent of the groundwater contaminant plume in three dimensions, and aquifer soil properties. However, the first question in designing a pumping recovery well system is whether pumping is even feasible. If the hydraulic conductivity is too low (below 10^{-5} cm/sec) or the hydrogeology is very complex and variable pumping is not feasible (FRTR 2005h). Once the groundwater is retrieved to the surface it must be treated to destroy the contaminants prior to discharge. Treatment technologies available for organochlorine pesticides include granulated activated carbon (GAC)/liquid phase carbon adsorption, advanced oxidation and chemical treatment. These are briefly described below.

54. *Granulated Activated Carbon (GAC)/Liquid Phase Carbon Adsorption.* The groundwater is pumped through a series of canisters or columns containing activated carbon to which the dissolved organic contaminants adsorb. The effluent is monitored and when contaminants in the effluent exceed the cleanup level, the activated carbon is replaced. The spent carbon is regenerated or removed and disposed off at a licensed facility.

55. *Advanced Oxidation.* Advanced oxidation processes use UV light, ozone or hydrogen peroxide to destroy the organic contaminant as the groundwater flows into the treatment tank. Oxidation of the contaminants results in the formation of carbon dioxide, water and salts. If ozone is used, the off gas is treated to destroy residual ozone before discharge.

56. **Advantages of Pump and Treat**

- ③ Pumping is a commercially available technology that can be easily implemented using conventional pumps in wells or trenches;
- ③ Cost is low to moderate;

- ③ Treatment by granulated activated charcoal (GAC) is a well established technique and has been used to treat municipal, industrial, and hazardous waste streams;
- ③ GAC is relatively non-specific and is effective for removing many organic, explosive, and some inorganic contaminants;
- ③ Practically any organic contaminant that is reactive with the hydroxyl radical can potentially be treated by advanced UV oxidation, for example chlorinated hydrocarbons that are generally resistant to oxidation but they may be treated by UV/oxidation;
- ③ The contaminant is destroyed in UV/oxidation and chemical treatment compared to other techniques such as GAC and air stripping.

57. **Limitations of Pump and Treat**

- ③ Time frame require to reach remedial goal may be long;
- ③ Pumping is not applicable to aquifers with hydraulic conductivity of less than 10^{-5} cm/sec;
- ③ Chemicals with high sorption capabilities may not be removed from the aquifer;
- ③ Off site migration of contaminants is possible before complete remediation;
- ③ Cost for installing and operating the system may be high;
- ③ Potential for biofouling of the extraction wells and associated treatment stream which may impact system performance;
- ③ Additional cost for disposal or regeneration of spent cartridges is treatment is by GAC;
- ③ Multiple contaminants may affect the performance of GAC and treatability test will be needed to assess the performance of the cartridges;
- ③ High suspended solids (>50 mg/L) and oil and grease (>10 mg/L) may cause fouling of the cartridges leading to frequent changes and higher costs; and,
- ③ Advanced oxidation requires the handling of large volumes of hazardous reagents.

58. **Applicability of Pump and Treat.** Pumping is a commercially available technology that can be easily implemented using conventional pumps in wells or trenches. The retrieved water can be treated by granulated activated charcoal with of-site disposal of spent cartridges. Apart from the contaminant concentrations, volumes and extent, hydrogeologic information would be required. This includes the size of the contaminated aquifer, depth to water table, hydraulic conductivity of the surrounding aquifer material, ground water flow direction and velocity, recharge and discharge areas, seasonal variations of ground water conditions. Methods such as slug test or pump test can be used to assess aquifer properties.

Physical Barriers, Passive/Reactive Treatment Walls

59. **Description of the Technology.** Physical barriers (or slurry walls) are used to contain the contaminated ground water and prevent migration into the surrounding environment. A trench is excavated and slurry, usually consisting of bentonite and water, is placed into it to provide the barrier. Other wall compositions, such as cement/bentonite, pozzolan/bentonite, attapulgite, organically modified bentonite, or slurry/geomembrane composite, may be used if greater structural strength is required or if chemical

incompatibilities between bentonite and site contaminants exist (FRTR, 2005i). Since this is not a contaminant treatment process it is applicable to a wide range of contaminants.

60. For passive treatment walls, the barrier is used is permeable to water but not the contaminant. The barrier allows the passage of water while causing the degradation or removal of contaminants. The degradation or retention of contaminants is achieved using such agents as zero-valent metals, chelators (ligands selected for their specificity for a given metal), sorbents, microbes, and others. Target contaminant groups for passive treatment walls are VOCs, SVOCs, and inorganics (FRTR, 2005i). For chlorinated hydrocarbons, the reaction barrier consists of an iron treatment wall. This is made of iron granules or other iron bearing minerals. As the iron is oxidized, a chlorine atom is removed from the compound by one or more reductive dechlorination mechanisms, using electrons supplied by the oxidation of iron. The iron granules are dissolved by the process, but the metal disappears so slowly that the remediation barriers can be expected to remain effective for many years, possibly even decades (FRTR, 2005j).

61. The permeable wall can also be made of a bioactive filter. This is an innovative technology that consists of native sand mixed with a carbon material that will selectively adsorb dissolved organic contaminants. A natural organic material such as peat may be used for the barrier. If peat is used, the organic compounds collected by the filter may biodegrade more rapidly when adsorbed to this more biologically active material.

62. **Advantages of Treatment Walls**

- ③ Slurry walls contain the contaminant and prevent migration;
- ③ Slurry walls are applicable to a wide range of contaminants and it is a relatively easy to install technology;
- ③ Treatment walls have the added advantage of treating the contaminants in situ.

63. **Limitations of Treatment Walls**

- ③ Slurry walls only contain the contaminants with no treatment;
- ③ Strong acids, bases, and some organic chemicals can degrade the soil-bentonite slurry;
- ③ Limited to depths that can be reached with excavation equipment;
- ③ Treatment walls may loose their capacity before all the contaminants are remediated necessitating reinstallation;
- ③ Precipitation of metal salts may limit the permeability of a treatment wall;
- ③ Biological activity may limit the effectiveness of a treatment wall;
- ③ High cost of treatment media.

64. **Applicability of Physical Barrier or Treatment Wall.** Slurry walls are well established technology however the excavation backfilling of the trench is critical and requires experienced contractors. In addition the contaminant is not treated and an interceptor trench may be needed to allow for recovery and treatment of the contaminated water. The installation of reactive walls requires specialized reagents which may not be available in China. There will the need for additional site characterization data and monitoring. These technologies are not recommended for the treatment of groundwater at the site.

Summary

65. The discussion presented above, mostly from the US, indicate that the most common technologies employed for the treatment of chlorinated pesticide contaminated soils include incineration, thermal desorption and excavation and disposal in a secure landfill. All three technologies are available in China and one or a combination could be employed. Technologies such as bioremediation, vitrification, pyrolysis and chemical treatment have also been used. Of these, ex situ bioremediation will be the most applicable in China. Treatability studies and additional data will be required as presented in relevant sections above. Natural attenuation has also been employed for groundwater following removal of contaminated soil and could be used at the Liyang Guaghua Chemical Plant.

Environmental Impacts

1. The closure of the Liyang Guanghua Chemical Company, Ltd. and the remediation of the contaminated production site of the company will largely eliminate pollution sources of chlordane and mirex and other toxic chemicals previously produced or used at the site but contained in soil, equipment, packaging materials, construction materials and other wastes. The proper disposal of these contaminated wastes will minimize environmental and health risks associated with these wastes. By doing so, the closure and site remediation activities will generate positive impacts on the environment, positive health impacts on people working or living close to the contaminated sites. Ultimately, the remediation of this site will generate a global benefit as it reduce the risks of having chlordane and mirex enter and accumulate in the human food chain.

2. The closure of the Liyang Guanghua Chemical Company, Ltd. will also generate two types of social impacts: the loss of jobs for employees used to work at the Liyang Guanghua Chemical Company; potential public concerns over the remediation of the Liyang site. The first type of social impacts will be addressed through a careful designed compensation and retrenchment plan (see the Social Assessment Report of this EIA). The second type of social impacts was addressed through a well designed and implemented two-round public participation and consultation practices during the preparation of this EIA. It will also be addressed during the site clean-up through public information campaign.

Environmental Impacts of Site Remediation Activities

Positive impacts associated with the site remediation actions

3. The proposed closure of the Liyang Guanghua Chemical Company, Ltd. and the remediation of the contaminated production site of the company will greatly improve environmental status of the contaminated site. The proposed soil remediation activities will remove about 1,900 metric tons of contaminated soil, about 900 metric tons of contaminated and 400 metric tons of general construction materials, 10 metric tons of production equipment, about 1500 plastic HCP casks and 300 iron CTC drums, 200 metric tons of wastewater and sludge stored in the wastewater treatment plant, about 150 metric tons of dicyclo-polymer waste residue, and 1 metric ton of asbestos contaminated insulation materials.

4. Proper removal and disposal of all toxic chemicals and chemical wastes stored on site will totally eliminate the risks that any of these chemicals or chemical wastes will be released on site due to negligence or natural disaster. Proper demolition and disposal of chlordane and mirex contaminated construction materials and production equipment will eliminate the chances for these contaminants to be gradually released into the air, soil or water environment, and thus minimize the risks of human exposure to chlordane and mirex.

5. According to the proposed remediation activities, proper soil excavation will reduce chlordane and mirex concentration in contaminated soil to much less than 50ppm. This action will greatly reduce estimated health risks associated with exposure to chlordane and mirex contaminated soil. Furthermore, this action will ensure that the bulk of soil contaminated with high concentration of chlordane and mirex will be removed so that chlordane and mirex cannot migrate into the groundwater and surface water system. This will further reduce the risks of human exposure to chlordane and mirex contaminated water.

6. The reduction of risks for human exposure to chlordane and mirex will benefit local people who work or live close to the contaminated site. The implementation of this remediation effort will educate local public, business owner and officials about environmental and health risks. As chlordane and mirex are persistent organic pollutants, the proper disposal of chlordane and mirex wastes will have a global benefit as it eliminates the risks of accumulating chlordane and mirex in the human food chain.

7. The experience and knowledge gained from the remediation of the Liyang site will benefit the remediation of the remaining eight chlordane/mirex production facilities in China. As China has very limited experience and knowledge in remediation of contaminated sites, this site remediation effort will help both Chinese government and business develop their capacity in managing risks associated with the production and disposal of chemical products, especially those persistent organic pollutants.

8. The remediation of the Liyang facility and the remaining eight chlordane and mirex production facilities will help China fulfill its commitments under the Stockholm Convention successfully.

Potential negative impacts associated with the site remediation actions

9. The remediation activities include soil excavation, building demolition, removal of production equipment, loading and unloading of contaminated wastes, and transportation of contaminated wastes for properly disposal. Potential negative environmental impacts resulting from these activities are: (1) noise and exhaust gases of excavating machinery and trucks; (2) dusts from soil excavation, building demolition, and removal of the production line; and (3) environmental impact related to borrow pits.

10. Two potential environmental risks associated with the site remediation are: (1) careless excavation may cause disturbance to ground water by allowing contaminated soil entering ground water; and (2) careless transport or traffic accident may cause the release of contaminated wastes to the environment. Site investigation of the EIA has revealed that the ground water level at the site is about 2 meters. As the site remediation will excavate contaminated soil up to 1.5 meters, any over excavation may disturb groundwater, causing contaminated soil to fall into groundwater, and lead to the further contamination of groundwater and its sediments. As the contaminated soil and wastes will have to be transported to appropriate landfill for disposal, proper measures have to be taken to prevent any of the waste from releasing to the environment during the transportation and to prevent any traffic accidents.

11. **Noise**. Noise is one of the major pollutants in the remediation process. Excavators, bulldozers and trucks will be main noise sources. According to related data, the noise condition of the major construction machineries is shown in Table 7-1.

Table 0-1 Noise of Construction Machinery and Equipment

Name of construction equipment	Average sound level A 10m from the equipment dB(A)
Excavator	82
bulldozer	76
Truck	85

12. It can be seen from Table 7-1 that noise produced by site construction machinery and equipment is very high and in actual construction process, many types of machineries often work at the same time and mutual superposition of various noise sources makes the noise level even higher and radiation range even wider.

13. Impact of construction noise on the acoustic environment in the surrounding regions is evaluated according to the "Noise Limit for Construction Site" (GB12523-90), in which the noise limit value for bulldozer, excavator and loader etc in daytime and at night is 75 dB(A) and 5 dB(A) respectively.

14. The noise produced by the construction machinery during clean-up process is mainly medium and low frequency noise, thus only diffusive attenuation is considered in the prediction of its impact, i.e. prediction model can use:

$L_2=L_1—20lgr_2/r_1 \qquad (r_2>r_1)$

Where: L_1 and L_2 are equivalent sound level A (dB(A)) from sound sources r_1 and r_2;

r_1 and r_2 are distance from receiving point to sound source (m).

15. It is predicted that the range of noise generated by the construction machinery exceeding the standard is within 100m in daytime and 300m at night. The protection target of this project is at 150m-300m and the noise produced from the cleanup activities has a minor impact on nearby residents in daytime and has certain impact on the protection target at 150m. Thus this EIA suggests that all excavation activities should be conducted during day time only.

16. **Exhaust gases of excavators and trucks**. The waste gases in the cleanup process are generated from excavators and trucks. As the remediation will be a short-term operation, impacts of these exhaust gases will be short-term.

17. **Borrow pits.** After the soil excavation, the site will be filled with soil from borrow pits. The removal of soil from borrow pits may have negative environmental impacts to the environment surrounding the pit. In addition, the excavation and transportation of borrowed soil may lead to the release of dusts to the environment.

18. **Dusts.** Soil excavation, building demolition, and removal of the production line may increase the risks of the release of contaminated soil dusts. Moreover, the removal of insulation materials containing asbestos may lead to the release of asbestos particles to the environment. As chlordane, mirex, asbestos and other chemicals used or produced on site are toxic chemicals; the direct inhalation of any of these chemicals may pose immediate health threats to workers participating in the site remediation.

Environmental Impacts of Disposal of Contaminated Wastes

19. Environmental impacts related to the disposal of contaminated wastes mainly include: (1) vibration, noise from disposal process at a landfill; (2) leachate and odor of the landfill; (3) wastewater and sludge from the treatment of acid wastewater and sludge; and (4) wastewater from triple washing of containers. If not treated or improperly treated, they will generate certain impact on the local atmosphere, water, soil and acoustic environment.

20. Detail risks to the environment from remediation activities are shown in Table 7-2.

Table 0-2 Environment Risk Caused by Cleanup Activities in this Project

Activities	Environmental impacts
Triple washing of used containers with water	Waste water
Landfill of contaminated wastes	Vibration and noise; Leachate and odor
Wastewater and sludge treated at industrial wastewater treatment plant	Wastewater and sludge

Environmental Impacts of Storage and Sales of Raw Materials and Products

21. As noted, the facility still has in stock about six metric tons of hexachlorocyclopentadiene, five metric tons of dicyclopentadiene, ten metric tons of carbon tetrachloride, three tons of liquid chlorine, two tons of caustic soda and one ton of ethanol. Stored products include sixteen tons of chlordane and two tons of mirex. These raw materials and products will be liquidated before the site remediation of the facility.

22. The sale of these stored chemicals will not generate adverse impacts on the environment. However, the storage and transportation of these chemicals on site and from the site to buyers may pose risks to the environment and workers involved in the transfer of these chemicals. Improper packaging, loading and unloading of these chemicals may lead to emission, overflow, dripping, leaking or spill of chemicals. As most of these chemicals are toxic, these events will lead to contamination to the environment, tools or trucks used to transport these chemicals, and workers operating these tools or trucks. Measures have to be taken to ensure the proper handling of these chemicals.

Environment Management Plan

1. The environmental management plan includes measures for mitigating the potential impacts created by the previous production of chlordane and mirex at the site and generated during the clean up work, dismantling of production equipment, transportation and disposal waste from the site. For all site clean-up activities, the following requirements have to be followed:

- Contractors should be licensed hazardous waste management companies to carry out any site clean-up task related to chlordane, mirex and other hazardous chemicals and their wastes, and follow strictly national and local laws, regulations and technical guidance on hazardous waste management and disposal.
- Qualified (and certified if applicable) technical and management personnel should be hired for the clean-up of the Liyang Site. They are required to take training courses organized by the Termite Control Demonstration Project. Safety measures should be taken for and by the personnel work on site.

2. Detailed requirements of the qualifications for the contractor will be provided in terms of reference before the start of the site remediation.

Mitigation for Impacts Originated from Past Production

3. **Mitigation Measures for Disposal of Raw Materials.** The stockpile raw materials and products will be liquidated before the site clean-up starts. These chemicals will be stored and handled strictly following the Regulation for Safe Management of Hazardous Chemicals (issued by the State Council in 1987 and revised in March, 2002) to avoid any spill and leakage of any of these chemical and to ensure that these chemicals will be safely transported from Liyang to interested buyers.

4. As China will implement a production quota system to control the production of chlordane and mirex, the production quotas for 2006 (assumed the first year of the implementation of the Termite Control Demonstration Project) for chlordane and mirex will be reduced accordingly.

Clean-up of Contaminated Soil

5. Licensed hazardous waste management companies will be hired through a competitive bidding process to perform remediation activities to be performed at the Liyang site.

6. **Amount of Contaminated Soil.** Based on the clean-up standard for wastes contaminated with all identified chemicals at the Liyang Guanghua Chemical

Company Ltd., this EIA determines that only soil around the monitoring well GH1 has been contaminated with chlordane 73.6ppm (over 50ppm standard) at a depth of 0.1 meter. The next highest concentrations of chlordane in the soil are found at the monitoring well GH1 at a depth of 1.0 meters (about 36.5ppm), at the monitoring well GH2 at a depth of 0.6 meters (about 21.4ppm) and at the monitoring well GH3 at a depth of 0.6 meters (about 26.3ppm). In practice, these three monitoring wells are positioning immediately outside to places where chlordane and mirex are produced, stored, and production facilities are maintained. In particular, the monitoring wells GH1 and GH3 are positioned on the aisle between the chlordane/mirex production workshop and the chlordane formulating workshop and warehouse (i.e., the Workshop (Building 7) and Warehouse (Building 8) below the Chlordane and Mirex Workshop (Building 5) shown on Figures 4-4 and 4-8), and the monitoring well GH2 is positioned on the aisle between the chlordane formulating workshop and warehouse and the machine maintenance room and the warehouse for chlordane products (i.e. Warehouse and Machine Maintenance Room shown on Figures 4-4 and 4-8). The high concentrations of chlordane in the soil are consistent with the manners of production, formulating, packaging, and storage activities at the facility.

7. As the monitoring data does not provide a sufficient concentration gradient map to reliably reflect the actual concentration changes between the monitoring wells, this EIA suggests a conservative approach that all soil around these wells be remedied. To minimize the risk of relatively high concentration of chlordane in the soil around the monitoring well GH1 from migrating in the soil or even to the ground water, this EIA suggests that a radius of 14m (the longest distance between any two of the three monitoring wells) around the monitoring well GH1 be classified as contaminated soil to be remedied. This equals to a round area of about 616 square meters. Considering that previous excavation has indicated that groundwater levels at GH1, GH2 and GH3 are all about 1.5 meters below the surface soil, it is recommended that the soil up to 1.5 meters be remedied to avoid disturbing groundwater. Therefore, this EIA suggests that a cylindrical soil remediation area with a total volume of 924 cubic meters (i.e., 616 square meters times 1.5 meters) be included for remediation.

8. **Selection of Soil Remediation Technologies.** Based on discussion earlier in this chapter, this EIA has identified the following technologies available in China for treating soils contaminated with halogenated semi-volatile organic pesticides: incineration, thermal desorption, and excavation and off-site disposal in a landfill. Based on the following considerations, this EIA suggests that the third approach, excavation and off-site disposal in a regulated hazardous waste landfill, be selected for the remediation of contaminated soil at the facility.

(1) Concentration of pollutants in the soil. As discussed in this report, soil to be considered for remediation at the facility has chlordane concentration slightly above the standard and concentration of all other contaminants below the standards. Internationally, it is the common practice to dispose soils with low concentrated wastes to a hazardous waste landfill. Another suitable option for

soil decontamination, as noted in Chapter 6, is thermal desorption, which can treat chlordane and mirex contaminated soil (although this technology was not recommended for this particular clean up for cost and risk reasons discussed below).

(2) Technology availability. China has developed its hazardous waste incineration facilities since 2001. However, few of these facilities are built with best available technologies (BAT). Here, a hazardous waste incinerator with BAT refers to the incinerator has adopted internationally best available incineration technologies, inter alia, designed for high temperature and equipped with prevention of reformation of dioxins and furans and dedicated dioxin and furans removal. In contrast to incineration, hazardous waste landfill is technologically simple and has been widely operated in many places in China for a couple of decades. As China will have a thermal desorption unit under the GEF funded PCB Management and Disposal Demonstration Project, thermo desorption will also be available for the treatment of contaminated soil at the Liyang Site.

(3) Treatment costs. It is estimated that the unit cost for incinerating wastes at a BAT hazardous waste incinerator in China is about US$2,500 per ton of waste, and the cost for thermal desorption will be around US$2,000.25 In contrast to the high cost of incineration and thermal desorption, the unit cost for hazardous waste landfill is only about US$300.

(4) Potential risks associated with technologies. As China has yet to systematically monitor dioxin and furan emission from hazardous waste incinerators, there are risks that these facilities have failed to take necessary measures to minimize the release of dioxins and furans. In addition to air and wastewater releases during the thermal desorption process that need to be treated, contaminants concentrated by the thermal desorption process will have to be treated by the second disposal technologies, which is often incineration. As soil at the Liyang Guanghua site is mainly clay or sub-clay, the decontamination of such soil may compromise the removal efficiency and generate excessive dusts, which places a greater dust loading on the downstream air pollution control equipment.[26] In contrast to incineration and thermal desorption, well regulated and operated hazardous landfill is a safe disposal technology for low concentration contaminants and poses a low risk of producing secondary pollution.

9. The following table summarizes the above discussion for the applicability of these technologies at the Liyang Guanghua site.

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[25] This estimation is quoted from the EIA Reports of the China PCB Management and Disposal Demonstration Project.

[26] Clay content in soil reduces the effectiveness of thermal desorption technology and increases the dust loading.

Table 8-1 Applicability of Three Disposal Technologies for the Liyang Site

	Incineration	Thermal desorption	Hazardous waste landfill
Concentration of contaminants	High	Low	Low
Technology availability	BAT yet to be adopted.	Available around 2007 under the PCB Project	Yes
Treatment costs	High	Medium	Low
Risks for secondary pollution	High	High	Low

10. A certified hazardous waste management company will be hired to perform all soil remediation tasks. Landfill will be carried out according to a national standard - Standard for Pollution Control at Hazardous Waste Landfill (GB18598-2001). In addition, the operation and design of the landfill will be reviewed as a part of the landfill selection process to ensure that the landfill is safe for disposal of chlordane and mirex hazardous waste. Particular attention will be paid to safe operation of the landfill, e.g., regular monitoring of groundwater in the vicinity of the landfill in established monitoring wells, not mixing of waste to avoid chemical reactions, tracking of waste location within the landfill, and keeping of records of what disposed wastes (their source, time of disposal, etc.) Also reviewed will be design issues, such as the existence of a proper liner system with permeability below 10 E-07 cm/s, adequate leachate collection and treatment system, and possibly gas collection and ventilation system.

11. **Estimated Costs for Soil Remediation.** The costs for soil remediation will include four types of costs: the cost for protective clothing and respiratory equipment for workers, the cost for excavating contaminated soil, the cost for packaging and transporting the excavated soil from the Liyang facility to a licensed hazardous waste landfill, and the cost to disposal the excavated soil at the landfill. In sum, the estimated total costs for soil remediation is about US$622,428.

(1) Cost for protective clothing and respiratory equipment.

It is estimated that a total of 10 workers will involve in the task. The cost will be around $1,500.

(2) Soil excavation cost:

It is estimated that unit price for soil excavation is US$6 per metric tons. It is also estimated that each cubic meter of soil weigh about two metric tons. So the cost for excavation of a total of 924 cubic meters will be US$11,088.

(3) Packaging and transportation cost:

It is assumed that the unit packaging and transportation cost is about US$30 per metric tons. So the cost for transportation of a total of 924 cubic meters (or 1,848 metric tons) will be US$55,440.

(4) Landfill cost:

It is estimated that the unit cost for hazardous landfill of a metric ton is about US$300. So the cost for the landfill of a total of 924 cubic meters (or 1,848 metric tons) will be US$554,400.

12. **Disposal of Insulation Materials Containing Asbestos.** This EIA has identified that at the Liyang facility, insulation materials containing asbestos has been used on some pipes transmitting heating vapor (or cooling water) to the chlordane production line. As asbestos is well recognized as a health hazard and is highly regulated in China, a certified waste management company will be hired to carefully remove all pipes together with their insulation materials, which containing asbestos, from the production line. This action will be conducted before all other site remediation activities.

13. The removed pipes and asbestos will be sealed in thick plastic bags with plastic tapes. The sealed bag should be clearly marked with warning signs and the content of the bag such as chemical asbestos waste (in Chinese). This clearly marked and tightly sealed bag will be sealed in a transparent plastic bag. All contaminated protective clothing of workers will be treated as asbestos wastes and disposed in the same manner.

14. As it is well acknowledged that the best technology to disposal of asbestos is hazardous waste landfill, this EIA suggests that all asbestos insulation materials should be disposed of at a licensed hazardous waste landfill. It is estimated that the total quantity of asbestos wastes, including the pipes on which insulation materials are, will be around one metric ton. In sum, the estimated total costs for disposal of asbestos contaminated insulation materials are about US$8,500.

(1) Cost for protective clothing and respiratory equipment.

It is assumed that a total of 10 workers will involve in the task. The cost will be around $1,500.

(2) Removal, packaging and transportation cost:

It is estimated that the cost will be around US$2,000.

(3) Landfill cost:

It is estimated that the cost will be around US$5,000.

15. **Disposal of Contaminated Building Materials.** Two types of building materials have been identified in this EIA: contaminated construction materials and general construction materials. Contaminated construction materials refer to floors, walls and ceiling of both chlordane/mirex and endosulfan production workshops, storage rooms for raw materials and products, chlordane formulating room, and the workshop for equipment maintenance. All other construction materials will be deemed as general construction materials. Note that some of the floor areas of production related building will be removed during the excavation of contaminated soil.

16. For contaminated construction materials, the appropriate remediation technology will be hazardous waste landfill due to low concentration of contaminants

on/in these materials and large quantity of these materials. For general construction materials, this EIA suggests that these materials to be disposed of at municipal landfill. The option of on site cleaning was considered, which will allow all wastes could be sent to ordinary landfill. However, it is rejected due to its negative environmental impact of on-site cleaning.

17. It is estimated that the 2000 square meters of production related building will produce about 900 metric tons of contaminated construction materials, and about 900 square meters of other buildings will generate about 400 metric tons of general construction materials. As noted earlier in this report, insulation materials containing asbestos will be removed before the demolition of any existing building. In sum, the estimated total costs for soil remediation is about US$356,500.

(1) Cost for protective clothing and respiratory equipment.
It is estimated that a total of 10 workers will involve in the task. The cost will be around $1,500.

(2) Building demolition cost:
It is estimated the total cost for demolition of all buildings will cost about $30,000.

(3) Packaging and transportation cost:
For contaminated construction materials, it is assumed that the unit packaging and transportation cost is about US$30 per metric ton, the cost for transportation of a total of 900 metric tons will be US$27,000. For general construction materials, it is assumed that the unit packaging and transportation cost is about US$20 per metric ton, the cost for transportation of a total of 400 metric tons will be US$8,000.

(4) Landfill cost:
It is estimated that the unit cost for hazardous waste landfill of a cubic meter is about US$300; the cost for the landfill of a total of 900 metric tons will be US$270,000. It is estimated that the unit cost for municipal waste landfill of a metric ton is about US$50; the cost for the landfill of a total of 400 metric tons will be US$20,000.

18. **Disposal of Contaminated Production Equipments.** All production equipment will be properly dismantled and disposed of as contaminated wastes. Three technical options are considered: landfill, solvent cleaning and incineration. It has been documented that solvent cleaning will increase the emission of chlordane and mirex during the cleaning process. Not to mention, this option requires the disposal of used solvent. As China has no previous experience in solvent cleaning of POP related wastes, this EIA suggests that solvent cleaning not be considered. For the incineration option, it is documented that metals will react with chlorine or sulfur in wastes and form more volatile and toxic compounds than the original species. As noted earlier, the cost of incineration is also much higher than the cost of landfill. Therefore, hazardous waste landfill is the best option for the disposal of the remaining production equipment at the Liyang facility.

19. A special note on the disposal of the wastewater treatment plant at the Liyang facility is that the disposal of the wastewater treatment plant can be performed only after all wastewater and sludge contained in the plant have been removed. See the sub-section on the disposal of wastewater and sludge in this section for details on how to dispose of this wastewater.

20. It is estimated that there are about 10 metric tons of equipment left at the Liyang facility. In sum, the estimated total costs for soil remediation is about US$14,500.

(1) Cost for protective clothing and respiratory equipment.
It is estimated that a total of 10 workers will involve in the task. The cost will be around $1,500.

(2) Equipment removal, packaging and transportation cost:
It is estimated the total cost for removal, packaging and transportation of a total of 10 metric tons equipment will be US$10,000.

(3) Landfill cost:
It is estimated that the unit cost for hazardous waste landfill of a metric ton is about US$300, the cost for the landfill of a total of 10 metric tons will be US$3,000.

21. **Disposal of Contaminated Packaging Materials.** As noted earlier in this report, there are about 1500 plastic HCP casks and 300 iron CTC drums. Based on current industrial practices, the most cost efficient approach for the disposal of these containers will be washing, i.e. triple rinse and pressure rinse. This EIA suggests that a licensed waste management company be hired to pressure rinse all containers with water. Rinse water shall be properly collected and treated at a licensed industrial wastewater treatment plant. Based on the condition of these containers, cleaned casks or drums can be re-used (or recycled), or crushed and disposed of at municipal landfill. Incineration is not suggested due to its high costs and negative environmental impacts.

22. It is estimated that the unit cost for transporting and cleaning up all these containers at the waste management company’s facility will cost about US$3 per container. Therefore the total cost will be US$5,400. Costs for landfill unusable casks or barrels will be minimal and thus not estimated in this EIA.

23. **Disposal of Wastewater and Sludge in the Wastewater Treatment Plant.** The 200 metric tons of wastewater and sludge stored in the wastewater treatment plant are acid in nature and contain hexachloro-cyclopentadiene. This EIA suggests that these wastewater and sludge be treated at a licensed industrial wastewater treatment facility that is capable of treating such wastewater and sludge, including chlordane and mirex residues through appropriate technology (e.g., carbon absorption or another suitable kind of tertiary treatment). It is estimated that the unit cost for transferring these wastewater and sludge to the licensed industrial wastewater treatment facility will be US$100 per metric ton. Therefore, the costs for 200 metric tons will be US$20,000.

24. **Disposal of Dicyclo-polymer Waste Residue.** Similar to other contaminated solid wastes, the best option for the disposal of about 150 metric tons of dicyclo-polymer waste residue will be disposal at a licensed hazardous waste landfill. Cost for the disposal is estimated as below. In sum, the estimated total costs for soil remediation is about US$51,000.

(1) Cost for protective clothing and respiratory equipment.
It is estimated that a total of 10 workers will involve in the task. The cost will be around $1,500.

(2) Equipment removal, packaging and transportation cost:
It is assumed that the unit packaging and transportation cost is about US$30 per metric ton. For a total of 150 metric tons, the total costs will be US$4,500.

(3) Landfill cost:
It is estimated that the unit cost for hazardous waste landfill of a cubic meter is about US$300; the cost for the landfill of a total of 150 metric tons of wastes will be US$45,000.

25. **Summary.** Table 8-2 summarizes the mitigation measures proposed by the EIA for impacts originated from past production of chlordane and mirex at the Liyang site. Annex 4 lists identified hazardous waste management companies registered in Jiangsu Province. Qualified landfills, wastewater treatment plants and hazardous waste management companies will be selected through a national competitive bidding process to participate in the clean-up of the Liyang Guanghua site.

Table 8-2 Summary of Proposed Mitigation Measures and Cost Estimation

Wastes	Quantity (MT)	Mitigation measures	Costs (US$)
Contaminated soil	1,848	Disposal of at a licensed hazardous waste landfill	~622,500
Asbestos contaminated insulation materials	1	Disposal of at a licensed hazardous waste landfill	8,500
Building materials			356,500
Contaminated	900	Disposal of at a licensed hazardous waste landfill	
General	400	Disposal of at a licensed municipal landfill	
Contaminated production equipment	10	Disposal of at a licensed hazardous waste landfill	14,500
Contaminated packaging materials			5,400
Plastic HCP casks	1500 pcs	Triple rinse with water and based on the condition, reuse (including recycle), or crush and landfill	
Iron CTC drum	300 pcs		
Wastewater and sludge	200	Treated at a licensed industrial wastewater treatment plant	20,000
Dicyclo-polymer waste residue	150	Disposal of at a licensed hazardous waste landfill	51,000
Total		--	~1,080,000

Mitigation Measures for Social Impacts Associated with Plant Closure

26. As noted in Chapter 7, the closure of the Liyang Guanghua Chemical Company, Ltd. will also generate two types of social impacts: displacement of workers of the Liyang Guanghua Chemical Company; potential public concerns over the remediation of the Liyang site. Social impacts on displaced workers are addressed by compensation plan and re-training discussed in more details in the Social Assessment Report of the EIA.

27. To alleviate possible public concerns over the site remediation operation may stem from unusual activities at the site (workers in protective gear and respirators demolishing otherwise perfectly sound buildings), a public information campaign will be implemented prior and during the clean up operations. The campaign will target the nearby residents to explain what activities are going on at the site and why.

Mitigation Measures Associated with Remediation Activities

28. All the mitigation measures will strictly follow the national regulation on the hazardous waste and hazardous cargo including the Standards for Hazardous Cargo

Categorization and Numbering (GB 6499-86); the Standards for Hazardous Cargo Labeling (GB 190-85); the Standards for Markers for Packaging, Storage and Transportation (GB 191-85); the Standards for Receipt/Departure Labeling for Transportation (GB 6833-86); the Regulation on Hazardous Material Transportation by Vehicle (JT 3130-88); the Standards for Labeling of Hazardous Material Transportation Vehicles (GB13392); the Management Regulation on Road Transportation of Hazardous Material; the Permit Management Method for Hazardous Waste Business; etc.

29. Site cleanup supervision will be carried out during the whole cleanup process.

30. To avoid secondary pollution to the surface water, air, soil, ground water and other surroundings on-site, effective measures should be taken during the clean up work including dismantling of production equipment and buildings and excavation and removal of contaminated soil on the site. Measures such as set up of windproof and rainproof shed, leakage-proof ground and water collection ditches, need to be taken to prevent leaching, dust diffusion, raining, and rain water run off from jeopardize the site remediation.

31. The containers for wastes should meet the standards for hazardous waste containers to prevent leakage and diffusion of waste from containers. Each container with wastes from the site will be labeled with detailed information on the name of the site, waste contained in the container (such as characteristics of wastes, emergent and remedial measures for accidental leakage and diffusion, and weight).

32. Transport of hazardous wastes from the site to a disposal center or landfill will be closely supervised. Hazardous wastes manifests will be filled and submitted for approval to environmental protection authorities in Changzhou and the municipality where the hazardous wastes will be disposed. The drivers, loading personnel and supervisors will be trained in regard to the hazardous features of the wastes, the properties of containers, and emergent and remedial measures for accidental leakage and diffusion. Necessary personal protection equipment (including clothing) and emergency treatment equipments will be prepared. The transportation of hazardous wastes will conform to the requirement of the Regulation on Hazardous Waste Transportation Manifest and other relevant regulations.

33. Information and warning signs will be installed at the Liyang Guanghua site, disposal sites, and treatment sites of hazardous waste based on the requirements of environmental protection authorities.

34. Equipment, containers, packages and other materials used for the collection, storage, transportation and disposal of waste should be treated and decontaminated before other use.

35. The following table summarizes identified impacts related to the closure of the Liyang Guanghua Chemical Company Ltd. and the remediation activities to be carried out at the Liyang Guanghua site. Figure 8-1 shows the site cleanup plan.

Table 0-3 Cleanup, Environment Danger and Mitigation Measures

Activities		Environment impacts	Mitigation Measures
Liquidation of stockpile raw materials and products		1. Spill and leakage of container during storage; 2. Accident during transportation from the site to new owners	Strictly follow the national regulations on proper handling of hazardous chemicals.
Closure of the Liyang Guanghua Company		1. Displacement of workers of the Liyang Guanghua Chemical Company; 2. Potential public concerns over the remediation of the Liyang site.	Social impacts on displaced workers are addressed by compensation plan and re-training discussed in the Social Assessment Report of the EIA; Public information campaign prior and during the clean up operations.
Remediation Activities	Contaminated soil: to be excavated and landfilled; Asbestos insulation materials: to be removed and landfilled; Production Equipments: to be dismantled and landfilled; Contaminated construction materials: to be dismantled and landfilled; Dicyclic polymer waste residue: landfilled;	1. Release of contaminated dusts; 2. Accidents during transportation to the landfill; 3. Leachate from landfill 4. Noise, air pollution and wastewater	Contract the licensed hazardous waste management company to perform the task; Require protective clothing and respirators for workers; Follow strictly the Regulation for Safe Management of Hazardous Chemicals and the Management Regulation on Hazardous Wastes Manifests, and use sealed hazardous waste containers to transport wastes. Landfill at a licensed hazardous waste landfill. Follow strictly the Standard for Pollution Control at Hazardous Waste Landfill (GB18598-2001) to manage the landfill. Use low-noise equipments and work only during day time to avoid disturbing local residents. Collect and transport wastewater to a licensed industrial wastewater treatment plant.
	Packaging materials: pressure rinse with water, and then re-use or disposal	1. Rinse water;	Contract the licensed hazardous waste management company to perform the task; Rinse water to be disposed of at a licensed industrial wastewater treatment plant.

Activities		Environment impacts	Mitigation Measures
	General construction materials: dismantled and landfilled	1□Noise 2. Leachate from landfill	Contract the licensed hazardous waste management company to perform the task; Landfill at a licensed landfill and follow strictly proper landfill procedure (Pollution Control Standards for Hazardous Wastes Landfill, GB 18598-2001). Use low-noise equipments and work only during day time to avoid disturbing local residents
	Contaminated wastewater and sludge: to be treated at a licensed industrial wastewater treatment plant	1. Sludge and air pollution 2. Transportation accidents	Contract to the licensed industrial wastewater treatment plant with technology suitable for chlordane and mirex treatment and ensure emission standards are met. Strictly following the Regulation for Safe Management of Hazardous Chemicals and the Management Regulation on Hazardous Wastes Manifests.

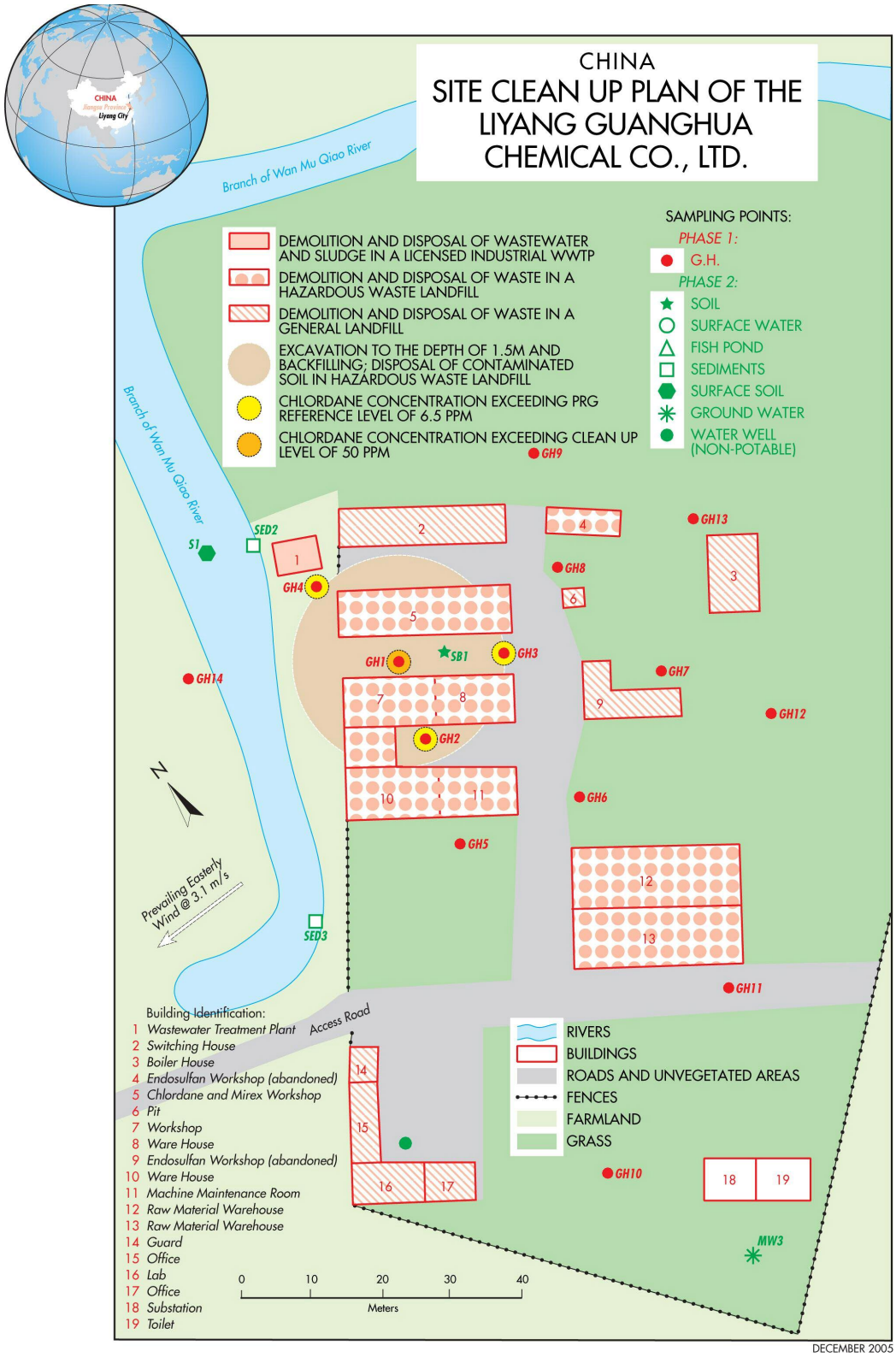

Figure 8-1 Site Clean Up Plan of the Liyang Guanghua Chemical Company, Ltd.

Monitoring Plan

36. **Monitoring Implementation Unit.** According to the result of bidding, the project implementation unit will select qualified organizations to monitor the mitigation activities. Detailed requirements for contractors' qualifications will be provided in the bidding documents for the cleanup activity.

37. **Environmental Monitoring Plan**

38. Environmental Monitoring Parameters. The target pollutants to be controlled under the proposed project are chlordane and mirex according to the requirements of the Stockholm Convention. Chlordane and mirex are selected as environmental monitoring factors and periodical monitoring should be carried out in the process of and after the closure of the plant and clean up of pollutants to monitor the effects of mitigation measures and propose corresponding measures for possible problems appeared.

39. Monitoring Method. The monitoring method adopted by this EIA will be used. In other words, the analysis method of chlordane and mirex is according to the requirement of "Organic Compounds-LSE/cap col GC/MS of EPA525".

40. Monitoring Position.

(1) Soil: About thirty composite soil samples at 10 cm below the excavation level at the excavation site. About five additional soil sampling poijnts around the site will be monitored. These will include a sampling point placed just north of the switching house (between the switching and the MW7), sampling point placed between MW5 and MW7, sampling point placed about twenty meters west to S1, sampling point placed 40 meters south to the third, and sampling point placed 40 meters east to GH12. At selected sampling points, samples will be taken from depth below 2 meters, to confirm that the concentration in greater depths is acceptable (particularly in respect to mirex, which measured relatively high concentration registered at 2 m depth at GH2)

(2) Potentially affected people: Two randomly selected workers for the contractor and two randomly selected residents from neighboring communities will be monitored.

(3) Biological sample: 2 fish samples in the fishpond out of the northern boundary of the plant will be monitored untill the fishpond is filled.

(4) Fishpond Water: Water in the fishpond out of the northern boundary of the Liyang facility will be monitored till the fishpond is filled. The sampling scheme is the same as that adopted by EIA.

(5) Surface Water: The sampling scheme is the same as that adopted by EIA (referring to Fig. 3-1 of environmental status monitoring location for surface water).

(6) Ground Water: The sampling scheme is the same as that adopted by EIA (referring to Fig. 3-1 of environmental status monitoring location for groundwater). In addition, two additional samples will be taken between the switching house and the MW7 and between MW5 and MW7.

41. Monitoring Frequency

(1) Soil: After the remediation, take samples to confirm contaminated soil has been removed to the levels lower than the cleanup levels.

(2) Potentially affected people: Before and after the remediation, monitor the selected contractor's workers and residents (testing their fat) from neighboring communities to investigate the impact of chlordane and mirex.

(3) Biological sample: Monitoring crabs (tissue sample) once every three months until the fishpond is closed down.

(4) Fishpond Water: Monitoring the water of fish pond once every three months until the fishpond is closed down.

(5) Surface Water: After the remediation, continue monitoring of ground water once every three months within two years.

(6) Ground Water: After the remediation, continue monitoring of ground water once every three months within two years.

42. Annual monitoring report will be submitted within project period. Monitoring results will be carefully reviewed and evaluated. Any abnormality in the monitoring results will lead to further monitoring requirements, and if necessary, additional institutional control actions will be proposed based on the evaluation of monitoring data.

Institutional Arrangements

43. **National Management Institutions.** At the national level, the management institutions are NIP Leading Group and Convention Implementation Office (CIO) of State Environmental Protection Administration (SEPA), which are responsible for the daily leading and management work on the proposed demonstration project respectively.

44. **Local Management Institutions.** At the local level, the management institutions are Jiangsu Provincial Steering Group and Jiangsu Provincial Project Implementation Unit (PIU), which are responsible for the leading and management of this demonstration project respectively.

45. **Supervision Institutions.** The supervision institutions are provincial authorities related to environmental protection, fire prevention and public security, etc. The expert team is in charge of technical supervision.

46. **Implementation Institutions.** The contractors will be selected based on the bid evaluation and consistent with WB's procurement guideline.

47. **Expert Team**. An expert team will be established and take responsibility to prepare tendering documents, review documents and remediation Option, train staff and supervise the implementation of the monitoring Option and remediation Option, etc.

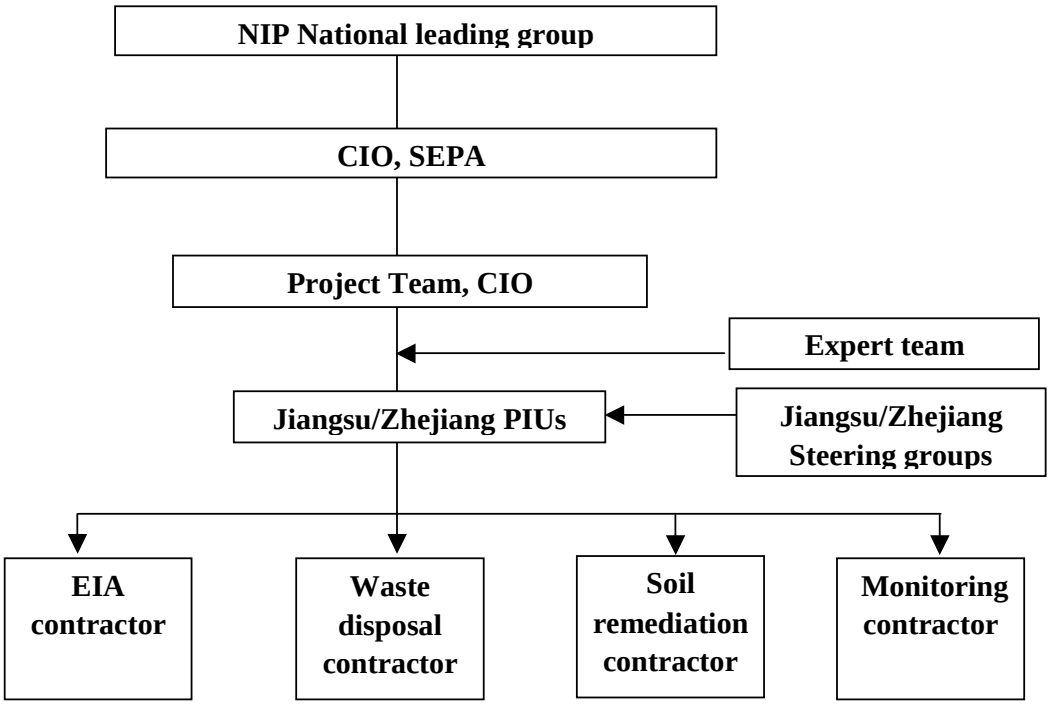

Figure 0-2 Organizations for Implementing Site Cleanup Plan

Implementation Arrangement

48. PIU will prepare a detailed implementation plan for the clean-up of the Liyang Guanghua site. The plan will cover details of site clean up, as well as transport of hazardous waste for disposal, and final disposal. This implementation plan will be submitted to the World Bank for review. After agreed by the World Bank, PIU will carry out of this implementation plan under the guidance of the CIO and the expert team. PIU will hire an independent supervision engineer to supervise site cleanup activities. The responsibility of the independent supervision engineer will be clearly defined by a terms of references approved by the Bank.

Institutional Controls of the Use of the Site

49. After the cleanup activities are completed at the Liyang site, the following institutional controls of the use of the site shall be instituted:

(1) The future use of the site as an industrial zone will be strictly enforced by the Liyang City land use planning and zoning authorities to ensure that the site will continue to be used for industrial purposes only;

(2) The fencing, gate and guard station at the site will be maintained and repaired if necessary. Warning signs prohibiting access to the site will be posted on the perimeter and at the entrance.

(3) The branch of Wanmuqiao River which received effluent from the waste water treatment plant will be sign-posted to warn that the water should not be used for swimming, fishing, irrigation or other similar uses.;

(4) A “non-portable” warning sign shall be installed at the ground water well on the site.

(5) All signs will refer to local regulations and fines, and will contain a phone number for the Environmental Protection Bureau and the Public Security Bureau for reporting of violations.

Capability Building and Training Program

50. **Capability Building.** Since the proposed demonstration project is exploratory in nature and China lacks experiences and capacities in site cleanup management presently, in-class and on-the-job training and study tour will be conducted.

51. **Training Program.** In-class and on-job training will be organized, international and domestic experts will be invited as instructors. Trainees should include but not limited to project managers, consultants, and construction managers, technicians, monitoring staff, supervisors and environmental administrators. Four trainings will be organized on (1) laws and regulations, (2) technical guidance and standards, (3) safety knowledge, and (4) vocational sanitation protection and emergency aid. About 15 trainees will participate in each training, and 60 trainees will participate in four trainings.

52. A study tour for short-term training will be organized. The delegation for the study tour will have 8 members.

Implementation Schedule

53. The implementation period of the mitigation measures is 3 years, from the initiation of the closure of Optiont to the end of the implementation of the monitoring Option, including the post environmental management and monitoring. Detailed schedule see Table 8-4.

Cost Analysis

54. The budget for mitigation measures is detailed in Table 8-5.

Table 0-4 Schedule for Mitigation Measures

Activities		Year 1												Year 2												Year 3											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Preparation period	Bidding and recruiting the contractor	□																																			
	In-class and on-the-job training and study tour		□	□																																	
	Apply for approval of declaration, registration, and permission.			□																																	
	Monitoring of workers for the contractor and local villagers.				□																																
Construction period	Setup of equipments and facilities on rainproof, leakage-proof, wind-proof, disposal of exhaust gas and collection of liquid waste.				□																																
	Liquidation of stockpile raw materials and products, as well as washing of polluted					□																															

	Activities	Year 1												Year 2												Year 3											
		1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
	Dismantling, washing, transporting and disposing of polluted equipments;					□																															
	Dismantling, washing, transporting and disposing of polluted workplace						□ □																														
	Remediation of contaminated soil							□ □																														
	Monitoring of soil								□																													
Post Cleanup Period	Monitoring of crab and water in the fishpond								□			□			□			□			□			□			□			□			□			□		
	Monitoring of workers for the contractor and local villagers.								□																													
	Monitoring of surface water and groundwater.								□			□			□			□			□			□			□			□			□			□		
	Transportation of the waste to disposal sites				□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□	□											
	Detailed recording and filing	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬	▬

Table 0-5 Budget for Mitigation Measures

Activities	Description	Unit Cost	Cost (US$)
Site cleanup	**All activities – see Table 8-2**	**n/a**	1,080,000
Expert Team	Prepare tendering documents, review documents and remediation plan, train staff and supervise the implementation of the monitoring plan and remediation plan, etc. It is estimated that 3 experts and 100 days each expert are needed.	US$ 125 per day per person	37,500
Site maintenance	Carry out security and maintenance work during and post the cleanup within 3 years, 3 workers will be recruited.	US$ 6,000 per person per year	18,000
Environ-mental Monitoring	Totally 10 times monitoring of soil, surface water, groundwater, fish and water in fishpond, as well as workers for contractor and local villagers.	US$ 5,000 per time	50,000
Trainings and study tour	4 trainings, totally about 60 participants, 3 days for per training, 1 overseas study tour, 8 participants; 3 foreign experts to China	Trainees: US$60/person Overseas study tour: US$ 6,000 per person; International experts: US$12,500 per experts	89,100
Site Cleanup Supervision Engineer	Supervision and detailed recording and filing for dismantling, cleanup, waste treatment and disposal, and storage site maintenance, within 3 years, 1 supervision engineer will be recruited.	Staff: US$ 6,000 per person per year; Equipment: US$ 5,000	23,000
Post-appraisal	Compilation of project interim report and post-appraisal report on Environmental Impact Assessment	US$ 25,000 per report	50,000
Contingency	Environmental administrative costs within 3 years	5% of above costs	67,380
Total Costs (in USD)			**1,414,980**

Reporting

55. The reporting on the progress of site clean up, waste disposal and post-cleanup monitoring will be an integral part of the regular Demonstration Project reporting (see Project Appraisal Document for detailed description of the Component 6 which deals with monitoring and evaluation). The Jiangsu Project Implementation Unit will be the key project body responsible for the reporting. The site cleanup reporting will include the following:

a) report on preparation of the TOR for the hazardous waste disposal company to carry out the cleanup

b) report on pre-qualification and selection of the hazardous waste disposal company (contractor)

c) report on pre-cleanup briefing, training and any other preparatory capacity building that the contractor will receive

d) report on pre-cleanup training and capacity building that the project personnel (staff of PIU and others involved in supervision of the cleanup) will receive to carry out informed supervision of the clean-up

e) report of the clean-up operation while ongoing; these short operational reports will be generated on a weekly basis between the start and the end of the cleanup and provided to the PIU

f) daily log, maintained by the contractor, and a separate daily supervision log maintained by the project personnel; these logs will be on file with the PIU

g) record of receipt from the centralized waste disposal facilities, e.g., sanitary landfill or industrial wastewater treatment plant, which will accept the waste from the site

h) clean up completion report, complete with disposal certificate from EPB, at the completion of the clean up and decommissioning of the site

i) post-clean up monitoring report at the time when post-clean up samples are analyzed and interpreted by an independent lab.

Public Participation

Legal Basis for Public Participation

1. The main legal basis for public participation is as following:

   a. **"The Law of the People's Republic of China on Environmental Impact Assessment".** Article 21 of the "The Law of the People's Republic of China on Environmental Impact Assessment (EIA Law)" (September 1, 2003) specifies that for the construction projects that may possibly cause major impact on environment and for which environmental impact statement should be compiled, except the situations of confidentiality specified by our country, the client shall hold demonstration meeting and hearing or use other forms to seek opinions from related organizations, experts and the public before submitting the construction project environmental impact statement for approval. The environmental impact statement submitted by the client shall be attached with description for adoption or refuse of the opinions from related organizations, experts and the public.

   b. **"Rules of Environmental Protection Management of the Construction Project".** Article 15 of the "Rules of Environmental Protection Management of the Construction Project" (Decree No.253 of the State Council of the People's Republic of China, November 29, 1998) specifies that in compiling environmental impact statement, the client shall seek opinions from related organizations and residents in the place of construction project according to related laws.

Public Participation/Consultation and Information Disclosure of the Project

2. **Purpose of Public Participation/consultation**. Public participation is a two way exchange between the project implementation unit or environmental impact assessment working group and the public, it is essential to the decision making and successful implementation of the project scheme. Through public participation, it is possible to report the specific situation of the project to the public completely at any time to:

   a. enable the public in the project affected area and particularly the people in the surrounding region of the project to promptly know information on the basic project situation and environmental problems including project survey, potential major environmental project influence and its solution, alternative scheme and mitigation measures;

   b. enable the public to have opportunities to express their opinions through normal channel and know the protection objectives or the issues cared mostly

by the public;

c. let the public to help identify the major and particularly many potential environmental problems possibly caused by the project so that appropriate measures can be taken to effectively protect sensitive protection objectives;

d. actively seek the public's opinions and suggestions on the project and pool the wisdom of the collective to find basis for safeguarding the public's vital interests;

e. enhance the social acceptability of the project environmental impact assessment and ensure the feasibility and rationality of environmental protection measures to make the project design, construction and operation management more complete and rational;

f. enable the public to supervise the implementation of the environmental protection measures for the project construction and make the public's various opinions and suggestions on the project as the supplementary basis for the environmental supervision and management; and

g. enable the project to be sufficiently recognized by the public and not to constitute hazard or threat to the public interests so as to realize the unification of economic benefit, social benefit and environmental benefit.

3. Public Consultation prior to the final EIA. There are two stages:

a. 1st stage -- public consultation. Prior to completion of the draft environmental impact assessment report, internet is used to provide some information to the public possibly affected by the project, including basic project situation, possible environmental impact and arrangement of project environmental assessment work. Such information was published on the official website of Jiangsu Department of Environmental Protection. At the same time, to know the public's attitude towards the project and their requirements for and suggestions on the project and environmental protection through field visit or questionnaire issuance to try to collect as many rational suggestions useable to this project as possible.

b. 2nd stage -- town hall meeting. After completion of draft environmental impact assessment report, (and following the World Bank review of the draft EIA at a safeguards meeting) publish draft report and the environmental protection counter-measures and means taken to reduce major pollution problems and hold meetings to seek the public opinions.

4. **Target groups.** Target groups include management personnel and workers of Liyang Guanghua Chemical Co. Ltd, residents near the company, owners of surrounding fish ponds and related personnel of government sectors etc.

5. **Information Disclosure.** Information release is also divided into two stages:

   a. Prior to drafting of the EIA. To release basic information of this project on the Jiangsu Environmental Protection Department Website, with brief description of the project as the main content, to tell the public that the environmental impact assessment of this project is under way, to seek the public opinions, welcome suggestions on this project, propose the issued concerned and publish the personnel and telephone number of the environmental impact assessment group.

   b. At the draft EIA stage. The draft EIA is released on the Jiangsu Environmental Protection Department Website and seeks extensive opinions from all walks of life.

Analysis of the First Round Public Participation

6. **Survey Methodology.** Public participation in the first stage was carried out in the combined form of questionnaire and field visit in April to May 2005. Random sampling was used to inquire the public with different occupations and different educational attainments, at different ages and in different areas and introduce to them the major project contents including international conventions, demonstration projects, general situation of this project and possible environmental impact. The "Demonstration Project of Alternative to Chlordane and Mirex in Termite Control in China – Public Participation Questionnaire of the Closure and Cleanup of Liyang Guanghua Chemical Products Co. Ltd – was filled in and the specific survey situation is shown in Table 9-1. The important contents not involved in the first stage (e.g. whether the inquired residents suffered the harm of its products or production process etc) will be supplemented in the second stage of the public participation.

Table 0-1 Public Participation Survey Methods in the First Stage

Stage	Time	Place	Number of persons consulted	Survey method	Information Disclosure
First stage	April 2005	The Development Zone, Niucheduo Nanfang Village, Yangzhuang Village, Shugang Village	32	Field visit and questionnaire survey	Released on Jiangsu Environmental Protection Bureau Website (http://www.jshb.gov.cn)
	May 2005	Niucheduo, Nanfang Village, Yangzhuang Shugang Village	31	Field visit and questionnaire survey	

7. **Target groups.** Among about 240 people in the study, 63 of them were consulted via two round questionnaires. The target groups are people in the study area including workers, peasants, technicians and management personnel (civil servants, teachers etc).The project team went to study area and informed them about the closure of the factory. These people were asked to fill up the questionnaires at the same time. The overall return rate is 100%. The first round consulted 32 people, while the second round consulted 31 people.

Table 0-2 Basic Information of Target Groups in the First Survey

Situation		Public participation Subjects			
Gender	M	(17 persons) 53%			
	F	(15 persons) 47%			
Age		20~40	40~60	Above 60	
		(13 persons) 41%	(17 persons) 53%	(2 persons) 6%	
Educational background		Primary school and below	Junior high school	Technical secondary school and senior high school	Junior college
		(7 persons) 22%	(17 persons) 53%	(6 persons) 19%	(2 persons) 6%
Occupation		Technician	Management personnel	Worker	Peasant
		(3 persons) 9%	(5 persons) 16%	(5 persons) 16%	(19 persons) 59%

Table 0-3 Basic Information of Target Groups in the Second Survey

Situation		Public participation Subjects			
Gender	M	(20 persons) 65%			
	F	(11 persons) 35%			
Age		20~40	40~60	Above 60	
		(9 persons) 29%	(16 persons 52%)	(6 persons) 19%	
Educational background		Primary school and below	Junior high school	Technical secondary school and senior high school	Junior college
		(7 persons) 22%	(18 persons) 58%	(3 persons) 10%	(3 persons) 10%
Occupation		Technician	Management personnel	Worker	Peasant
		(2 persons) 6%	(3 persons) 10%	(6 persons) 19%	(20 persons) 65%
Remarks		Including managers, employees of Guanghua Chemical Industry Co. Ltd and two fish pond contractors			

8. **Survey Results and Analysis**. Results of the two surveys are shown in Tables 9-4 and 9-5.

Table 0-4 Result of the First Survey

Content of questionnaire	Result analysis			
Are you satisfied with the environmental quality?	Very satisfied	Moderately satisfied	Unsatisfied	Very unsatisfied
	0	24	7	1
	0	75□	22□	3□
Do you know or know of this project?	No	A little	Yes	-
	4	20	8	-
	12.5□	62.5□	25□	-
Through which channel do you know the information on this project?	Newspaper	TV, broadcast	Billboard	Folk information
	1	5	11	15
	3□	16□	34□	47□
Do you think the implementation of this project will improve the environment?	Yes	No	-	-
	19	13	-	-
	59%	41%	-	-
Do you think the environment in the project location is polluted?	Yes	No	Not clear	-
	11	8	13	-
	34%	25%	41%	-
Do you think the implementation of the project will have influence on your life or work?	No	Minor influence	Major influence	-
	4	24	4	-
	12.5%	75%	12.5%	-
What factors of the project implementation do you think will influence your normal life or work?	Factory close down	Site clean-up	Others	No answer
	5	21	0	6
	16□	66□	0	18□
What altitude do you hold towards this project?	Absolute support	Conditional approval	Indifference	Objection
	18	4	10	0
	56.25□	12.5□	31.25□	0

Table 0-5 Result of the Second Survey

Content of questionnaire	**Result analysis**				
Are you satisfied with the environmental quality?	Very satisfied	Moderately satisfied	Unsatisfied	Very unsatisfied	
	0	11	8	12	
	0	35□	26□	39□	
Do you know or know of this project?	No	A little	Yes		
	13	13	5		
	42□	42□	16□		
Do you think the environment in the project location is polluted?	Yes	No	Not clear		
	29	1	1		
	94%	3%	3%		
What factors of the environment in the project location do you think are polluted?	Water	Air	Soil	Crops	
	21	21	19	23	
	68%	68%	61%	74%	
Do you think the implementation of this project will improve the environment?	Yes	No	No improvement in the near future		
	30	0	1		
	94%	0	6%		
Do you think the implementation of the project will have influence on your life or work?	No	Minor influence	Major influence		
	22	3	6		
	71%	10%	19%		
What factors of the project implementation do you think will influence your normal life or work?	Factory close down	Site clean-up	Construction	Farmland cultivation	Others (thought to have no influence)
	5	0	0	0	26
	16%	0	0	0	84%
What altitude do you hold towards this project?	Absolute support	Conditional approval	Indifference	Objection	
	27	2	2	0	
	87□	6□	6□	0	

9. Analysis of survey data from two round questionnaires indicates that:

a. The satisfaction degree of the public with the existing environment in the project location. Of the respondents, 35 were moderately satisfied with the local environmental quality, 15 were unsatisfied and 13 were very unsatisfied. The main reason is that the surrounding environment was thought to be polluted.

b. The public's knowledge degree of this project. 13 (21%) of the respondents knew this project, 33 knew a little (52%), and 17 (27%) knew nothing. Obviously, this project has received extensive attention from the public, but it is necessary to further increase the publicity of this project.

c. The public's support degree for this project. 45 (71%) people supported the project,10% expressed conditional approval, 19% showed indifference and nobody objected it.

d. The suggestions and requirements of the public for this project. 26 people thought that the implementation of this project would have no influence on their own normal work and life, 27 thought the influence would be insignificant and 10 thought the influence would be significant. The major influences are noise arising from site clean-up and unemployment resulting from factory close-down. The employees of Guanghua Chemical Products Co. Ltd hope that workers will be properly arranged after factory close-down. The public hopes that during the project implementation, the rules and regulations related to environmental protection are strictly executed, necessary environmental protection measures are taken and discharge of noise and pollutants reach various environmental standards to minimize the possible impact on environmental and human health.

Analysis of the Second Round Public Consultation

10. **Survey Methodology**. The second round of public consultation will be conducted in the form of town or village meetings in November 2005 to release the conclusion of project environmental impact assessment and environmental protection countermeasures and means to be taken to reduce major pollution problems and to seek the public opinions.

11. **Analysis of Survey Objects.** (To be added after the second round of public consultations.)

12. **Survey Results and Analysis.** (To be added after the second round of public consultations.)

Public disclosure

13. The EIA will be to be disclosed in the Jiangsu Environmental Protection Department Website and local public libraries. It may also be requested from the World Bank Infoshop in Washington, DC.

ANNEX 1: Chlordane and Mirex Producers in China

No.	Producers	Location	Chlordane Production	Mirex Production
1	Suzhou Jiangfeng Termite Control Company, Ltd.	Suzhou, Jiangsu	Yes	No
2	Liyang Guanghua Chemical Company, Ltd.	Liyang, Jiangsu	Yes	Yes
3	Taicang Xintang 2nd Chemical Factory	Suzhou, Jiangsu	Yes	Yes
4	Changzhou Yekang Chemical Products Company, Ltd.	Changzhou, Jiangsu	Yes	Yes
5	Shanghai Fengjiang Termite Control Materials Company, Ltd.	Shanghai	Yes	Yes
6	Liyang Xinhai Chemical Factory	Liyang, Jiangsu	Yes	Yes
7	Jintan Shuibei Termite Control Materials Factory	Changzhou, Jiangsu	Yes	No
8	Taicang Hushi Subsidary Company, Ltd.	Suzhou, Jiangsu	Yes	No
9	Dongtai 3rd Chemical Factory	Yancheng, Jiangsu	Yes	No

ANNEX 2: Additional Information on Chemicals at the Liyang Guanghua Site

Chlordane

1. Chlordane is a persistent organochlorine insecticide. It kills insects when ingested and on contact. Formulations include dusts, emulsifiable concentrates, granules, oil solutions, and wettable powders.

2. The oral LD50 for chlordane in rats is 200 to 700 mg/kg, in mice is 145 to 430 mg/kg, in rabbits is 20 to 300 mg/kg, and in hamsters is 1720 mg/kg. The dermal LD50 in rabbits is 780 mg/kg, and in rats is 530 to 690 mg/kg. The 4-hour inhalation LD50 in cats is 100 mg/L.

3. Chlordane is moderately to highly toxic through all routes of exposure. Symptoms usually start within 45 minutes to several hours after exposure to a toxic dose. Convulsions may be the first sign of poisoning, or they may be preceded by nausea, vomiting, and gut pain. Initially, poisoning victims may appear agitated or excited, but later they may become depressed, uncoordinated, tired, or confused. Other symptoms reported in cases of chlordane poisoning include headaches, dizziness, vision problems, irritability, and weakness or muscle twitching. In severe cases, respiratory failure and death may occur. Complete recovery from a toxic exposure to chlordane is possible if proper medical treatment is administered. Chlordane is very irritating to the skin and eyes. Chlordane affects liver function, so many interactions between medicines and this pesticide may occur. Among these are decreased effectiveness of anticoagulants, phenylbutazone, chlorpromazine, steroids, birth control pills, and diphenhydramine. Increased activity of thyroid hormone may also occur.

4. Chlordane is highly persistent in soils with a half-life of about 4 years. Several studies have found chlordane residues in excess of 10% of the initially applied amount 10 years or more after application. Sunlight may break down a small amount of the chlordane exposed to light. Evaporation is the major route of removal from soils. Chlordane does not chemically degrade and is not subject to biodegradation in soils. Despite its persistence, chlordane has a low potential for groundwater contamination because it is both insoluble in water and rapidly binds to soil particles making it highly immobile within the soil. Chlordane molecules usually remain adsorbed to clay particles or to soil organic matter in the top soil layers and slowly volatilize into the atmosphere. However, very low levels of chlordane (0.01 to 0.001 ug/L) have been detected in both ground and surface waters in areas where chlordane was heavily used. Sandy soils allow the passage of chlordane to groundwater.

5. Chlordane does not degrade rapidly in water. It can exit aquatic systems by adsorbing to sediments or by volatilization. The volatilization half-life for chlordane in lakes and ponds is estimated to be less than 10 days. Chlordane has been detected in surface water, groundwater, suspended solids, sediments, bottom detritus, drinking water, sewage sludge, and urban run-off, but not in rain water. Concentrations detected in surface water have been very low, while those found in suspended solids and sediments are always higher (<0.03 to 580 ug/L). The presence of chlordane in drinking water has almost always been associated with an accident rather than with normal use.

Mirex[27]

6. Mirex is a bait insecticide used against a number of insect pests. It had been used heavily in South America and South Africa. Secondary use of mirex as a fire retardant in plastics, paints, and electrical goods is currently heavily restricted or banned in most countries. Mirex is highly resistant to biodegradation and has a half-life of up to ten years in sediment. In the presence of sunlight, mirex breaks down to a fare more potent toxin, photomirex. Mirex is known to be one of the most stable and persistent pesticides. Mirex has been detected in Arctic freshwater, terrestrial organisms and in core sediment samples in Lake Ontario. It had also been found in lake trout captured in Lake Ontario, in fathead minnows and beluga whale oil from the St. Lawrence River.

7. Mirex levels in human milk are above average for communities consuming high amounts of fish and sea bird eggs. Levels in the milk of Inuit from Nunavik, northern Quebec, are 10 times higher than those in southern Canadian residents. Even higher concentrations of Mirex are seen in fat tissue from Greenland Inuit.(WFPHA, World Federation of Public Health Associations, 2000).

8. There have been few studies on human exposures, and little data exists for human health effects of mirex. Animal studies have shown several adverse reactions to mirex doses administered through diet. In rats, mirex exhibits toxic effects on fetuses, including cataract formation and it caused liver hypertrophy following long-term, low-dose exposure in rats. Mirex is also associated with suppression of the immune system. (WFPHA, 2000).

9. Mirex is a highly stable insecticide formerly used for fire ant control in the southeastern US. Mirex was also employed as a flame-retardant. Release into the environment has occurred via effluents from manufacturing plants and sites where mirex was utilized as a fire resistant additive to polymers, and at points of application where it was used as a insecticide. Mirex is expected to persist in the environment despite the 1978 ban on its use in the US. For the most part mirex is resistant to biological and chemical degradation. Photolysis of mirex may occur. However,

[27] *http://www.speclab.com/compound/c2385855.htm*

sorption is likely to be a more important fate process. Persistent compounds such as kepone, and monohydro- and dihydro- derivatives of mirex have been identified as products of extremely slow transformation of mirex. Mirex has been shown to bioconcentrate in aquatic organisms. A Koc value of 2.4X10 7 indicates mirex will strongly adsorb to organic materials in soils and sediments. Therefore mirex is expected to be immobile in soil and partition from the water column to sediments and suspended material. A Henry's Law Constant for mirex of 5.16X10-4 atm-cu m/mole at 22 deg C suggests rapid volatilization may occur from environmental waters and moist soils where absorption does not dominate. Based on this Henry's Law Constant, the volatilization half-life from a model river (22 deg C; 1 meter deep flowing 1 m/sec with a wind speed of 3 m/sec) has been estimated to be 10.7 hr; however, this estimation neglects the potentially important effect of adsorption. The volatilization half-life from an environmental pond, which considers the effect of adsorption, can be estimated to be about 1143 years.

Hexachlorocyclopentadiene[28]

10. Hexachlorocyclopentadiene is an intermediate in the manufacture of some pesticides. Hexachlorocyclopentadiene is very toxic following acute (short-term) oral and inhalation exposures. The chemical is a severe eye, skin, and pulmonary irritant in humans, with effects including tearing of the eyes, sneezing, salivation, blistering, burns, and cough from acute exposures. Limited information is available on chronic (long-term), reproductive, developmental, and cancer effects of hexachlorocyclopentadiene in humans. Animal studies have seen effects on the lung, liver, kidney, and blood. EPA has classified hexachlorocyclopentadiene as a Group D, not classifiable as to human carcinogenicity.

11. Hexachlorocyclopentadiene is the key intermediate in the manufacture of some pesticides, including heptachlor, chlordane, aldrin, dieldrin, and endrin. (5, 6)

12. Hexachlorocyclopentadiene is also used in the manufacture of flame retardants and some resins and dyes. (1, 8)

Sources and Potential Exposure

13. Workers involved in the manufacture of hexachlorocyclopentadiene and during the manufacture of products containing the chemical would have the highest exposure to hexachlorocyclopentadiene. (1, 9)

14. Hexachlorocyclopentadiene has been detected at low levels in ambient air. The sources of the chemical in air appear to be releases from manufacturing processes or incineration and landfilling of waste containing hexachlorocyclopentadiene. (1)

[28] http://www.epa.gov/ttn/atw/hlthef/hexa-die.html

Assessing Personal Exposure

15. Laboratory tests can detect hexachlorocyclopentadiene in blood or urine. (1, 9)

Health Hazard Information

16. Acute Effects:

- Hexachlorocyclopentadiene is very toxic to humans. (2)
- Hexachlorocyclopentadiene is a severe eye, skin, and pulmonary irritant in humans. Inhalation of the chemical causes tearing, sneezing, and salivation, and skin contact can cause blisters and burns. (1, 3)
- The major target organ for acute hexachlorocyclopentadiene toxicity is the lung, with cough, chest pains, and difficulty in breathing reported in humans. Nervousness, headaches, and abdominal cramps are other symptoms reported from hexachlorocyclopentadiene toxicity. (1, 3)
- Tests involving acute exposure of rats have shown hexachlorocyclopentadiene to have extreme toxicity by inhalation exposure, moderate toxicity by oral exposure, and high to extreme toxicity by dermal exposure. (3, 4)

17. Chronic Effects (Noncancer):

- Epidemiologic studies on workers have not shown any significant differences in mortality between workers exposed to hexachlorocyclopentadiene and those in the general population. However, these studies are limited by short follow-up periods, lack of data on cigarette smoking, and other factors. (1, 2)
- Chronic exposure to hexachlorocyclopentadiene, via inhalation, has been studied in animals, with effects noted in the lung, liver, kidney, and blood. (1, 3, 9)
- EPA has established a Reference Concentration (RfC) of 0.0002 milligrams per cubic meter (mg/m^3) for hexachlorocyclopentadiene, based on respiratory effects in rats. (2)
- The Reference Dose (RfD) for hexachlorocyclopentadiene is 0.006 milligrams per kilogram body weight per day (mg/kg/d) based on stomach lesions in rats.
- The RfC and RfD are not direct estimators of risk but rather reference points to gauge the potential effects. At exposures increasingly above these levels, the potential for adverse health effects increases. Lifetime exposure above the RfC or RfD does not imply that an adverse health effect would necessarily occur. (2)

Carbon Tetrachloride[29]

[29] *http://www.chemicalland21.com/industrialchem/organic/CARBON%20TETRACHLORIDE.htm*

18. Carbon Tetrachloride, also called tetrachloromethane, is a colorless, dense, highly poisonous, highly volatile and nonflammable liquid with a characteristic aromatic odor, belonging to the family of organic halogen compounds. Carbon tetrachloride freezes at -23 C and boils at 77 C. It is sparingly soluble in water. When heated to decomposition, it forms highly toxic fumes of phosgene and hydrogen chloride. It is prepared by the reaction of chlorine with carbon disulfide or with methane in the presence of a catalyst. It is used principally in the manufacture of freon refrigerants e.g., dichlorodifluoromethane (Freon-12) and propellants for aerosol cans. Carbon tetrachloride is known to deplete the ozone layer. Its half-life is more than 30 years. It was used as a dry cleaning solvent and for degreasing metals as it is not flammable and is a good solvent for fats, oils, and greases. Due to the property of much denser than air, it is used in fire extinguishers in mixtures with potent fumigants to reduce the fire hazard, to render benzene nonflammable and separate xylene isomers as components to reduce flammability. In veterinary medicine, it is used as an anthelmintic and to treat liver fluke infections in sheep. In polymer industry, it is used as a reaction medium, catalyst and chain transfer agent, as a solvent for resins. In organic synthesis, it is useful as a feedstock for chlorination of organic compounds used in soap perfumery and insecticidal industries. In automobiles, it is used as an azeotropic drying agent for wet spark plugs. It is also used in petroleum refining, pharmaceutical manufacturing, and general solvent use.

Annex 3: QA/QC for Monitoring and Analysis

First Phase Monitoring:

Laboratory Quality Assurance System and Control Measures (QA/QC)

1. The quality assurance of this monitoring follows the *Quality Manual* developed by the Monitoring Center of Jiangsu Province. 20% of duplicate sample and 10% of matrix spike sample or standard sample is needed for wastewater sample. All monitoring staff have passed related examinations and hold certificates. All equipment is certificated by a metrology institution. All field equipment is calibrated. Monitoring data is audited.

2. Analysis procedures are:

1) Water:

- Pass 1L of water sample through C_{18} SPE cartridge , elute the cartridge with methylene chloride
- Concentrate the elute to 1ml
- Analyze using GC/MS

2) Soil:

- Extract the 10g of soil sample with solvent of ethane/acetone (1:1) for 30 minutes using microwave equipment
- Wash the extracted solution with 10ml sulfuric acid, dry with sodium sulfate
- Concentrate the extracted solution to 1ml
- Pass the concentrated solution to the 6ml(1g) of Floristic cartridge to remove interferences, elute with ethane/acetone solvent
- Concentrate to 1ml, add internal standard
- Analyze using GC/MS

- Quality control method

1) Sequence calibration

One concentration level of the standard solution is analyzed every 12 hours; the derivation should below 20%.

2) Contrast sample determination

Analyze the redistilled water or blank quartz sand with the same analysis procedure as the actual sample; no target compound is detected. The results are as follow:

Monitoring Factors	Results	
	redistilled water (ng/L)	blank quartz sand (mg/kg)
Chlordane	0.1L	0.01L
Mirex	0.1L	0.01L
Endosulfan	0.2L	0.02L
Hexachlorocyclopentadiene	0.4L	0.04L

3) Accuracy

Add 10,100,200 ng of standard to the redistilled water or blank quartz sand, the analysis results are as follow:

Compounds	Amount added Standard (ng)	Recovery(%)	
		water	soil
Chlordane	10	80.9	56.9
	100	95.8	76.9
	200	96.8	80.5
Mirex	10	85.9	60.9
	100	92.8	77.4
	200	99.2	95.8
Endosulfan	10	85.4	63.8
	100	92.9	69.5
	200	95.8	89.2
Hexachlorocyclopentadiene	10	85.9	50.8
	100	95.5	62.1
	200	96.9	90.6

The recovery of sample is as follow. The results meet the requirement of the accuracy and are acceptable.

Matrix	Monitoring Factors	Recovery/(%)
water	Chlordane	82.3~89.6
	Mirex	89.6~90.3
	Endosulfan	90.6~94.9
	Hexachlorocyclopentadiene	86.1~95.9
soil	Chlordane	60.5~75.9
	Mirex	62.3~72.9
	Endosulfan	70.5~80.9
	Hexachlorocyclopentadiene	58.9~75.9

4) Precision

Add 10, 100, 200ng of standard to the redistilled water or blank quartz sand, repeat analysis 6 times, the results is like below:

Monitoring Factors	Amount added Standard (ng)	Coefficient of variation (CV%)		Permitted derivation (%)	
		water	soil	water	soil
Chlordane	10	1.5	3.6	15.2	20.2
	100	0.9	1.5	10.6	15.2
	200	0.2	0.5	20.4	20.5
Mirex	10	2.5	2.9	18.9	22.5
	100	0.5	1.0	20.8	25.9
	200	0.2	0.7	25.9	30.0
Endosulfan	10	1.5	2.5	20.5	16.3
	100	0.6	0.9	15.5	17.8
	200	0.2	0.5	17.9	18.8
Hexachlorocyclo-pentadiene	10	2.1	2.8	21.3	22.8
	100	0.5	1.6	20.5	25.8
	200	0.2	0.5	22.3	19.8

The coefficient of variation (CV) of sample is as follow. The results meet the requirement of the accuracy and are acceptable.

The repetition meets the requirement of the precision, the results are acceptable.

matrix	Monitoring Factors	CV (%)
water	Chlordane	0.9~1.0
	Mirex	0.8~1.5
	Endosulfan	0.9~1.0
	Hexachlorocyclopentadiene	0.5~0.7
Soil	Chlordane	2.0~2.2
	Mirex	1.9~2.0
	Endosulfan	0.9~1.2
	Hexachlorocyclopentadiene	0.7~1.0

5) Detection limit

The minimum quantification limit is 1ng/L for water and 0.1ug/kg for soil.

The standard derivation is calculated by seven analyzable results, which is 0.01~0.15 for water and 0.02~0.18 for soil. The detection limit is 3 times of the standard derivation (soil sample is calculated based on 10g).

Monitoring Factors	Detection limit	
	Water (ng/L)	Soil (μg/kg)
Chlorodane	0.1	0.01
Mirex	0.1	0.01
Endosulfan	0.2	0.02
Hexachlorocyclopentadiene	0.4	0.04

6) Apparatus Check-up

The transfer rate from DDT into DDD should not be higher than 20%.

Second Phase Monitoring:

Laboratory Quality Assurance System and Quality Control Measures (QA/QC)

3. The quality assurance of this monitoring also follows the *Quality Manual* developed by Monitoring Center of Jiangsu Province. 20% of duplicate sample and 10% of matrix spike sample or standard sample is needed for wastewater sample according to the quality control requirement. All the monitoring staff passed examinations and hold certificates. All the metrology of equipments is certificated by the metrology institution. All the equipments used in the field are calibrated, and monitoring data is audited

1) Sequence calibration

One concentration level of the standard solution is analyzed every 12 hours, the deviation should □20%.

2) Contrast sample determination

Analyze the redistilled water or blank quartz sand with the same analysis procedure as the actual sample; no target compound is detected.

Monitoring factors	Results	
	Redistilled water (μg/L)	**Blank quartz sand** (μg/kg)
Chlordane	0.01L	0.1L
Mirex	0.01L	0.1L

3) Accuracy

Add 10,100,200 ng of standard to the redistilled water or blank quartz sand, the analysis results are as follow:

Monitoring factor	Amount added Standard (ng)	Accuracy (Recovery)/(%)	
		Water	Soil
Chlordane	10	82.5	75.5
	100	97.7	80.7
	200	98.7	84.5
Mirex	10	87.6	63.9
	100	94.7	81.3
	200	101	101

Add 10,100,200 ng of standard to the samples. The results are as follow. The results meet the requirement of the accuracy and are acceptable.

Samples	Monitoring factor	number of samples	Number of added standards	Accuracy (Recovery)/(%)
water	Chlordane	9	3	83.6~95.6
	Mirex	9	3	88.5~99.0
soil	Chlordane	10	3	80.2~81.5
	Mirex	10	3	70.1~99.5

4) Precision

Add 10,100,200ng of standard to the redistilled water or blank quartz sand, repeat analyses 6 times, the results are like below:

Monitoring factor	Amount of added standards(ng)	Coefficient of variation (CV%)	
		Water	Soil
Chlordane	10	1.5	3.6
	100	0.9	1.5
	200	0.2	0.5
Mirex	10	2.5	2.9
	100	0.5	1.0
	200	0.2	0.7

Add 10,100,200 ng of standard to the samples. The repetition meets the requirement of the precision, the results are acceptable.

samples	Monitoring factor	Number of samples	Parallel samples	CV(%)
water	Chlordane	12	3	1.2~1.5
	Mirex	9	3	1.5~2.1
soil	Chlordane	12	3	1.5~1.9
	Mirex	9	3	1.2~2.5

5)Minimum quantification limit

The minimum quantification limit is 1ng/L for water and 0.1ug/kg for soil.

6)Check-up of Apparatus

The transfer rate from DDT into DDD should not be higher than 20%.

Annex 4: Registered Hazardous Waste Disposal and Management Companies in Jiangsu

Hazardous Wastes Landfill Sites in Jiangsu[30]

1. As of 2005, Jiangsu Province has built a landfill site for disposal of general industrial solid wastes. It is located in Zhangjiagang, Jiangsu. It can dispose of non-hazadous industrial solid wastes.

2. Wuxi Municipality has built a hazardous waste landfill site in September 2005. Two other hazardous waste landfills – Nanjing, Suzhou – are under construction and are expected to be in operation around 2007. Location of the Nanjing Hazardous Waste Landfill has been identified, and the design of this landfill is in progress. The Nanjing Landfill is expected to be in operation after 2007. The construction of the Suzhou Hazardous Waste Landfill is at its site selection stage, and thus its completion time is yet to be confirmed.

Container Cleaning Companies

3. In Wuxi and Suzhou, approximately 10 companies have permits issued by the Jiangsu Provincial Environmental Protection Bureau to handling contaminated metal and plastic containers. The following table provides a list of such enterprises. Note this is not a complete list for all such companies registered in Jiangsu.

Name of enterprises	Location	Capacity
Wuxi Zhongtian Environmental Protection Company, Ltd.	Wuxi	20000 pieces/a
Kunshan City Huisheng Metal Container Regeneration Company, Ltd.	Kunshan City, Suzhou	80000 pieces/a
Changzhou Kanglong Chemical Company, Ltd.	Changzhou	15000 pieces/a
Kunshan City Shuanglin Packing Container Regeneration Company, Ltd.	Kunshan City, Suzhou	60000 pieces/a
Changshu City Fuxin Drum Company	Changshu City, Suzhou	70000 pieces/a
Jiangyin City Jiangnan Metal Drum Factory Co. Ltd	Jiangyin City, Wuxi	40000 pieces/a

Soil Remediation Enterprises

4. As of 2005, there are no soil remediation companies registered in Jiangsu Province.

[30] Outside Jiangsu, Shanghai and Hangzhou (in Zhejiang) have hazardous waste landfills in operation.

Hazardous Waste Incinerators

5. Jiangsu province has built 32 centralized centers for incineration of industry hazardous wastes in recent years. These thirty two incineration centers have thirty seven incinerators with annual disposal capacity of 10,000 tons of hazardous wastes. The following table provides a list of these centers.

No.	Name	Location	Capacity (tones/a)	Main facilities
1.	Nanjing Jianbei Waste Disposal Center	Nanjing	5500	2 incinerators (A)
2.	Nanjing Huifeng Waste Disposal Cener	Nanjing	1500	1 incinerator (A)
3.	Nanjing Jingzhijie Solid Wastes Treatment Co.,Ltd	Nanjing	9000	2 incinerators (B, C)
4.	Wuxi Industrial Wastes Security Disposal Co., Ltd	Wuxi	9000	2 incinerators (B)
5.	Fuding Env. Engeering Co.·Fuding Industrial Waste Security Disposal Center	Yixing, Wuxi	720	1 incinerator (A)
6.	Jiangyin Industrial Solid Waste Disposal Center	Jiangyin, Wuxi	1800	1 incinerator (A)
7.	Changzhou Industrial wastes Treatment Center	Changzhou	5400	1 incinerator (B)
8.	Jiangsu Fuchang Chemical Residue Treatment Co.	Wujin, Changzhou	3000	1 incinerator (A)
9.	Jintan Huazhen Waste Treatment Co.	Jintan, Changzhou	3000	1 incinerator (A)
10.	Wuzhong District Solid Wastes Treatment Center	Suzhou	4000	1 incinerator (A)
11.	Suzhou Rongwang Env. Protection Co.	xiangcheng District, Suzhou	8000	1 incinerator (B)
12.	Wujiang Taihu Industrial Waste Treatment Center	Wujiang, Suzhou	2500	2 incinerator (A)
13.	Wujiang Luyi Solid Wastes Recycling and Disposal Co.,Ltd	Wujiang, Suzhou	6000	1 incinerator (B)
14.	Suzhou Industrial Park Heshun Solid Wastes Treatment Co.,Ltd	Suzhou	4000	1 incinerator (B)
15.	Suzhou Industrial Park Zhongxing Solid Wastes Disposal Co.,Ltd	Suzhou	3000	1 incinerator (A)
16.	Suzhou New District Env. Protection Service Center	Suzhou	5000	3 incinerators (B, 2A)

No.	Name	Location	Capacity (tones/a)	Main facilities
17.	Kunshan Jinxin Material Recycling Co.	Kunshan, Suzhou	1500	1 incinerator (A)
18.	Kunshan Liqun Solid Wastes Treatment Co.,Ltd	Kunshan, Suzhou	7200	1 incinerator (C)
19.	Suzhou Env. Engeering Co.·Solid Waste Disposal Center	Kunshan, Suzhou	900	1 incinerator (A)
20.	Taicang Kelin Solid Waste Treatment Co.	Taicang, Suzhou	2000	1 incinerator (B)
21.	Nantong Qingyuan Industrial Solid Waste Treatment Factory	Nantong	6000	1 incinerator (A)
22.	Qidong Shisong Solid Waste Disposal Co.	Qidong, Nantong	1500	1 incinerator (A)
23.	Rudong Daheng Hazardous Waste Treatment Co.	Rudong, Nantong	2000	1 incinerator (A)
24.	Lianyungang Linmuzu Waste Treatment Co.	Lianyungang	3000	2 incinerator (A, C)
25.	Huai'an Solid Waste Security Disposal Center	Huai'an	2000	1 incinerator (A)
26.	Yizheng Fuchang Chemical Residue Treatment Co.	Yizheng, Yangzhou	3000	1 incinerator (A)
27.	Zhenjiang Xinyu Soild Wastes Treatment Co.,Ltd	Zhenjiang	3000	1 incinerator (B)
28.	Yancheng Yuxin Solid Waste Disposal Co.	Yancheng	3000	1 incinerator (B)
29.	Taixing Fuchang Solid Waste Disposal Co.	Taixing, Taizhou	2250	1 incinerator (A)
30.	Taizhou Yuxin Solid Waste Disposal Co.	Taixing, Taizhou	3000	1 incinerator (B)
31.	Suqian Kelin Solid Waste Disposal Co.	Suqian	3000	1 incinerator (B)
32.	Total	--	107260	37 incinerators

Note

A: direct combustion incineration kiln;
B: destructive distillation gasification pyrolysis;
C: rotary kiln