Thailand "Map Ta Phut Industrial Complex Project[1]"

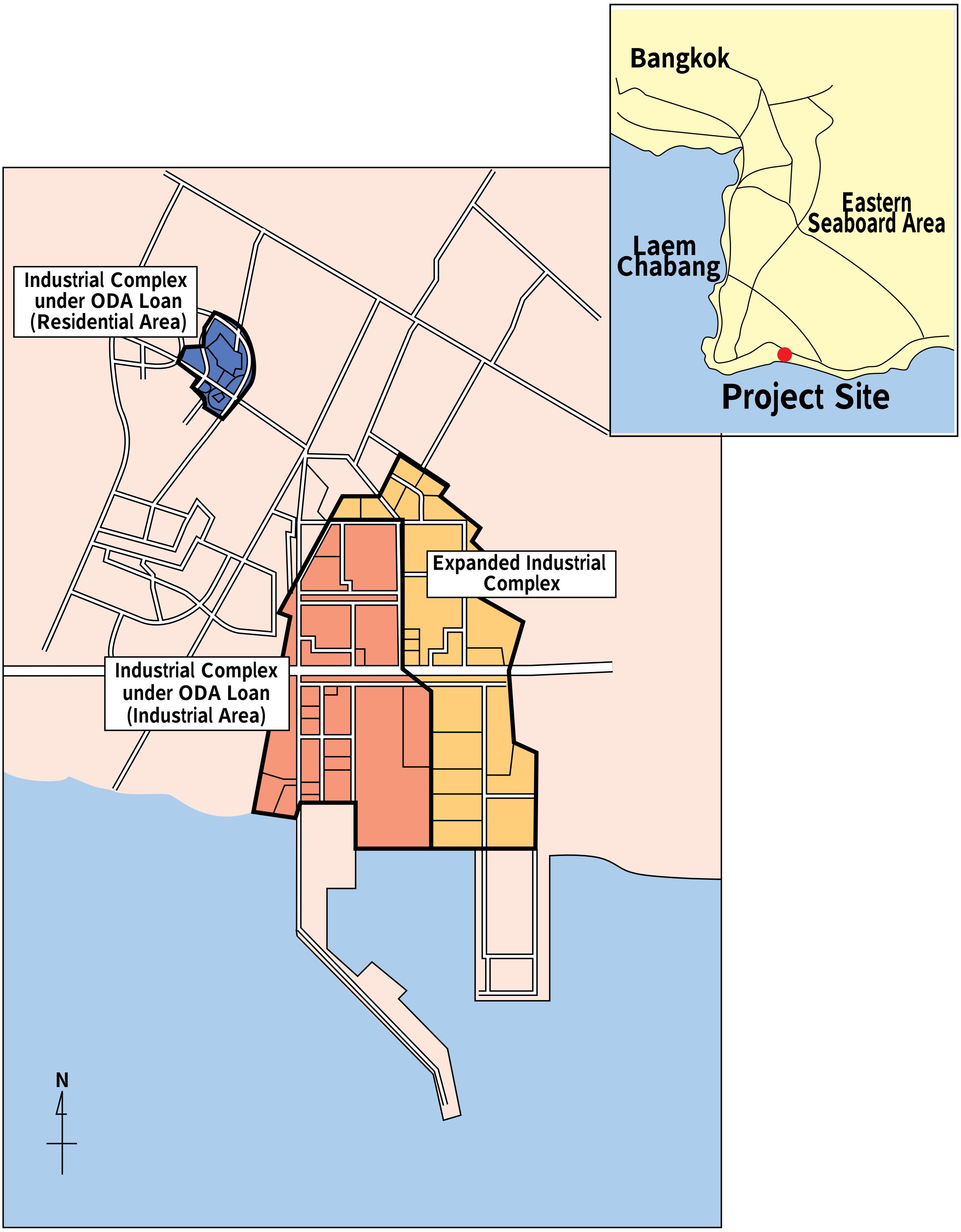
Report date : August 1999
Field Survey : November 1998
Evaluator :The Tokyo Metropolitan
Research Institute
for Environmental Protection
Yasuhiko Miyoshi

Project Summary

Borrower:	Industrial Estate Authority of Thailand (IEAT)
Executing Agency:	Industrial Estate Authority of Thailand (IEAT)
Exchange of Notes:	September 30, 1985
Date of Loan Agreement:	October 4, 1985
Final Disbursement date:	October 4, 1991
Loan Amount:	¥3,207 million
Loan Disbursed Amount:	¥1,415 million (including charge)
Procurement Conditions:	General Untied (Partial Untied for Consulting Service)
Loan Conditions:	Interest 3.5% a year Repayment Period 30 years (Grace period 10 years)

[1] This evaluation by the third party is made focusing on pollution control policies in Map Ta Phut Industrial Complex, as one component of the overall impact evaluation of the ODA loan granted to Eastern Seaboard Development Program (in Kingdom of Thailand.
The overall evaluation report on Eastern Seaboard Development Program is still under the survey as of July, 1999 and a final report will be published separately.

Project Location



Project Summary and JBIC Portion

(1) Background

At the time of the planning of Eastern Seaboard Development Program (ESDP), the Thai government took a policy to promote a large scale heavy-chemical industry project in Thailand, where light industries have been playing a major role till then. More concretely, this project is to develop Map Ta Phut area in Rayong province as a heavy-chemical industrial area utilizing natural gas from the Gulf of Thailand and to construct industrial estates to support installation of the Petrochemical plants.

(2) Objectives

This project is to promote heavy-chemical industry in Map Ta Phut area.

(3) Project Scope

Project scope covers the construction of Map Ta Phut Industrial Complex (380.8ha), which includes land readjustment, road, water supply and sewerage, drainage, etc. The ODA loan covers the foreign currency portion of the project cost.

(4) Borrower/Executing Agency

Borrower and Executing Agency are both Industrial Estate Authority of Thailand (IEAT) (Thai government guarantees the loan)

(5) Summary of Loan Agreement

Loan Amount/Loan Disbursed Amount	¥ 3,207 million / ¥ 1,415 million
Exchange of Note/Date of Loan Agreement	September, 1985 / October, 1985
Loan Conditions	Interest 3.5% Repayment Period 30 years (10 years grace period) General Untied (Partial Untied for consulting portion)
Final Disbursement Date	October, 1991

(6) Evaluation

Map Ta Phut Industrial Complex is now has 808.8ha, expanded by IEAT on their own after the completion of the project under ODA loan (380.8ha). All industrial area in the complex have been contracted as of 1998 and this complex plays a very important role in the Thai economy as the largest petrochemical industry base in Thailand. This time, an evaluation on the pollution control policies in the Complex was requested to The Tokyo Metropolitan Research Institute for Environmental Protection as a third party, with focusing on the importance of pollution countermeasures in the nature of Map Ta Phut Industrial Complex.

Comparison of Original Plan and Actual

	Plan	Actual
1) Project Scope		
a) Land readjustment (Industrial Complex/Urban)	380.8ha / 40 ha	Same
b) Water Supply/Sewerage		
Water Purification Plant	10,000 m^3/day	5,100 m^3/day
Sewerage Plant (for Complex / Residence)	4,000 m^3/day / 2,400 m^3/day	4,000 m^3/day / 2,400 m^3/day
c) Other equipment	Road, drainage etc.	Same
d) Consulting Service	175 M/M	124 M/M
2) Implementation Schedule		
a) Civil Work/Erection (Commencement–Completion)	April 1986 – March 1988	December 1987- May 1990
b) Consulting Service	June 1985 – March 1988	December 1987 - May 1990
3) Project Cost		
a) Foreign Currency	¥ 3,207 million	¥ 1,415 million
b) Local Currency	Bahts 638 million	Bahts 269 million
c) Total Cost	Bahts 991 million (¥ 9,015 million)	Bahts 517 million (¥ 2,948 million)
d) Exchange Rate	Bahts 1 = ¥ 9.1	Bahts 1 = ¥ 5.7

Third-Party Evaluation Report

"Evaluation on Environmental Monitoring and Pollution Control Policies in Map Ta Phut Industrial Complex"

The Tokyo Metropolitan Research Institute for Environmental Protection

Yasuhiko Miyoshi

Abbreviations and Terminology

Abbreviations of institutions (organization)

IEAT: Industrial Estate Authority of Thailand
OEPP: Office of Environmental Policy and Planning
DIW: Department of Industrial Works
PCD Pollution Control Department
GENCO: General Environmental Conservation Co., Ltd.
An industrial waste treatment company. The Ministry of Industry holds 25% of its capital. Its activities center on the Map Ta Phut Industrial Complex.

Terms related to environment

ISO 14001:

ISO14001 is an international standard for environmental management created by the International Organization for Standardization (ISO) and determines environmental management systems which enable organizations to set environmental policies/goals independently and design support programs for achieving these policies/goals in each division/layer of the organization. Standards that deal with environmental management are called the ISO14000 series. Within this series, ISO14001 is the sole standard for appraisal and registration, while the other ISO14000 standards are not compulsory ones.

Terms related to odors

Triangle bag method for odor sensory measurement:

Triangle bag method for odor sensory measurement is one of the methods for testing the intensity of odors through the human sense of smell. In this method, a sample of the air at the measurement point is collected in a polyethylene bag. Six test panelists are each given three bags, consisting of one bag with a diluted odor and two odorless bags. They are then asked to identify the bag that contains the smell. This process is repeated with gradually increasing degrees of dilution. The rate of correct answers is high while the concentration is high, but it gradually falls as the concentration is reduced. The test is repeated until all the test panelists become unable to correctly identify the bag with the odor. Then the highest dilution rates for which the test panelists answered correctly are tabulated (this rate is called the odor concentration), and the average is calculated to obtain the odor concentration (no dimension number).

Terms related to air pollution

Scrubber:

A device for removing noxious gases or solid and liquid particles contained in exhaust gas by using such liquid as water.

Methane conversion:

A method for converting and displaying hydrocarbon concentrations by methane. For example, methane has 1 unit of carbon and ethane has 2 units of carbon, so that in the case of an ethane concentration of 1 ppm, methane conversion results in 2 ppmC. In the case of benzene, which has 6 units of carbon, methane conversion of a concentration of 1 ppm results in 6 ppmC. The C in ppmC indicates that methane conversion (C) has been performed.

Photochemical oxidants:

Photochemical oxidants are oxidants generated through the reaction of nitrogen dioxide and non-methane hydrocarbons under UV rays. The principal component is ozone, and the component that irritates the eyes is an oxidant called per-oxy-acetyl-nitrate (PAN).

TSP:

Total Suspended Particulate

Terms related to water pollution

BOD: Bio-chemical Oxygen Demand

Bio-chemical oxygen demand shows the amount of oxygen required by microorganisms to decompose organic substances, and is expressed in mg/l. The larger this value, the higher the degree of pollution. If this value is 10 mg/l or higher, an odor is emitted and fish become unable to live. In case where organic substances are not broken down by microorganisms, the amount of oxygen is not expressed.

COD: Chemical Oxygen Demand

Chemical oxygen demand shows the amount of oxygen required for organic substances in water to be oxidized with oxidizers, and is expressed in mg/l. The larger this value, the higher the degree of pollution. However, unlike the BOD, even in case where organic substances are not broken down by microorganisms, if these substances are oxidized by oxidants, the oxygen amount is counted.

SS: Suspended Solids

Suspended solids are expressed in mg per liter of the dried substance of material obtained by filtering an adequate amount of sample through a sieve with 2 mm openings with a glass fiber filter with an aperture size of 1 μm.

T-S: Total Solids

Solids obtained by drying sample including dissolved salt.

DO: Dissolved Oxygen

Dissolved oxygen indicates the concentration of oxygen dissolved in water in terms of mg/l. If the water does not contain organic substances, this value is generally large, so that it is used as an indicator of water quality. The saturated dissolution amount at a water temperature of 20℃ is only 8.84 mg/l.

ppt: Parts per Thousand

Expressed as 1,000 times the percentage of salt included in 1,000 g of sea water. For example, the salt concentration of salt water is normally 3%, and this is expressed as 30 ppt by multiplying concentration by 1000.

NO_3-N: Nitrate Nitrogen

Nitrate nitrogen is nitrogen contained in nitrate. The nitrate nitrogen concentration is expressed as mg of nitrogen per liter of sample.

NH_3-N: Ammonia Nitrogen

Ammonia nitrogen is nitrogen contained in ammonia. The ammonia nitrogen concentration is expressed as mg of nitrogen per liter of sample.

T-P: Total Phosphate

Red tide:

Red tide is a customary visual description that refers to the phenomenon of water turning red in color when microorganisms in water (mainly phytoplankton) suddenly start to propagate at an abnormal rate. However, opinions regarding how to quantify this phenomenon are diversified, and are not clear yet. As reference, the Tokyo Metropolitan government has established the following judgment criteria: <1> Sea water is a blackish brown color, a yellowish brown color, or a green color; <2> The degree of clearness of the water is 1.5 meters or less; <3> A large number of red tide plankton can be seen with a microscope; <4> The chlorophyll concentration (total of chlorophyl α and pheochromoblastoma) is 50 mg/m^3. However, red tides are not all caused by chlorophy, and may also be caused by things like animal plankton. Chlorophyll is a common component of phytoplankton.

TKN: Total Kjeldahl Nitrogen

Total Kjeldahl Nitrogen is the amount of nitrogen in organic matter such as protein, and is expressed in units of mg/l.

Benthos: Benthonic organisms that live on or closely to the bottom of a body of water, especially the ocean.

Terms related to noise

Equivalent noise level:

If the noise level changes over time, the equivalent noise level is the noise level of continuous steady sound giving an equivalent sound pressure level during the measurement period. The equivalent noise level is usually expressed in dB, and the quantifier is Leq. The equivalent noise level expresses the time mean value level for the total energy of noise during a given measurement period. It enables the stable expression of variable noise, and it is particularly suited for expressing the extent to which human are exposed to noise. The equivalent noise level has been widely used in the world for the evaluation of environmental noise, and its introduction to Japan was done in 1998.

1. Background of This Evaluation

This report, which was requested by Japan Bank for International Cooperation (JBIC), consists of third party evaluation results and findings with regard to anti-pollution policies in the Map Ta Phut Industrial Complex in the Kingdom of Thailand, which was built with the use of Japanese ODA loan. The Map Ta Phut Industrial Complex is part of the Eastern Seaboard Development Program (ESDP) of Thailand. The ESDP has been implemented since the 1980s, and Japan has strongly supported the Map Ta Phut Industrial Complex, the Laem Chabang Industrial Estate, and other nearby infrastructure in the Easter Seaboard, in part through the Japanese ODA loans. The Map Ta Phut Industrial Complex is the location of primarily oil refineries and petrochemical plants, while the Laem Chabang Industrial Estate houses mainly non-petrol-related plants.

The development of the Eastern Seaboard is among the representative examples of Japanese economic cooperation vis-a-vis Thailand, and post-evaluation of the results and course of this cooperation is important for both countries. As part of the post-evaluation of the ESDP, it was decided to evaluate the air pollution, water contamination, industrial waste treatment and monitoring systems of the Map Ta Phut Industrial Complex.

The Map Ta Phut Industrial Complex was selected out of the two industrial complexes supported by ODA loans for the following two reasons: 1) The Map Ta Phut Industrial Complex houses principally petrochemical plants, and as such requires greater attention on environmental aspects compared to the Laem Chabang Industrial Estate; 2) Over the past two years, odor from plants in the Map Ta Phut Industrial Complex have become a problem, and anti-pollution measures at the Map Ta Phut Industrial Complex are the object of attention in Thailand.

In addition to the problem of odors, this report covers the status of general air pollution, water contamination, noise, and industrial waste treatment at the Map Ta Phut Industrial Complex, as well as the countermeasures by the government, mainly the Industrial Estate Authority of Thailand (IEAT).

2. Survey Period and Survey Method

2.1 Field Survey Period

November 16 to November 26, 1998

2.2 Survey Method

(1) Since this report is the result of a short-term survey, the status of pollution was not measured in the survey. Instead, the results of the measurement of air pollution and water contamination performed by the IEAT in 1998 were used to evaluate the current environmental conditions. In addition, the author visited and interviewed related parties and made field observation.

(2) The interviews and visits of related parties consisted of the following.

Interviews and Visits	Government organizations, plants, and counterparts or major products
① Government agencies responsible for anti-pollution measures at Map Ta Phut Industrial Complex	• Detailed interviews with persons responsible for pollution control at the IEAT, an agency primarily responsible for environmental policies at the Map Ta Phut Industrial Complex. • The officers of three other government agencies participating in an inter-agency committee established for the odor problem mainly at the Map Ta Phut Industrial Complex were invited to the Complex to be interviewed. Of these three government agencies, only the Office of Environmental Policy and Planning (OEPP) and the Department of Industrial Works (DIW) did participate. The Pollution Control Department (PCD) was unable to participate.
② Plants at Map Ta Phut Industrial Complex	10 plants were visited and their officers in charge of the environment were interviewed. Some of the environmental facilities were checked. The 10 plants were selected by obtaining a list of the plants at the Map Ta Phut Industrial Complex and by choosing plants which may produce pollution. The plants bylaws which forbid the foreigners' observation of production processes and the plants where production was stopped or which were under periodic checks at the time of the visit were excluded from the initial list of the plants to visit.
③ Local government	Interview of the department manager and another personnel of the Department of Environment and Public Health of the Map Ta Phut Municipality where the Map Ta Phut Industrial Complex is located.
④ Local residents	The senior teacher in charge of environmental problems and students at the Map Ta Phut Phunpettayakarn School next to the Map Ta Phut Industrial Complex that suffered from malodorousness were interviewed. The representatives of two communities adjacent to the Map Ta Phut Industrial Complex that also suffered from malodorousness were interviewed.
⑤ Health Office of local province	Interview with the person in charge at Provincial Health Office of Rayong Province where Map Ta Phut Industrial Complex is located.

⑥ Industrial waste treatment operators	Visit of GENCO, Thailand's only private industrial waste (including toxic waste) treatment and disposal operator, located in the Map Ta Phut Industrial Complex. Also interview of PR manager. Inspection of waste treatment and disposal facilities.	
⑦ Visit of 10 plants	Company names	Products
	Company A	Petroleum refining
	Company B	Terephtalic acid
	Company C	Ta and Nb smelting
	Company D	ABS, etc.
	Company E	Phosphoric acid fertilizers
	Company F	Melamine resin
	Company G	Styrene
	Company H	Latex
	Company I	Vinyl chloride
	Company J	Rubber additives

3. Evaluation of Environmental Conditions and Pollution Countermeasures at Map Ta Phut Industrial Complex

3.1 Malodorousness

3.1.1 History of Odor Problem

The Map Ta Phut Industrial Complex is located some 200 km southeast of Bangkok, a drive of about 2 hours by car from the capital. The industrial complex houses two oil refineries and more than 40 plants of petrochemical products, inorganic chemical fertilizers, steel and so on.

The construction of the first plants at the Map Ta Phut Industrial Complex began in the 1980s, and the majority of plants began operation from about 1996. The operation brought odors gradually. The wind direction in this area is southwest in the spring and the summer (from the sea toward the industrial complex and surrounding residential areas). In the fall and the winter, the wind direction reverses to northeast (from the industrial complex to the sea). Therefore, complaints about malodors increase in the spring and the summer, when the wind comes from the industrial complex to the peripheral residential area. The Map Ta Phut Phunpettayakarn school which is most affected by malodorousness (about 1,000 pupils) is located northeast of the industrial complex (A5 in Figure 3-1), directly in the southwest wind path from the industrial complex.

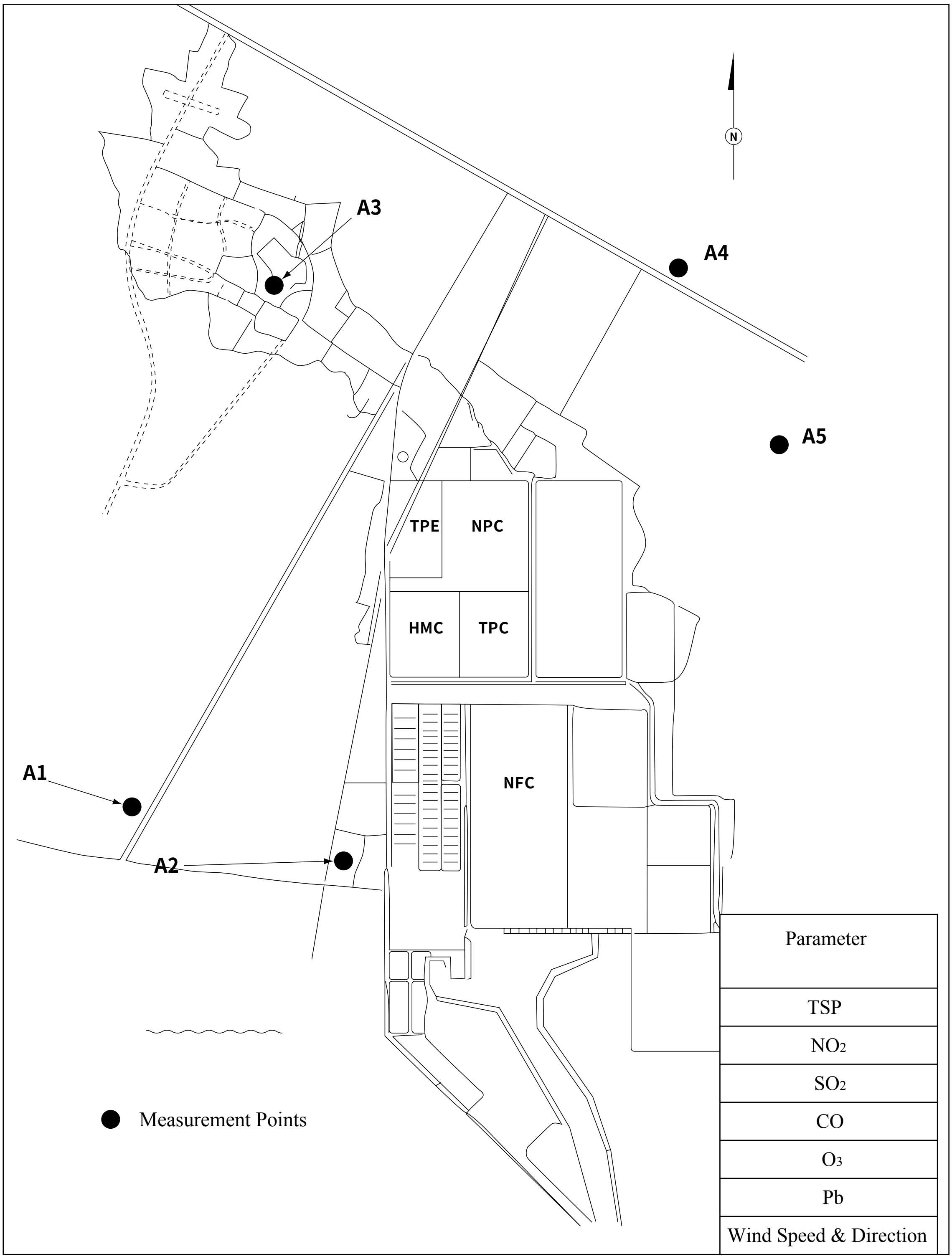
According to the investigation of the senior teacher in charge of environmental issues at the Phunpettayakarn school, all the students were bothered by the odor, and when it became particularly intolerable, the students had to be temporarily sent to home. Furthermore, during the six month period from September 1997 to February 1998, the school was transferred to temporary quarters 4 km away. Moreover, the authorities installed fans, and later air conditioners in all the classrooms as a countermeasure.

During interviews, local residents complained that the noise level was high when the construction of the plants began, and the odor became worse gradually. Initially, the companies operating these plants did not listen to the complaints of local residents, but due to government pressure, they gradually began listening to residents, and companies causing such emissions apologized. Moreover, when complaints began arising in Map Ta Phut City, the residents demanded the government to have the plants implement measures against malodorousness.

Acting upon the complaints of the residents, four agencies of the Thai government (the IEAT, which has prime responsibility for pollution countermeasures at the Map Ta Phut Industrial Complex; the OEPP, which is responsible for environmental policy and planning in general; the PCD, which is responsible for pollution countermeasures in general; and the DIW, which is responsible for pollution countermeasures at factories) organized a committee to work on the problem of odor at the Map Ta Phut Industrial Complex. This committee selected seven plants expected to emit odors and began working intensively on guidance for improving the problem.

Currently, a team composed of the government agencies and the city surveys odor conditions around the school twice a week, and studies countermeasures for the plants. Although, the Map Ta Phut area once experienced hostile relations among local residents and plants with regard to the odor problem. It can now be said that three parties, the local residents, government agencies, and the plants, are working cooperatively in the direction for solving the problem.

Figure 3-1 Air Pollution Measurement Points



3.1.2 Odor Status

Implemented measures began taking effect around August or September 1998. The effects of these measures can be known through environmental surveys done by the IEAT. Table 3-1 lists figures obtained through the analysis of odor components at 5 measurement points outside the Map Ta Phut Industrial Complex (No. 1 to 5) and at 5 measurement points inside the complex (No. 6 to 10) collected in June, September, and October 1998 by the IEAT. Components with a strong odor are listed in particular in the upper table. The threshold value indicates the concentration at which the odor becomes imperceptible.

Table 3-1 Odor Components Contained in Atmosphere According to IEAT Survey

Particularly Strong Odor Components in Map Ta Phut Industrial Complex		Threshold Value
・Hydrogen sulfide(H_2S)		0.5ppb(0.0005ppm)
・Mercaptan	Methyl mercaptan(CH_3SH)	0.1ppb(0.0001ppm)
	Ethyl mercaptan(CH_3CH_2SH)	0.02ppb(0.00002ppm)
・Dimethyl sulfide $(CH_3)_2S$		0.1ppb(0.0001ppm)
・Diethyl sulfide $(CH_3CH_2)_2S$		0.4ppb(0.0004ppm)

Results of June 1998 Measurements

Measured Items (ppb)	Measurement Points									
	1	2	3	4	5	6	7	8	9	10
1. Benzene	0.192	0.255	0.812	0.296	ND	NM	0.901	0.897	0.453	0.366
2. Toluene	0.383	0.077	0.313	ND	ND	NM	0.086	0.086	0.360	0.343
3. p-Xylene	0.234	0.193	0.517	0.371	ND	NM	0.518	0.511	0.257	0.169
4. m-Xylene	0.106	0.143	0.283	0.330	ND	NM	0.377	0.401	0.207	0.096
5. o-Xylene	0.077	0.166	0.314	0.340	ND	NM	0.422	0.415	0.210	0.056
6. Styrene	0.263	0.093	0.551	0.526	ND	NM	0.314	0.329	1.008	0.741
7. Acrylonitrile	ND	ND	ND	ND	ND	NM	ND	NM	0.011	ND
8. Butadiene	ND	ND	NM	NM	ND	NM	NM	NM	0.075	NM
9. Hydrogen sulfide	0.940	ND	1.818	ND	ND	NM	NM	1.185	1.933	1.235
10. Mercaptan	1.101	ND	1.723	ND	ND	NM	NM	1.265	2.134	1.684
11. Dimethyl sulfide	2.202	ND	0.483	ND	ND	NM	NM	0.521	1.456	0.904
12. Diethyl sulfide	0.142	ND	0.377	ND	ND	NM	NM	0.342	0.886	1.340
13. Acetic acid	ND	ND	0.739	ND	ND	NM	2.280	NM	ND	ND
14. Na	ND	ND	NM	NM	ND	NM	NM	4.083	NM	NM
15. Si	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM
16. K	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM
17. Cl	ND	ND	NM	NM	ND	NM	NM	1.211	NM	NM
18. Acetaldehyde	ND	ND	NM	NM	ND	ND	ND	NM	NM	NM
19. Glycol	ND	ND	NM	NM	ND	ND	ND	NM	NM	NM

Source: IEAT (same for the two tables below).

Note: ND (Non Detectable: Which cannot be detected, a concentration that is too low to be detected through accurate measurement), NM (Non Measurable: Which could not be measured for some reason or another) (same for the two tables below)

Results of September 1998 Measurements

Measured Items (ppb)	Measurement Points									
	1	2	3	4	5	6	7	8	9	10
1. Benzene	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND
2. Toluene	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND
3. p-Xylene	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND
4. m-Xylene	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND
5. o-Xylene	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND
6. Styrene	ND	ND	ND	ND	ND	NM	ND	ND	ND	ND
7. Acrylonitrile	ND	ND	ND	ND	ND	NM	ND	NM	ND	ND
8. Butadiene	ND	ND	NM	NM	ND	NM	NM	NM	ND	NM
9. Hydrogen sulfide	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND
10. Mercaptan	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND
11. Dimethyl sulfide	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND
12. Diethyl sulfide	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND
13. Acetic acid	ND	ND	ND	ND	ND	NM	ND	NM	ND	ND
14. Na	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM
15. Si	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM
16. K	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM
17. Cl	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM
18. Acetaldehyde	ND	ND	NM	NM	ND	ND	ND	NM	NM	NM
19. Glycol	ND	ND	NM	NM	ND	ND	ND	NM	NM	NM

Results of October 1998 Measurements

Measured Items (ppb)	Measurement Points										
	1	2	3	4	5	6	7	8	9	10	11
1. Benzene	ND	ND	ND	ND	ND	NM	0.435	0.448	ND	ND	ND
2. Toluene	ND	ND	ND	ND	ND	NM	0.059	0.059	ND	ND	ND
3. p-Xylene	ND	ND	ND	ND	ND	NM	0.296	0.327	ND	ND	ND
4. m-Xylene	ND	ND	ND	ND	ND	NM	0.189	0.176	ND	ND	ND
5. o-Xylene	ND	ND	ND	ND	ND	NM	0.226	0.231	ND	ND	ND
6. Styrene	ND	ND	ND	ND	ND	NM	0.144	0.139	ND	ND	ND
7. Acrylonitrile	ND	ND	ND	ND	ND	NM	ND	NM	ND	ND	ND
8. Butadiene	ND	ND	NM	NM	ND	NM	NM	NM	ND	NM	NM
9. Hydrogen sulfide	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND	ND
10. Mercaptan	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND	ND
11. Dimethyl sulfide	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND	ND
12. Diethyl sulfide	ND	ND	ND	ND	ND	NM	NM	ND	ND	ND	ND
13. Acetic acid	ND	ND	ND	ND	ND	NM	1.469	NM	ND	ND	ND
14. Na	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM	NM
15. Si	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM	NM
16. K	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM	NM
17. Cl	ND	ND	NM	NM	ND	NM	NM	ND	NM	NM	NM
18. Acetaldehyde	ND	ND	NM	NM	ND	ND	ND	NM	NM	NM	NM
19. Glycol	ND	ND	NM	NM	ND	ND	ND	NM	NM	NM	NM

Source: IEAT

In the June 1998 measurement, concentrations of mercaptan and dimethyl sulfide were between 11 and 22 times higher than the threshold value at measurement points No. 1 and No. 3 outside the Map Ta Phut Industrial Complex. Similarly, concentration levels were between 14 and 21 times higher than the threshold value at measurement points No. 8 to No. 10 within the Map Ta Phut Industrial Complex. The sulfur-type smell is so unpleasant that the occurrence of complaints at such a concentration level seems to be natural.

In the measurements done in September and October, however, the concentrations of these odor components were at non detectable (ND) level. This is explained partially by the fact that the wind was going in the opposite direction. According to the IEAT, however, the plants that had improvement guidance implemented measures primarily in June and July 1998, and the effect of these measures also contribute to the improvement.

During the same period, physical checkups were performed for middle school pupils and teachers. Table 3-2 shows the results of physical checkups conducted by the Rayong Provincial Health Office targeting middle school pupils and teachers. According to this result, the percentage of people complaining of some kind of illness was lower compared to May 1998. Based on these survey results, it is difficult to determine, whether these headaches, laryngitis, respiratory disease, respiratory tract inflammation, rhinitis and so on, were all caused by malodorousness and a small quantity of toxic agents. This fact is admitted even by the senior teacher in charge of environmental issues at the school. As of the September physical checkups, however, malodorousness decreased greatly and is not giving mental anxiety to pupils, and it is surmised that such improvement also brought about a decrease in the percentage of complaints about bad physical conditions.

Table 3-2 Results of Physical Checkups Among Middle School Pupils and Teachers

Survey Period / Contents	May 1998	September 1998
Number of surveyed subjects	871 persons	809 persons
Some kind of illness	524 persons (60.16%)	324 persons (40.05%)
Headache	21.30%	8.33%
Laryngitis	17.37%	12.34%
Cold	12.40%	-
Rash	9.92%	-
Vertigo	9.92%	-
Respiratory tract inflammation	8.20%	17.28%
Rhinitis	8.01%	14.81%
Tonsillis	2.67%	8.02%
Respiratory disease	-	18.52%
Skin diseases	-	8.02%
Others	14.69%	14.20%

Source: Rayong Provincial Health Office.

3.1.3 Evaluation of Odor Countermeasures by IEAT

Generally the odor problem was brought about by complaints from the victims. In Japan, too, there were many complaints about malodorousness around 1965. As there are accumulations of solving problems one by one, however, today if problems occurred they would be solved quickly. Whereas in Thailand, the government agency which should take the initiative in solving odor problems through guidance and supervision, has no experience in malodor problems, and factories are not experienced in starting and operating such a large-scale petrochemical plant. Their inexperience can be considered as the cause of an extensive odor pollution by gas leaks and accidents.

Furthermore, the fact that the industrial area and residential area are close to each other, where the land zoning is not thoroughly observed, can also be mentioned as a major factor.

As emergency measures to cope with the malodor problem, the IEAT has given guidance for improvements, centering on the seven factories that are assumed to have discharged odor. The method of guidance is to let them list specific points to be improved and guide them to improve conditions, within certain time limits.

Accepting the IEAT's guidance, these factories have finished applying most of the measures. For example, guidance includes the items shown in Table 3-3.

Table 3-3 Example of Guidance for Malodor Countermeasures by IEAT

Companies under Guidance	Guidance Contents
① Company K	• Installation of scrubbers until July 20, 1998 • Installation of covers for waste oil disposal facilities until June 1998 • Installation of odor combustion facilities until October 1998
② Company L	• Installation of scrubbers for gas leaks from tanks, etc., until June 1998 • Installation of odor substances combustion facilities until July 1998

Source: IEAT

Odor countermeasures at the Map Ta Phut Industrial Complex until now have focused principally on the clearly identified sources. Since most of the plants are foreign-affiliated, most of them implemented technologies of their respective country. It is expected that if the plants continued current measures, odor would improve remarkably. The IEAT's response so far has been to take emergency measures toward complaints about odor from the residents, instead of monitoring odors periodically and quantitatively.

If the number of plants and production volume increase further, however, the current measures, which do not adopt quantitative evaluation of odor, will become insufficient. This is because, even if odor decreases considerably as the result of the current implementation of measures by the plants, the total odor of the Map Ta Phut Industrial Complex, which is the aggregate odor of the various plants in the complex, may be so bad so as to cause complaints from neighboring residents. In the future, it will be necessary to quantify the odor level of each individual contamination source, in order to grasp the total level of odor emission of the Map Ta Phut Industrial Complex.

3.1.4 Suggestions regarding odor countermeasures

(1) Improvement of odor measuring methods

In the future, even if the odor emission from individual plants declines, the increase in the number of plants and production volume may result in worsening of total odor emitted from the Map Ta Phut Industrial Complex. In this case, individual plants will have to implement more detailed and delicate measures than those being handled at present. Without an objective way of grasping the level of odor through quantification, it will be difficult to determine the extent of countermeasures needed at each plant. Moreover, odor may leak from various places due to the obsolescence of plant facilities, regardless of the efforts of various plants to implement countermeasures. Under the current approach, which does not quantify odor, the identification of the responsible plants and the promotion of countermeasures is expected to be difficult.

It would be possible to grasp the extent of odor emission from every plant and for the Map Ta Phut Industrial Complex as a whole by quantifying odor, and to establish object and fair goals for each plant. This in turn would promote precise measures and grasp the effects of such measures.

While there are many ways to quantify the level of odor, the triangle bag method for odor sensory measurement[2] is objective and reliable, and it is utilized for odor prevention law in Japan, its use will be useful for Thailand. Currently, the IEAT is working on grasping odor using a method modeled after Japan's triangle bag method for odor sensory measurement, but the level of odor is not quantified. Therefore, it is necessary to quantify odor in the future.

(2) Continuation of improvement guidance

The basics of odor countermeasures, as guided by the IEAT until now, is to cover the sources of odor, and burn, adsorb, or absorb odor components. It is necessary to keep adopting such guidance. Furthermore, for each source of odor contamination, it would be desirable to measure "odor concentrations" and "gas amounts" in order to obtain the "odor intensity", which is a product of these two values. It will be effective to start implementation of improvement guidance from contamination sources with a high "odor intensity" value.

(3) Creation of guidance standard

As plants have adopted various measures against odor, it is necessary for the IEAT to generalize experiences for each industry and to prepare a handbook and guidance standards for each industry. This will become an important asset for pollution control technology in Thailand in the future, and will be instructive to other Asian nations.

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[2] For a description of the "triangle bag method for odor sensory measurement", refer to the "Explanation of Abbreviations and Terminology" at the beginning of this report.

(4) Promotion of ISO 14001 certification

The majority of plants at the Map Ta Phut Industrial Complex are aiming to obtain the ISO 14001 certification, an international standard for environmental management systems for organizations. Measures to handle the problem of odor requires constant inspections and improvements are basically the same as the environmental management system of the ISO 14001 standard. Therefore, it is necessary to promote ISO 14001 certification, and then, to have plants set odor improvement targets, and to guide them to progress systematically toward the achievement of these targets.

3.2 General Air Pollution

3.2.1 Current Status of General Air Pollution

(1) Measurement items and measurement points defined by the IEAT

The measurement items consisted of TSP (Total Suspended Particulate), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), carbon monoxide (CO), ozone (O_3) and lead (Pb).

The measurement points were points A1 to A5 shown in Figure 3-1. During the spring and the summer, the wind direction is southwest, while it is northeast during the fall and the winter, so that these measurement points are considered to be appropriate.

(2) Weather conditions at Map Ta Phut

(i) Temperature and precipitation (1981-1996)

Month	Temperature (°C)	Precipitation (mm)	Month	Temperature (°C)	Precipitation (mm)
Jan.	25.8	21.9	Jul.	28.8	161.7
Feb.	27.7	38.8	Aug.	28.6	133.0
Mar.	28.8	65.6	Sep.	27.9	260.5
Apr.	29.9	66.7	Oct.	27.4	206.9
May	29.7	197.1	Nov.	27.0	67.8
Jun.	29.3	177.4	Dec.	25.5	5.2

Characteristics: There is almost no temperature change throughout the year. The amount of annual precipitation is approximately 1,403 mm, which is almost the same as in Tokyo (1,405 mm).

(ii) Wind direction

The wind direction was monitored during three days in July 1998, and was mostly southwest, west-southwest, south, or south-southwest.

(3) Measurement results[3]

(i) Relationship with environmental standard and pollution status

The results of the atmospheric environment measurement performed by the IEAT in 1998 are shown in Table 3-4. The environmental standard of Thailand and Japan are shown in Table 3-5. Generally, Thailand's environmental standard is more permissive than that of Japan, except with regard to carbon monoxide. The average times for nitrogen dioxide (NO_2) prescribed in the environmental standards of Thailand and Japan differ, but double the 24-hour value can be considered to be equivalent to approximately the 1-hour value.

[3] The results of the atmospheric environment measurements done by the IEAT were not obtained over a long period of time, and thus they do not grasp an accurate atmospheric pollution conditions. The arguments presented in this report are based solely on these measurement results by the IEAT.

Table 3.4 Results of General Atmospheric Environment Measurement by IEAT

Measured Items	Unit	Measurement Points					Environmental Standard
		A1	A2	A3	A4	A5	
TSP	mg/m^3	0.04 0.06 0.07	0.04 0.03 0.04	0.08 0.08 0.07	0.01 0.05 0.04	0.04 0.07 0.06	0.33 24-hour average value
NO_2	mg/m^3	0.01 0.01 0.01	0.04 0.01 0.02	0.02 0.01 0.01	0.01 0.01 0.01	0.02 0.01 0.02	0.32 1-hour average value
SO_2	mg/m^3	ND ND ND	0.01 0.01 0.01	ND ND ND	0.01 0.01 0.01	0.01 0.01 0.01	0.30 24-hour average value
CO	mg/m^3	1.04 1.09 1.47	1.09 1.04 1.40	ND 0.11 0.23	1.08 1.48 1.24	1.08 1.13 1.88	10.26 8-hour average value
O_3	mg/m^3	0.04 0.06 0.06	0.14 0.10 0.12	0.02 0.02 0.02	0.04 0.06 0.04	0.12 0.16 0.12	0.20 1-hour average value
Pb	$\mu g/m^3$	0.01 0.01 0.01	0.04 0.02 0.01	0.02 0.01 0.01	0.02 0.01 0.01	0.02 0.02 0.01	1.5 1-month average value

Source: IEAT

Table 3.5 Environmental Standard in Thailand and Japan

Measured Items	Environmental Standard in Thailand (average hour)	Environmental Standard in Japan (average hour)
TSP	$0.33mg/m^3$ (24h)	$0.10mg/m^3$ (24h)
NO_2	$0.32mg/m^3$ (1h)	0.08～$0.12mg/m^3$ (24h)
SO_2	$0.30mg/m^3$ (24h)	$0.11mg/m^3$ (24h)
CO	$10.26mg/m^3$ (8h)	$25mg/m^3$ (8h)
O_3	$0.20mg/m^3$ (1h)	$0.13mg/m^3$ (1h)
Pb	$1.5 \mu g/m^3$ (1h)	None

The measurement results presented in Table 3-4 meet the environmental standard of Thailand. Furthermore, the results also meet the standard of Japan except ozone (O_3).

With regard to the concentration of total suspended particulate (TSP), no more than about 50% of measurement points in Japan meet the environmental standard while measurement points in Map Ta Phut fully meet Japan's environmental standard. The nitrogen dioxide (NO_2) concentration is approximately one tenth of the environmental standard of Japan. The sulfur dioxide (SO_2) concentration, at ND-0.01 mg/m^3, is less than one tenth of Japan's environmental standard. This is due to the fact that most plants burn natural gas, which is abundantly available. The carbon monoxide (CO) concentration, which is at the same level as currently in Japan, can be said to be very low.

(2) Possibility of photochemical oxidant emissions

While the ozone (O_3) concentration is lower than Thailand's environmental standard, the ozone concentration between 10 and 11 o'clock at measurement point 5 is 0.16 mg/m^3, which is close to the environmental standard of Thailand but exceeds that of Japan. The following two factors can be considered.

<1> UV rays are strong in the coastal area originally, and part of the oxygen in this area is converted into ozone under UV radiation.

<2> As a result of photochemical oxidant generation by photochemical reactions, the ozone concentration has grown higher.

Regarding factor <1>, the ozone concentration is thought to be slightly higher in Map Ta Phut than in Tokyo, where it is normally 0.11 mg/m^3. Even considering the natural increase in ozone due to UV radiation, the ozone concentration in Map Ta Phut is considered to be slightly too high.

Next, regarding factor <2>, ozone, which is the main component of photochemical oxidants, is produced under UV rays when non-methane hydrocarbons and nitrogen dioxide exceed a given level. Needless to say, in this area, plenty of UV radiation exist, and non-methane hydrocarbons is also expected to exist in ample amounts (0.3 ppmC or more using methane conversion) due to the large number of oil refineries and petrochemical plants, as well as the large number of diesel and other types of automobiles, which emit large amount of hydrocarbons. Nitrogen dioxide, while in low concentrations (0.01 to 0.04 mg/m^3), also exist, so that photochemical reactions occur and produce ozone. As a result, ozone concentration is suspected to have increased.

The generation of photochemical oxidants is commonly referred to as photochemical smog. Photochemical smog has various effects on human health, including membrane irritation of the eyes and respiratory tract.

According to IEAT staff, there have been complaints about eye irritation from local residents. Since this symptom matches the characteristic of PAN (peroxyacetyl nitrate, an oxidant constituent), this supports the hypothesis mentioned above, but since detailed survey results are not available at this time, the above remains to be a hypothesis.

In the future, the increase in the number of automobiles and plants, and in its production volume is feared to result in an increase in nitrogen dioxide (NO_2). Therefore, in the future, the generation of photochemical oxidants is predicted to be almost certain, and the implementation of necessary counter measures is desirable at an early stage.

(3) Comments arising from field survey (visual inspection)

The stay at Map Ta Phut was about a week from November 17, 1998, and the weather was clement during this period. The Map Ta Phut Industrial Complex contains a lot of green, and sprinklers have been installed for the trees planted at the center divide of the roads. The atmosphere at the complex is almost entirely free of the dark smoke that was so common in Japan in the late 1960’s. Man-made mists were not observed, and visibility was high. As previously mentioned, this is thought to be due to the fact that most plants use natural gas as their fuel. Although visible pollution such as black smoke was almost not perceived, odor was apparent to a certain degree. Atmospheric pollution caused by vehicles such as poorly maintained trucks running inside and outside the industrial complex was also a source of concern.

3.2.2 Evaluation of general atmosphere monitoring by IEAT

(1) Measurement frequency and method

Air pollutants spread over large areas due to atmospheric dispersion. Factors include wind direction, wind speed, stability of the atmosphere, height of smokestacks, temperature of exhaust gasses, exhaust speed, level of contamination, and outside air temperature. Among these factors, wind direction, wind speed, and stability of the atmosphere have mainly influence on it and will considerably vary depend on season or even in the course of a single day. Therefore, it is difficult to obtain an accurate picture of the overall pollution level based on the atmospheric pollution measurements conducted by the IEAT just a few times a year. In the future, in order to promote proper atmospheric pollution countermeasures based on accurate environmental measurement results, it will be necessary to grasp pollution conditions through long-term continuous measurements performed throughout the entire year.

Measurement methods can be divided into manual analysis methods and methods using automatic equipment. The latter is preferable from the perspective of the uniformity of the measurement procedure. The initial purchase cost of automatic measurement equipment is considerable, thus, making the rapid introduction of such equipment difficult. In such circumstances, manual analysis is the only practical method, but this requires careful planning and efficient implementation in order to enable a comprehensive grasp of pollution conditions by minimum manpower.

(2) Measured items

With regard to measured items, the measurement of non-methane hydrocarbons for the purpose of monitoring photochemical oxidant generation is necessary in addition to the current items. Measurement of methane itself is not required as it is not involved in photochemical reactions. The measurement of non-methane hydrocarbons is performed using a flame ionization detector (FID) combined with methane separation through gas chromatography.

Another measurement item, hydrocarbon-type toxic substances (such as benzene), need to be included, since there are a large number of oil refineries and petrochemical plants. As there are a large number of hydrocarbon-type toxic substances, measuring all of them on a continuous basis is rather difficult in terms of cost. In such a case, a possible approach is to conduct a precise measurement of generation sources and ambient air quality once, and then narrow down measurement items to those with the highest toxicity and the largest generation amounts.

(3) Necessity of forecasts and countermeasures through basic data collection and computer simulation

In the future, it will be desirable to identify the largest sources of pollutants and the distribution of diffused odor and to implement the countermeasures effectively by computer simulations using data on generation sources and weather information, in order to devise more detailed monitoring of atmospheric pollution and countermeasures.

The basic data to be collected includes measured values of sulfer oxides, nitrogen oxides, and soot and dust emissions; fuel usage amounts; evaporated hydrocarbons amounts; and odor intensity.

Furthermore, the collection of additional information, such as the height of the smokestacks at each plant, and the exhaust velocity and temperature of exhaust gases, is also important.

Moreover, it would also be possible to minimize the occurrence of harm by establishing a system that could promptly indicate the best direction to escape in the case of accidents, and to avoid generated toxic substances in relation to wind direction, based on the above simulations.

Furthermore, based on the same simulations, it would be possible to forecast the generation of photochemical oxidants and use the results to devise preventive measures.

(4) Areawide total pollutant load control

In the future, if it is difficult to prevent increases in pollution through emission concentration regulation because of the increasing number of plants and production volume, another effective approach would be an areawide total pollutant load control so as not to increase pollutants in the area. Such a system is already being used in Japan (only for sulfur oxides and nitrogen oxides) and the Japanese system would be a useful guide with regard to the implementation method.

3.2.3 Suggestions about atmospheric monitoring by IEAT

(1) Continuation of plant monitoring

Continue to perform monitoring of and guidance to each plant, conducting periodic plant inspections aimed at checking the functions of pollution control facilities (such as activated carbon adsorption towers) and other related facilities.

(2) Improvement of measurement frequency and increase in number of measured items

Raise the measurement frequency in order to accurately grasp the status of atmospheric pollution. In order to achieve this, examine the introduction of automatic measuring equipment that can be used for long-term continuous monitoring.

With regard to measured items, measure non-methane hydrocarbons for examination of possibility of photochemical oxidant generation. Also, regarding the many hydrocarbon-type toxic substances, it is also necessary to narrow down items according to their toxicity and emission amounts. Benzene will probably be one of these main items for some time due to its comparatively high toxicity and large emission volume.

(3) Collection of basic information

(i) Collection of basic information on environmental aspects of each plant (such as soot and smoke amounts and fuel usage amounts)

Such information is being collected from plants in the form of questionnaires and should be input into computer databases. The questionnaire format used by the Environment Agency in Japan, which delegates such data collection to local governments, could be useful.

(ii) Collection of meteorological information

The effect of toxic substances of generation source on the surrounding terrestrial area depends on the meteorological conditions at the time. The maximum ground level concentration points and their concentrations greatly depend on the wind speed, wind direction, and stability of the atmosphere. Thus, the examinations on temperature differs by altitude, flux of insolation (high, medium, low), nocturnal emission collection amounts, as well as the amount of cloud during daytime and nighttime should be conducted using meteorological instruments.

(4) Pollution forecasts by computer, applying to countermeasures, and study of areawide total pollutant load control

Basic information should be used in computer simulations to forecast the generation of photochemical oxidants, the points of maximum ground level concentration of toxic substances and the escape directions in the case of accidents. Furthermore, in the future, the improvement of the environment only through emission concentration controls is thought to be difficult. In this case, it would be necessary to study the areawide total pollutant load controls designed to regulate the amount of pollutants at each plant, using simulations which enable us to estimate emission amounts of each generation source point (plant) and meteorological conditions.

(5) Preparation of guidance standards

It is recommended to explain pollution generating facilities and pollution control facilities such as boilers, heating furnace, incinerator, desulfurization equipment and toxic gas processing facilities in an easy way, and to prepare a guidance manual which could be used in other industrial complexes. It is important to prepare this guidance manual based on data that has actually been measured by monitoring and guiding of the facilities installed at the plants. This is because, if manuals using materials from countries other than Thailand were prepared, they may not be used due to the fact that the fuel quality and the control methods differ from those in Thailand.

3.3 Water Pollution

3.3.1 Pollution Status of Canals Inside the Industrial Complex

(1) Water sampling points

Canals cross the industrial complex as shown in Figure 3-2, which carry wastewater from the plants to the sea. The five points W1 to W5 are the water sampling points. W1 and W5 are small streams outside the industrial complex.

Figure 3-2 Atmospheric, Water, and Noise Measurement Points and Measurement Results

Parameter	Unit	Standard	Result
pH	-	5-9	6.56
DO	mg/l	<2	7.93
BOD	mg/l	>4	2.90
Pb	mg/l	0.05	0.021
Hg	mg/l	0.002	<0.002

Parameter	Unit	Standard	Result
TSP	mg/m³	0.33	0.040
NO_2	mg/m³	0.32	0.010
SO_2	mg/m³	0.3	0.010
CO	mg/m³	10.26	1.270

Parameter	Unit	Standard	Result
TSP	mg/m³	0.33	0.060
NO_2	mg/m³	0.32	0.020
SO_2	mg/m³	0.3	0.010
CO	mg/m³	10.26	1.360

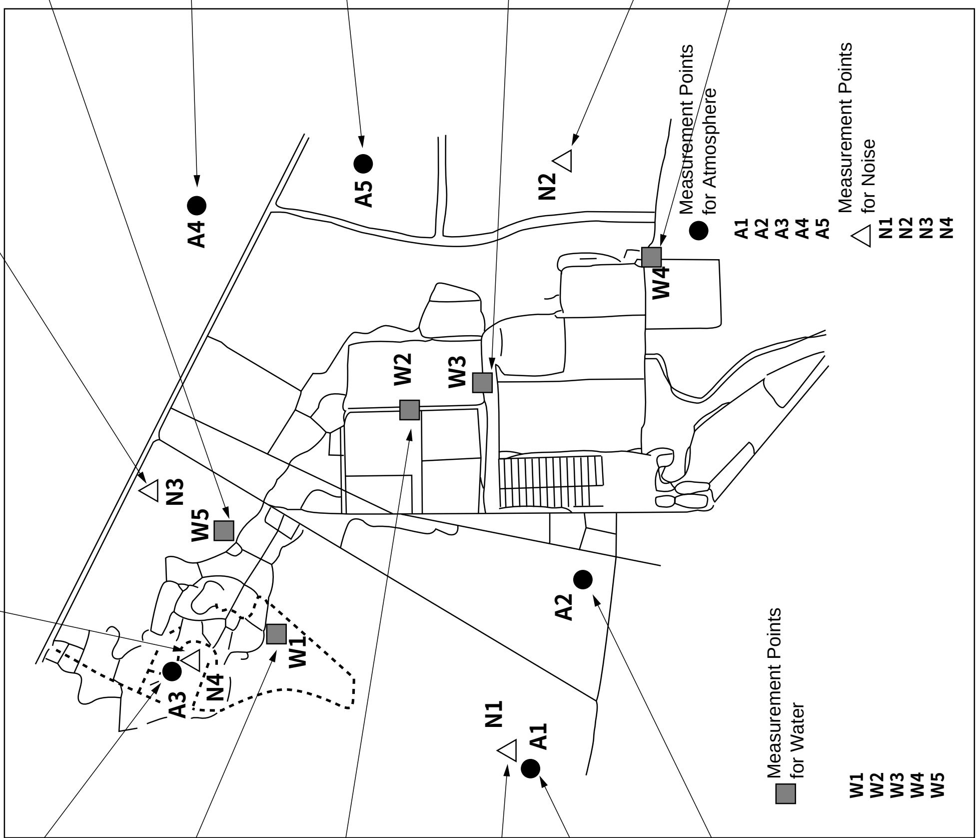
Parameter	Unit	Standard	Result
pH	-	5-9	8.10
DO	mg/l	<2	7.10
BOD	mg/l	>4	4.00
Pb	mg/l	0.05	0.015
Hg	mg/l	0.002	<0.002

Parameter	Unit	Standard	Result
Leq(24)	dBA	70	56.00

Parameter	Unit	Standard	Result
pH	-	5-9	7.92
DO	mg/l	<2	6.28
BOD	mg/l	>4	4.50
Pb	mg/l	0.05	0.017
Hg	mg/l	0.002	<0.002

Parameter	Unit	Standard	Result
Leq(24)	dBA	70	60.20

Parameter	Unit	Standard	Result
Leq(24)	dBA	70	58.30



Parameter	Unit	Standard	Result
TSP	mg/m³	0.33	0.080
NO_2	mg/m³	0.32	0.010
SO_2	mg/m³	0.3	ND
CO	mg/m³	10.26	0.110

Parameter	Unit	Standard	Result
pH	-	5-9	6.94
DO	mg/l	<2	5.00
BOD	mg/l	>4	5.70
Pb	mg/l	0.05	0.019
Hg	mg/l	0.002	<0.002

Parameter	Unit	Standard	Result
pH	-	5-9	7.10
DO	mg/l	<2	6.90
BOD	mg/l	>4	9.50
Pb	mg/l	0.05	0.019
Hg	mg/l	0.002	<0.002

Parameter	Unit	Standard	Result
Leq(24)	dBA	70	61.20

Parameter	Unit	Standard	Result
TSP	mg/m³	0.33	0.060
NO_2	mg/m³	0.32	0.010
SO_2	mg/m³	0.3	ND
CO	mg/m³	10.26	1.20

Parameter	Unit	Standard	Result
TSP	mg/m³	0.33	0.040
NO_2	mg/m³	0.32	0.010
SO_2	mg/m³	0.3	0.010
CO	mg/m³	10.26	1.18

(2) Environmental standard and measurement results

The environmental standard and measurement results at each of the measurement points are shown in Figure 3-2. The measured items which have no environmental standard are shown in Table 3-6.

Table 3-6 Results of Canal Water Quality Measurement by IEAT (July 1998)

Measured items	Unit	Detection limit	Measurement points					Environmental standard
			W1	W2	W3	W4	W5	
1. BOD	mg/kg	-	5.7	9.5	4.0	4.5	2.9	4.0
2. COD	mg/L	-	15.41	29.20	400.61	256.16	11.80	-
3. DO	mg/L	-	5.00	6.90	7.10	6.28	7.93	2.0
4. Grease & Oil	mg/kg	-	0	0	0	0	0	-
5. Nitrate Nitrogen	mg/L as NO_3^--N	-	0.27	0.48	0.74	1.22	0.05	-
6. Ammonia Nitrogen	mg/L as NH_3^--N	-	0.80	9.10	1.96	2.01	1.13	-
7. pH at 25.0ºC	-	-	6.94	7.10	8.10	7.92	6.56	-
8. Total Phosphate	mg/L	-	0.49	0.53	1.11	1.39	0.36	-
9. Suspended Solids	mg/L	-	63	53	127	110	0	-
10. Total Solids	mg/L	-	190	560	28,269	21,593	185	-
11. Salinity	ppt	-	0.1	0.4	10.0	7.8	0.1	-
12. Temperature	ºC	-	28.0	28.0	28.0	28.0	28.0	-
13. Turbidity	NTU	-	58.30	40.90	17.90	25.40	8.26	-
14. Total Cadmium	ppm	0.01	0.002	0.002	0.003	0.002	0.001	0.05
15. Total Lead	ppm	0.05	0.019	0.019	0.015	0.017	0.021	0.05
16. Total Mercury	ppm	0.001	<0.002	<0.002	<0.002	<0.002	<0.002	0.002
17. Total Zinc	mg/L as Zn	0.05	0.07	0.07	0.10	0.10	0.10	1.00
18. Fecal Coliform Bacteria	MPN: 100ml	-	130	80	50	23	8	-

Source: IEAT

(3) Pollution status

The outline of the pollution status considering environmental standard is as follows.

The measured values for lead (Pb) and mercury (Hg), which are both toxic metals, meet the environmental standard at all measurement points. Therefore, it can be said that there is no heavy metals pollution.

However, the BOD values exceed the environmental standard at all measurement points except W5. It can be said that, within the industrial complex, water is contaminated due to wastewater from plants. Particular in W2, the BOD concentration is 9.5 mg/l, which is more than double the environmental standard, indicating a high level of pollution through organic substances.

Values of COD which has no environmental standard is high at W3 and W4 (400 and 256 mg/l, respectively) while values of the BOD is low, indicating a high level of pollution through organic substances that are not easily decomposed by microorganisms.

The oxygen concentration was 5 mg/l or higher at all measurement points, a level where fish can live, but around W3 high salinity was recorded (10 ppt = 1%, while sea water = 3%), a level that is normally considered wherein fish cannot live in fresh water.

The suspended solid (SS) and total solid (TS) concentrations were high. Due to the high SS, the water is highly turbid, and is far from the level characterizing a pleasant environment. At the time of the survey, however, the water color was brown, which may indicate that soil fell into the canals from both sides during the construction of plants and roads.

Although there is no environmental standard for the concentrations of nitrates (NO_3-N, NH_3-N) and total phosphates (T-P), which cause red tides, the concentrations in these two items were 10 times higher than the normal level due to wastewater from the plants.

3.3.2 Pollution status in coastal area by industrial complex

(1) Water sampling points

The 5 water sampling points, S1 to S5 shown in Figure 3-3, are located in an area that extends east and west. Among these points, S1 is distant from the industrial complex, and the influence of waste water from residence may tend to be comparatively larger there. Measurement points S3, S4, and S5 are comparatively near the industrial complex, so they are considered to be influenced by waste water from the plants.

(2) Environmental standard and measurement results

Some of the measured values of July 18, 1998 are shown along with environmental standard in Figure 3-3, and all the measurement results are shown in Table 3-7. Cadmium (standard value: 0.005 mg/l) and total mercury (standard value: 0.0001 mg/l), which are classified as toxic substances, have standards.

(3) Pollution status

The water quality in the sea has a sign of red tide (a phenomenon that water turns red when microorganisms that live in water, mainly phytoplankton, suddenly start to propagate at an abnormal rate)[4], and it can be said that pollution is progressing. An observation (in checking the transparency of water and the degree of the attached shellfish) from the port of Map Ta Phut (an exclusive berth for fertilizer plants) shows that pollution has not yet grown exceedingly severe to the point that sludge deposits form on the sea floor due to the remains of dead phytoplankton.

The total cadmium and total mercury concentrations fully meet environmental standard, and no pollution is thought to exist from these two toxic substances.

But, the level of dissolved oxygen (DO) exceeds the saturation concentration (6.5 mg/l), a sign that phytoplankton is breeding plentifully.

A phytoplankton survey was conducted at the same time, as shown in Table 3-8. At point S4, which is located closest to the discharge point of the canal, the phytoplankton count from the middle to the

[4] For a definition of red tides and their judgment criteria, refer to "Abbreviations and Teminology" at the beginning of this report.

surface is 87,945/l, which is exceedingly high compared to the count at other locations. It is possible that the color of the sea may change in the presence of such an amount of phytoplankton.

Furthermore, the concentrations of nitrogen and phosphor, which are nutrient salts of phytoplankton are as follows. The concentration of NH3-N is higher than of Tokyo Bay. With regard to phosphor, the concentration at measurement point S5 is high and exceeds that of Tokyo Bay. Based on these measurement results, it may be said that there is a sufficient concentration of nutrients for phytoplankton to multiply, in other words, water quality level may have reached eutrophication levels.

The results of surveys on zooplankton, egg and larva, as well as benthos, are shown in Tables 3-9 to 3-11. Unlike phytoplankton, the more the number and kind of the species, the better the quality of the water. Compared to the offshore points in Tokyo bay, the number of zooplankton is 1 digit lower, and the number of bivalves (such as short-neck clams) is smaller.

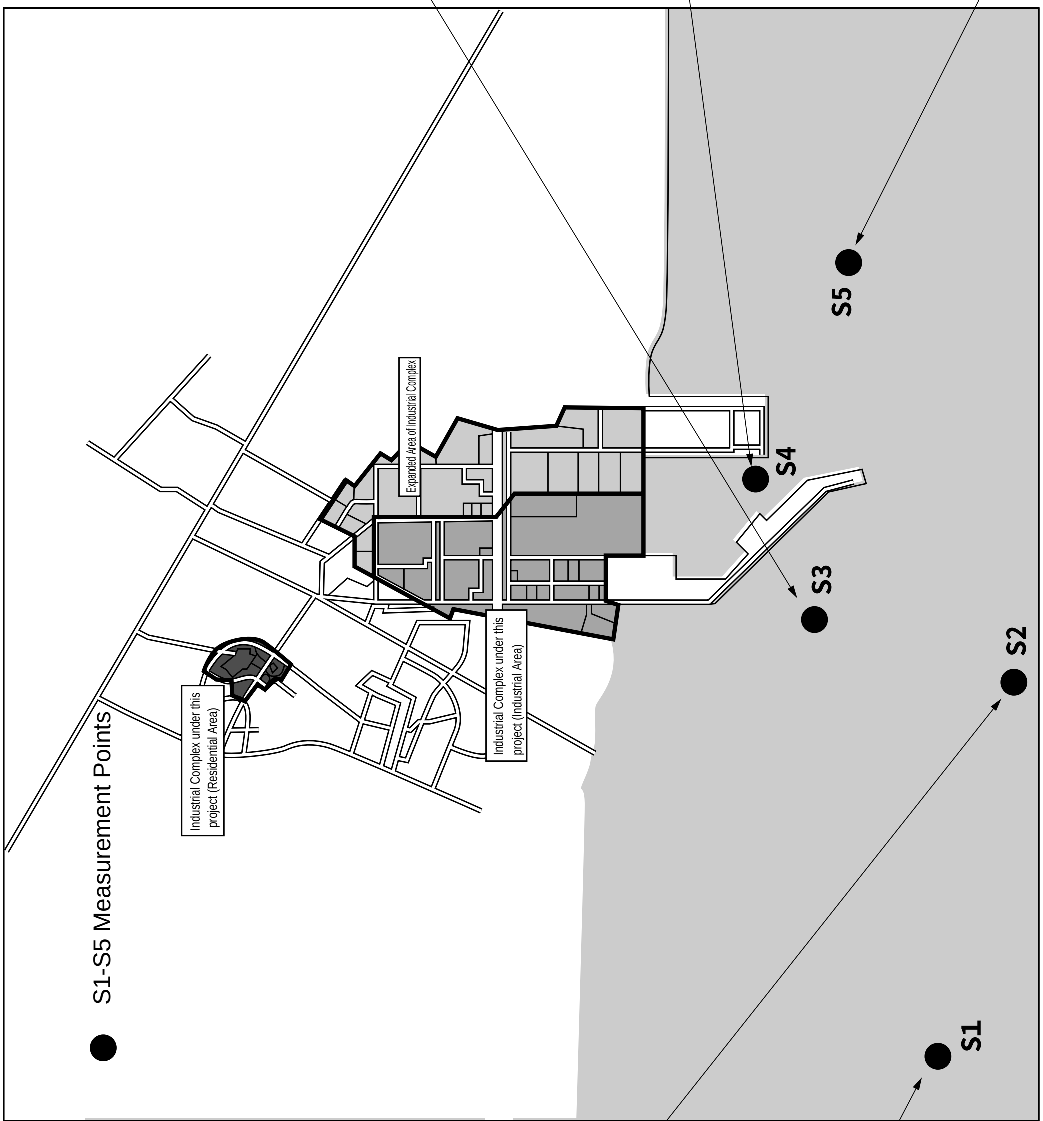
BOD measurements were made as part of the IEAT survey of the sea water quality, but the BOD cannot be measured accurately where phytoplankton exist. Moreover, since sea water contains a sufficient amount of dissolved oxygen, measurements results indicating that NO_3-N is ND is not possible. These facts suggest doubts on the reliability of the measurements.

Figure 3-3 Water Sampling Points of Sea Water

Parameter	Unit	Standard	Result
pH	-	-	8.36
DO	mg/l	-	8.20
BOD	mg/l	-	1.60
Cd	mg/l	0.005	ND
Hg	mg/l	0.0001	ND

Parameter	Unit	Standard	Result
pH	-	-	8.25
DO	mg/l	-	8.00
BOD	mg/l	-	3.10
Cd	mg/l	0.005	ND
Hg	mg/l	0.0001	ND

Parameter	Unit	Standard	Result
pH	-	-	8.31
DO	mg/l	-	13.80
BOD	mg/l	-	1.80
Cd	mg/l	0.005	ND
Hg	mg/l	0.0001	ND



Parameter	Unit	Standard	Result
pH	-	-	8.29
DO	mg/l	-	8.00
BOD	mg/l	-	1.60
Cd	mg/l	0.005	ND
Hg	mg/l	0.0001	ND

Parameter	Unit	Standard	Result
pH	-	-	8.31
DO	mg/l	-	7.88
BOD	mg/l	-	1.20
Cd	mg/l	0.005	ND
Hg	mg/l	0.0001	ND

Table 3-7 Results of Sea Water Quality Measurement by IEAT (July 1998)

Measured items	Unit	Detection limit	Measurement points					Environmental standard
			S1	S2	S3	S4	S5	
1. BOD	mg/L		1.2	1.6	1.6	3.1	1.8	-
2. DO	mg/L		7.88	8.00	8.20	8.00	13.80	-
3. Grease & Oil	mg/L		0	0	0	0	0	-
4. (Ammonia Nitrogen)	mg/L as NH_3^--N		0.56	0.28	0.14	0.56	0.28	-
5. (Nitrate Nitrogen)	mg/L as NO_3^--N		N D	ND	ND	ND	ND	—
6. (pH at 25.0ºC)			8.31	8.29	8.36	8.25	8.31	-
7. Phenol	mg/L		0.003	0.003	0.001	0.002	0.001	
8. Total Phosphate	mg/L		0.07	ND	ND	ND	0.36	
9. Salinity	mg/L		29.2	29.3	28.9	29.1	29.2	-
10. Suspended Solids	mg/L		0	0	0	5	3	-
11. Total Solids	mg/L							
12. Transparency			4.0	5.0	5.0	1.5	1.0	
12. Temperature	ºC		32	32	31	32	34	-
13. Turbidity	NTU		1.16	1.09	1.38	3.67	4.62	
14. Total Cadmium	mg/L as Cd	0.005	ND	ND	ND	ND	ND	0.005
15. Total Lead	mg/L as Pb	0.01	ND	ND	ND	ND	ND	-
16. Total Mercury	mg/L as Hg	0.001	ND	ND	ND	ND	ND	0.0001
17. Total Zinc	mg/L as Zn	0.01	0.01	0.01	0.01	<0.01	,0.01	-
18. Fecal Coliform Bacteria	MPN: 100ml		<2	<2	<2	<2	<2	-

Source: IEAT

Table 3-8 Phytoplankton Status by IEAT (July 1998)

Phytoplankton	Measurement Point S1		Measurement Point S2		Measurement Point S3		Measurement Point S4		Measurement Point S5	
	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface
Asterolampra sp.	—	—	—	—	4.77	—	—	—	—	—
Bacteriastrum sp.	4.94	19.8	24.7	49.5	81.1	49.5	42.9	34	28	—
Ceratium sp.	29.6	33	14.8	69.3	9.55	29.7	25.7	34	28	—
Chaetoceros sp.	217	495	791	1,250	850	1,350	702	1,110	203	266
Chlorella sp.	29.6	99.1	—	—	273	79.2	—	—	—	—
Coseinodiscus sp.	9.88	33	—	59.4	23.9	79.2	154	68	42	140
Dietyocha sp.	—	—	—	—	4.3	—	25.7	—	14	—
Dinophysis sp.	4.94	6.6	9.88	9.91	143	—	17.1	68	14	—
Ditylum sp.	—	—	—	19.8	4.77	—	—	17	—	—
Eunotia sp.	—	—	—	—	4.77	—	—	—	—	—
Grammatophora sp.	—	—	—	—	—	—	—	—	42	28
Guinardia sp.	9.88	6.6	—	—	23.9	—	—	—	28	—
Gyrosigma sp.	—	—	—	9.91	9.55	—	8.57	34	1.4	28
Hemiaulus sp.	24.7	26.4	39.5	19.8	38.2	29.7	34.3	34	7	—
Laudaria sp.	—	—	—	—	—	—	—	—	14	—
Navicula sp.	—	—	4.94	—	—	19.8	—	—	28	56
Nitzchia sp.	306	42.3	1,450	1,750	1670	1,390	3,020	4,050	643	1,020
Odontella sp.	—	—	—	9.91	19.1	—	8.57	17	42	—
Oscillatoria sp.	445	679	391	1,220	582	1,020	386	81,800	63	112
Paralia sp.	—	—	—	—	—	—	—	—	14	—
Pleurosigma sp.	—	6.6	4.94	9.91	4.77	—	—	—	21	—
Prorocentrum sp.	—	—	—	—	—	—	—	—	14	—
Proroperisinium sp.	29.6	—	24.8	39.6	52.5	99.1	214	441	35	196
Prychodiscus sp.	14.8	6.6	—	—	9.55	29.7	111	51	56	112
Rhizosolenia sp.	29.6	72.6	148	139	134	149	51.4	119	77	154
Scripsiella sp.	—	—	19.8	39.6	3.82	9.91	—	17	—	—
Strepiotheca sp.	4.94	—	—	—	33.4	—	—	—	7	—
Tabellaria sp.	—	13.2	—	—	—	—	—	—	—	—
Thalassionema sp.	—	—	—	—	—	—	8.57	34	14	140
Thalassiothrix sp.	—	—	—	—	—	—	8.57	17	14	—
Unknown 1	—	—	4.94	49.5	—	9.91	—	—	—	42
Unknown 2	—	—	4.94	29.7	—	—	—	—	—	140
Unknown 3	—	—	4.94	29.7	—	—	—	—	—	—
Unknown 4	—	—	4.94	9.91	—	—	—	—	—	—
Unknown 5	—	—	4.94	9.91	—	—	—	—	—	—
Unknown 6	—	—	—	9.91	—	—	—	—	—	—
Total	1,160	1,540	2,948	4,834	3,980	4,345	4,818	87,945	1,449	2,434

Source: IEAT

Table 3-9 Zooplankton Status by IEAT (July 1998)

Zooplankton	Measurement Point S1		Measurement Point S2		Measurement Point S3		Measurement Point S4		Measurement Point S5	
	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface	Bottom - Surface	Middle - Surface
Amphipod	—	1.98	—	—	—	—	—	—	—	—
Amphorela sp.	—	—	0.99	—	—	—	—	—	—	—
Amphorellopsis sp.	—	1.98	3.95	7.92	0.95	3.96	0.86	—	—	2.8
Cladoceran sp.	—	—	—	—	—	—	—	—	—	—
Codonellopsis sp.	—	—	—	—	—	—	—	—	—	—
Copepod	6.92	9.91	3.95	1.98	5.73	9.91	13.7	28.91	30.2	58.67
Eutintinnus sp.	—	—	1.98	3.96	—	—	—	1.7	2.1	—
Favella sp.	—	—	—	—	—	—	1.71	1.7	—	—
Hydrozoa	—	1.98	—	1.98	—	—	—	—	—	—
Isopod	—	—	—	—	—	—	—	—	—	—
Leprotintinnus sp.	—	—	—	1.98	—	—	2.57	1.7	2.8	—
Metacylis sp.	—	—	—	—	—	—	—	1.7	—	—
Mysid	—	—	—	—	—	1.98	—	—	—	—
Oikopleura sp.	0.99	1.98	0.99	3.96	—	—	5.14	8.5	1.4	8.4
Rhabdonella sp.	—	—	—	—	—	—	—	28.91	—	—
Rotifer	—	—	—	—	1.91	—	—	—	—	—
Parafavella sp.	—	7.92	1.98	1.98	0.95	—	—	—	—	—
Parundella sp.	—	3.96	—	5.94	—	—	1.71	—	1.4	2.8
Protorhabdonella sp.	—	—	—	—	—	—	—	—	—	—
Sagitta sp.	—	—	0.99	—	0.95	—	—	—	1.4	—
Tintinnopsis sp.	3.95	3.96	10.87	15.85	12.4	3.96	35.9	79.76	59.5	210
Undella sp.	—	—	—	1.98	—	1.98	—	3.4	—	1.4
Zoothamnium sp.	—	—	—	—	—	1.98	—	—	—	—
	—	—	—	—	—	—	—	—	—	—
	11.86	33.67	25.7	47.53	22.89	23.77	61.59	156.28	98.8	284.07

Source: IEAT

Table 3-10 Egg and Larva Status by IEAT (July 1998)

Egg and larva	Measurement Point S1	Measurement Point S2	Measurement Point S3	Measurement Point S4	Measurement Point S5
	Middle - Surface	Middle - Surface	Middle - Surface	Middle - Surface	Middle - Surface
Crustaccan Larva	77.36	126.87	92.92	222.67	92.33
Shell Larva	13.87	19.81	13.87	1.70	14.00
Miscellaneous Egg	27.74	17.83	73.11	129.15	35.00
Unknown Larva 1	5.94	1.98	1.98	1.70	—
Unknown Larva 2	—	1.98	1.98	1.70	—
Unknown Larva 3	—	—	—	1.70	—
	124.91	168.47	183.86	358.62	141.33

Source: IEAT

Table 3-11 Benthos by IEAT (July 1998)

Benthos	Measurement Point S1	Measurement Point S2	Measurement Point S3	Measurement Point S4	Measurement Point S5
Amphioxous	2	4	—	—	—
Donax sp.	4	—	—	—	—
Holothuria sp.	—	1	—	—	—
Polychate	1	8	1	6	—
Temnopleurus sp.	15	8	6	—	—
Tapes sp.	—	—	—	—	1
Turritella sp.	1	—	—	—	—
	23	21	7	6	1

Source: IEAT

3.3.3 Ground Water Pollution Status

(1) Water sampling points

The ground water sampling points consisted of three points, G1 to G3, located outside the industrial complex, as shown in Figure 3-4.

(2) Environmental standard and measurement results

Ground water has no environmental standard, but the measured items at each measurement point and the measurement results are shown in Table 3-12.

(3) Pollution status

The quality of ground water is generally affected by the soil, and in some locations there is a high concentration of inorganic substances. However, the concentration of organic substances is generally low if the water is not contaminated. From this viewpoint, the ground water at the Map Ta Phut survey points has a high concentration of organic substances and can be said that it is already polluted.

Among the measurement points, the COD concentration at G3 is 38.40 mg/l, which is extremely high compared to the concentration at the other measurement points. It is difficult to attribute such a high concentration to natural causes. Furthermore, the concentration in dissolved solids (DS) is high compared to the other measurement points, which suggests the influence of specific sources of contamination.

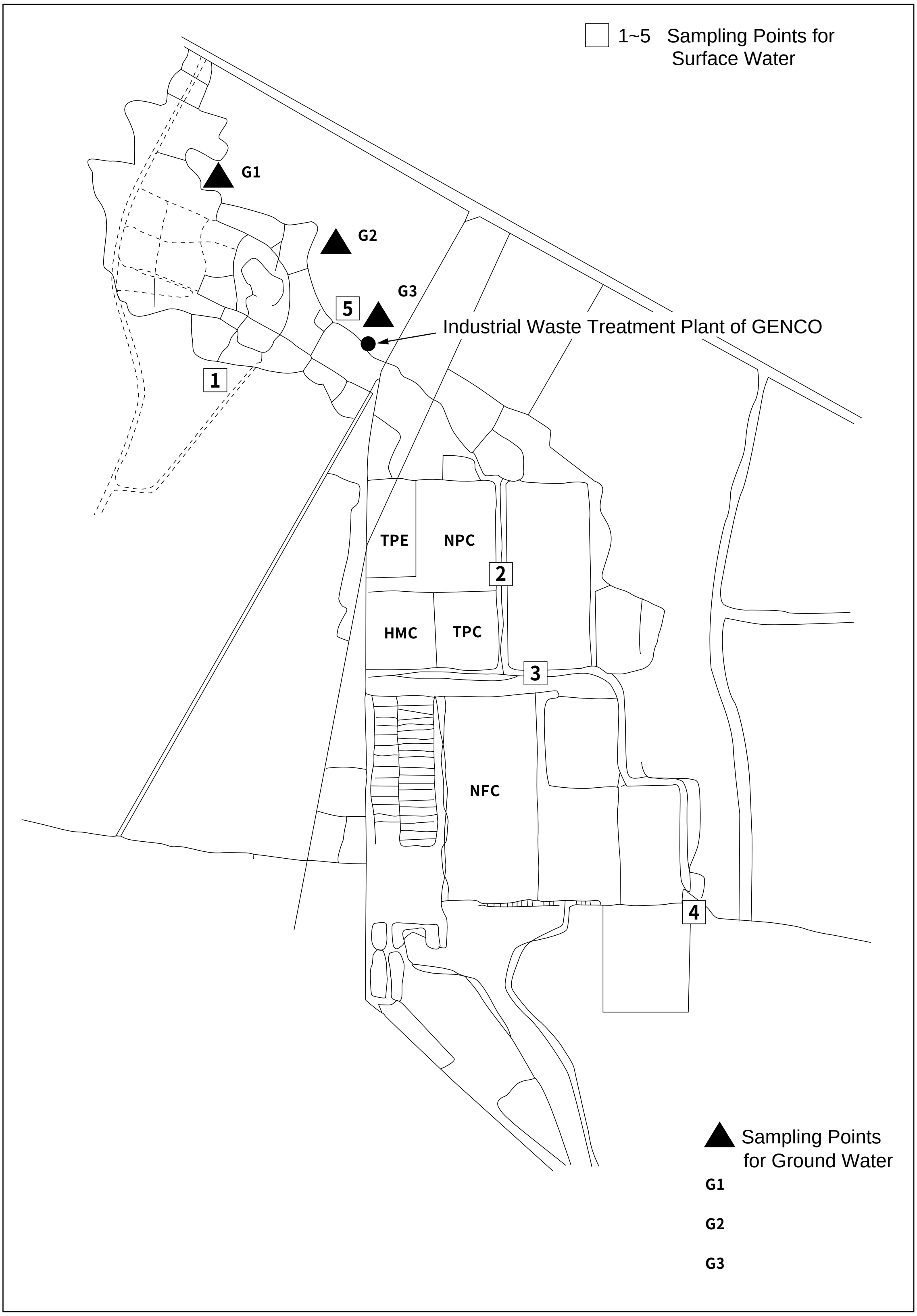
The presence of total Kjeldahl Nitrogen (TKN) indicates the existence of nearby sources of organic contamination. The TKN concentration was highest at G1, which indicates that it may possibly be caused by waste water from the households in the area.

Table 3-12 Measurement Results of Ground Water by IEAT (July 1998)

Measurement items	Unit	G1	G2	G3	Standard
1. COD	mg/L	0.82	1.00	38.40	None
2. Hardness	mg/L as $CaCO_3$	79.23	46.83	98.54	None
3. Total Kjeldahl Nitrogen	mg/L	2.23	0.56	0.84	None
4. pH at 25.0°C		6.57	6.22	7.39	None
5. Dissolved Solids	mg/L	75	83	221	None

Source: IEAT

Figure 3-4 Ground Water Sampling Points



3.3.4 Evaluation of Water Quality Monitoring by IEAT

(1) Common items of canals, sea, and ground water

(i) Measurement frequency and locations

Regarding waste waters from plants, the concentration of pollutants greatly differ depending on the manufacturing process and the container washing process. As a result, the concentration of the canals, which are strongly influenced by wastewater from plants, greatly vary. Therefore, it must be pointed out that making measurement only one time per day is not sufficient to obtain accurate water quality.

Furthermore, regarding the sampling of sea, the number of the phytoplankton differs depending on the sampling location, and considerable differences exist among different sampling points for benthos at the bottom of sea. It is necessary to carefully consider the sampling locations as well as the sampling frequency.

(ii) Reliability of measurements

<1> BOD measurements in sea

IEAT measures the BOD in sea, but generally, measuring the BOD in stagnant water area such as the sea is not appropriate because many phytoplankton exists there.

Normal method of BOD measurement is to pour a sample into a incubation bottle and measure the dissolved oxygen concentration, then leave the bottle in a tank with a constant temperature of 20℃, cutting light for 5 days, and measure the oxygen concentration in the same way as before. The BOD value is obtained from the consumed reduction in the concentration of oxygen, which reflects how much oxygen was consumed by microorganisms to dissolve the organic substances in the water.

Phytoplankton starts to breathe when the light is cut off and consume dissolved oxygen. Therefore, when the BOD of a sample tcontaining large amounts of phytoplankton is measured, it is impossible to tell whether the reduction in the concentration of oxygen after 5 days is caused by microorganisms or by phytoplankton. As a result, when phytoplankton is present in the sea, the BOD value tends to be overestimated. The BOD value at measurement point S4 (3.1 mg/l) is relatively high compared with the other points. This is thought to be due to the influence of phytoplankton.

For the above reasons, in Japan, BOD concentrations are not measured in stagnant water area where phytoplankton exists (lakes and the sea). COD concentrations are measured instead[5]. For the above, BOD measurements of sea are not adequate for water quality monitoring.

[5] Phytoplankton do not occur in rivers since rivers are flowing, and accurate BOD measurements are possible. Thus, BOD measurements are prescribed in case of rivers.

<2> NO_3-N concentrations in sea

NO_3-N in sea are all ND (concentration is too low to be measured). However, when NH_3-H exists, it is normally impossible that the NO_3-N concentration becomes ND.

NH_3-N ultimately changes into NO_3-N under the influence of nitrifying bacteria under aerobic conditions (condition of dissolved oxygen being present in the water). Under anaerobic conditions (condition of oxygen not present in the water), NO_3-N changes into nitrogen gas under the influence of denitrobacteria, and nitrogen disappears from the water. Since the concentration of dissolved oxygen in sea is high in this area, there should be no denitrification. Thus it is considered that the measurements of NO_3-N contain errors.

(2) Canal in the industrial complex

(i) Monitoring items

The monitoring items listed in Table 3-6 are sufficient. It is desirable to continue monitoring of these items.

(ii) Determining wastewater amount

The fact that COD, TS, T-S and other concentrations at canal measurement points differ greatly is considered to be due to the influence of waste water from plants. This is because the water volume of the canal is not very large compared to volume of waste water from the plants. Therefore, volume of the canal water and the volume of the waste water from each plant (such as discharge time, hourly discharge volume) can be used to understand the degree of dilution of the waste water from plants by the volume of the canal water. It leads to clarify the reasons for fluctuations in concentrations at the measurement points and if there were plants which needed measures, the location could be accurately determined.

(iii) Water quality targets

Water quality targets (for example, water quality that fish can live) for canals have not been established. It would be desirable to establish the aim of the canal water quality monitoring and targets of the canal water quality as well as biological indicators in order to clarify the extent of the measures in case such measures are required.

(iv) Regulation of industrial wastewater

Canals are drainages that receive industrial wastewater, but since there are plants that discharge wastewater with high concentrations of phosphorus and nitrogen, their discharges need to be regulated to specific levels in order to avoid red tides.

Moreover, waste water that includes high concentrations of nitrogen and phosphor may be utilized for sprinkling plants in the industrial complex or for agricultural fertilizer, either in part or as a whole.

(3) Adjacent sea of the industrial complex

(i) Monitoring items

It would be desirable to remove BOD and to add COD and phytoplankton in the list of monitoring items in Table 3-7. The other items listed in Table 3-7 are sufficient.

(ii) Measurement of organic substances in sea

As described in the common items, BOD measurement in sea is not appropriate. Moreover, since measured values of NO_3-N in the measured sea could not be ND, a review of the measurement procedure is required.

(iii) Possibility of red tides

It is necessary to periodically perform measurement of red tides caused by abnormal multiplication of phytoplankton. Various methods are available, including counting the number of the phytoplankton and measuring the concentration of chlorophyll which phytoplankton has in common.

Unlike Japan, considering meteorological conditions, the water temperature is high enough for red tides to occur. Consequently, it may not be possible to use Japanese survey and research data as it is.

(iv) Survey of eutrophication substances

The causes of abnormal multiplication of phytoplankton are nitrogen and phosphorus. These nutrient salts come from plants, agricultural fertilizers, and waste water from households. It is necessary to study the percentages and contribution ratios of each of these generation sources of nutrient salts and implement reduction measures based on the results.

In studying the generation sources of these nutrient salts, it is important to consider the influence of ocean currents during each season, due to the fact that it is possible that sea flows from the interior of the Gulf of Thailand to the Map Ta Phut coast by seasonal winds.

(4) Ground water

(i) Monitoring items

It is desirable to add electric conductivity to the list of items in Table 3-12. Electric conductivity greatly varies according to the salinity and therefore it is a good indicator of the degree of pollution of ground water. It is very easy to measure.

(ii) Identification of pollution sources

Since G3 is located near GENCO, there is a high possibility that GENCO is a source of pollution for ground water, and this should be investigated as soon as possible. At the same time, it is urgently necessary to survey to find out if local residents are using ground water as drinking water.

(iii) Survey of ground water flows

Pollutants in ground water are gradually dispersed through water flows. Therefore, the local residents living in downstream of ground water and using the ground water will soon suffer from ground water pollution. In order to check the possibility of harm to local residents, it would be desirable to check ground water flows.

Generally, in case the pollution source of ground water is detected, measures for stopping further dispersion of pollutants through pumping up ground water are implemented. If the problem is handled before ground water pollutants spread over a large area, through the prompt implementation of such measures, the scale of the damage can be reduced.

3.3.5 Suggestions About Water Quality Monitoring by IEAT

(1) Monitoring items and measurement frequency

The current canal monitoring items are acceptable. It would also be desirable to add COD and phytoplankton for sea, and electric conductivity for ground water as measured items.

With regard to the measurement frequency, it should be increased to a level permitting a grasp of the overall pollution situation. The pH level and electric conductivity can be measured in the long term using automatic measuring equipment.

(2) Improvement in reliability of monitoring measurements

NO_3-N measurement methods must be reviewed. With regard to organic substance measurement items such as BOD and COD, considerable care should be given to temperature control from sampling to measuring. Furthermore, in case the oxygen concentration in the sea is measured by using measuring instruments, such measurements should be performed by immersing the instruments in the sea. Measurements, performed after the sample has been placed in a container, must be avoided since gaseous oxygen will escape from the water. Since mercury, cadmium, and other toxic heavy metals are often used in water analyses in Thailand, as shown in Table 3-13, full attention should be paid to processing the waste liquid.

Table 3-13　　Pollution Level of Analysis Waste Liquid in ERTC

Analysis items	Analysis methods	Pollutants	Content (mg/ specimen)	Effluent standard (mg/l)	Required dilution volume [a] (l)	The number of analysis specimens (specimens/year)
COD	Potassium dichromate method	Ag Cr Hg	758 109 676	0.02[b] 0.5 0.005	37,900 218 135,200	480
DO/BOD	Natrium azide modification	Mn	0.24	5	0	1,150
Cl	Mohr method	Ag Cr	1.52 13.4	0.02[b] 0.5	76 27	300
Org-N	Kjeldahl method	Hg	88.3	0.005	17,660	500
NH_3	Nessler method	Hg	88.3	0.005	17,660	500
NO_3	Cu.Cd column reduction	Cd Cu	? 6.7	0.03 1	? 7	300
T-P	Molybdenum blue method (Ascorbic acid reduction)	Mo Sb	3.3 0.4	0.7[c] 0.02[c]	5 20	300

a)　Required dilution volume: The volume of water required for the dilution to meet the effluent standard

b)　Effluent standard for the zinc industry of Thailand

c)　10 times of the index value for monitoring-required items in Japan (in Thailand, no effluent standard has been established.)

(3) Promotion of industrial wastewater regulation

It is recommended to investigate the generation sources of nitrogen and phosphorus in sea and limit the discharged amounts of these two substances in order to prevent red tides. Moreover, in order to prevent the discharge of wastewaters with high concentrations of nutrients in public waters, it is desirable to consider sprinkling water for tree-lined roads and agricultural land, where evaporation is fast.

(4) Canals

It is recommended to clarify water quality targets. One possibility is to aim for water quality where fish can live. People would know if the canals of the Industrial Complex is an environment with a large number of aquatic life since they can see this for themselves.

(5) Sea

It would be desirable to survey the number of occurrence of red tides every year and take measures to prevent this number from increasing. For this purpose, it is necessary to accurately determine the concentrations of nitrogen and phosphorus, sea water flows, and sources of pollution.

(6) Ground water

Clarify sources of pollutants for ground water, urgently. It is also necessary to promptly implement measures if local residents were using ground water as drinking water.

3.4 Noise

3.4.1 Noise status

(1) Measurement points

N1 to N4 are the four measurement points for noise, as shown in Figure 3-2.

(2) Environmental standard and measurement results

The environmental standard for noise is set at 70 dB (equivalent sound level over 24 hours: Leq). The results of measurement done from July 9 to July 11, 1998, are shown in Table 3-14.

Table 3-14 Results of Environmental Sound Measurements by IEAT (July 1998)

Unit: dB

Time	Measurement points											
	N1			N2			N3			N4		
	Jul. 9	Jul. 10	Jul. 11	Jul. 9	Jul. 10	Jul. 11	Jul. 9	Jul. 10	Jul. 11	Jul. 9	Jul. 10	Jul. 11
8.00	67.6	61.6	56.3	56.0	52.3	51.9	58.7	56.7	57.0	53.1	53.7	53.8
9.00	64.5	58.1	56.3	49.1	49.1	55.6	59.6	57.1	57.5	53.2	53.4	53.3
10.00	67.8	60.2	64.0	56.3	52.3	51.8	56.6	56.2	58.2	53.2	52.3	52.6
11.00	55.9	66.0	56.4	54.5	51.4	49.9	57.4	54.9	56.5	54.6	50.0	53.0
12.00	53.3	60.8	53.1	52.9	53.7	55.8	59.2	60.1	56.8	54.0	51.7	52.4
13.00	60.1	53.5	55.3	51.3	54.2	52.0	58.4	59.0	56.9	53.9	51.8	55.6
14.00	58.3	52.9	55.3	54.1	55.5	52.4	57.3	61.1	56.0	54.3	51.3	54.8
15.00	59.9	56.2	55.1	57.3	52.6	50.1	56.6	58.5	56.4	54.9	51.5	55.6
16.00	59.1	54.2	56.6	57.2	58.0	57.0	57.0	58.5	57.4	56.6	52.8	66.5
17.00	56.5	57.9	52.4	55.0	56.7	54.5	59.3	59.3	58.2	57.8	52.8	61.6
18.00	55.2	56.7	49.7	51.5	53.0	47.1	59.7	61.3	61.4	59.7	58.0	58.2
19.00	53.1	54.4	49.7	52.5	51.2	51.1	59.4	61.3	64.3	54.5	58.3	58.1
20.00	50.0	55.6	49.8	48.8	45.9	55.2	58.6	61.9	64.2	54.6	58.6	58.4
21.00	48.5	52.1	52.6	47.5	45.9	47.7	59.7	59.6	64.3	55.6	60.2	58.1
22.00	48.5	52.5	49.1	48.0	45.9	51.9	61.9	58.6	60.8	55.6	60.1	57.8
23.00	49.4	50.5	65.2	46.3	48.9	53.6	60.0	56.9	59.6	57.5	57.8	56.3
24.00	48.1	54.7	73.3	45.8	41.4	65.8	57.5	54.5	57.5	56.4	56.3	55.2
1.00	47.1	55.8	62.0	43.9	44.5	70.2	55.7	53.7	73.5	54.7	54.3	74.6
2.00	49.1	46.7	60.1	44.9	65.8	52.1	55.2	56.6	70.4	53.9	52.7	73.3
3.00	50.4	46.0	59.5	55.5	50.3	54.2	54.4	52.0	62.1	53.1	52.7	55.6
4.00	57.5	57.2	57.9	50.4	54.6	59.7	56.8	54.1	60.8	53.1	52.5	57.6
5.00	58.4	47.0	63.3	57.5	53.1	51.3	57.7	56.2	59.5	54.1	52.8	56.1
6.00	60.7	57.0	61.7	52.8	50.7	52.6	59.8	58.5	58.3	54.4	52.8	53.8
7.00	66.7	60.2	56.3	54.5	53.9	60.2	61.2	59.6	56.9	53.7	53.1	53.5
Leq 24hr[a)]	60.6	57.8	62.2	53.4	55.2	59.3	58.6	58.5	63.6	55.2	55.3	64.3
Ldn[b)]	63.5	61.5	71.4	58.8	63.2	68.4	64.8	63.2	72.4	61.5	61.9	73.5

a) Equivalent noise level over 24 hours

b) Day-night average sound level

(3) Noise status

The measurement results at all the measurement points satisfy the environmental standard. While the noise level at times exceeds 70 dB, this is attributed to traffic noises such as trucks passing by rather than noise from plants.

3.4.2 Evaluation of Noise Monitoring by IEAT

(1) Survey of complaints

Since noise is a type of sensory nuisance, it is basically important that there are no complaints from local residents. Even if noise from generation sources meets environmental standard, the existence of a large number of complaints would still make it problematic. With regard to this point, the IEAT has failed to conduct a survey of complaints about noise from plants. Such a survey would be desirable.

(2) Clarification of noise classifications

Traffic noises and noise from plants are not separated and not separately evaluated at Map Ta Phut. Both types of sound should be separated and considered individually in order to more precisely identify noise sources and devise effective countermeasures.

Regarding traffic noise, vehicles passing at the time of measurement should be classified into large and small vehicles and their respective numbers should be recorded, in order to grasp the situation more clearly.

Noise from plants, which attenuates as the distance from the plants increases, can be calculated using so-called distance attenuation. This could be done by placing measurement points at uniform intervals in a straight line from the noise source (plant) and by measuring the noise level at all measurement points as much as possible simultaneously. The influence range of plant noise would become clear in this way, as would the influence range of noise from vehicles.

3.4.3 Suggestions About Noise Monitoring by IEAT

(1) Conduct a survey of complaints about noise, and implement noise-reduction measures if there were complaints even if the noise level meets the environmental standard.

(2) Clarify the types of noises (noise from plants and noise from vehicles). If there were complaints, the rational implementation of noise countermeasures directed at the correct source, plants and/or vehicles would be possible.

(3) Systematically implement zoning for industrial and residential areas.

3.5 Industrial Waste

Industrial waste are treated in part by each plant, and in part by GENCO, a private sector industrial waste treatment operator. GENCO was established in 1994 with the aim of industrial waste treatment, and the Ministry of Industry of Thailand invested 25% of the capital. Currently, all kinds of industrial waste are accumulating at GENCO, and adequate processing of these industrial wastes is considered to be an important key to the issue of industrial waste, which is expected to increase in the future. Therefore, the status of waste treatment mainly at GENCO was investigated.

3.5.1 Status of industrial waste treatment by GENCO

GENCO's waste treatment facilities are located in a area adjacent to the Map Ta Phut Industrial Complex, as shown in Figure 3-4. This area measures approximately 100,000 m^2. Its operation is landfill (direct disposal and disposal water stabilizing treatment) and waste oil treatment. As of November 1998, this area received industrial waste from approximately 300 companies. The industrial waste breakdown is 35% direct disposal, 30% stabilizing treatment, and 35% waste oil treatment. Waste oil is compounded for combustion heat and is sold to cement plants.

(1) Landfill disposal

Currently, GENCO has a landfill disposal capacity of 200,000 tons. The waste that is brought in is first inspected, and if it is not toxic, it is directly disposed of in landfills. If the waste includes toxic substances such as metals, it is rendered insoluble with chelating agents, and undergoes cement solidification (stabilizing treatment), then it is buried in landfills. From the inspection of industrial waste examination and analysis rooms, it can be said that samples were well arranged, and analysis equipments were in good condition.

As shown in Figure 3-5, European and US standards are applied for the waste disposal site bottom liner that separates polluted water from the waste that is disposed in landfills. The waste disposal site bottom liner consists of 100 cm of clay (No. 8 in Figure 3-5), 1.5 mm of polyethylene (No. 7 in Figure 3-5), geotextile (No. 6 in Figure 3-5), bentonite (No. 5 in Figure 3-5), 1.5 mm of high-density ethylene (No. 4 in Figure 3-5), geotextile (No. 3 in Figure 3-5), sand (No. 2 in Figure 3-5), and soil (No. 1 in Figure 3-5) from the lowermost layer to upper layers. A pipe is also inserted to drain rain water that has accumulated inside the waste disposal site bottom liner.

Polluted water that accumulates in the waste disposal site bottom liner is periodically sampled and analyzed. During the rainy season, however, approximately 45 tons of polluted water with a high BOD concentration (1000 mg/l or higher) is drained. This polluted water is transported by truck and treated by an IEAT waste water treatment plant located inside the Map Ta Phut Industrial Complex. The concentration of heavy metals in this polluted water is low (Figure 3-15), below the IEAT acceptance standard.

Figure 3-5 Waste Disposal Site Bottom Liner

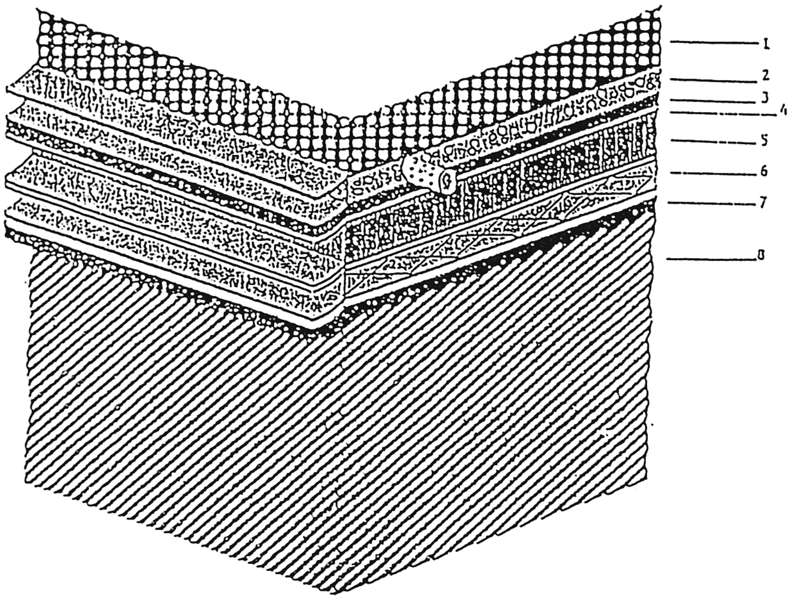


Table 3-15 Results of Measurement by IEAT of Heavy Metals in Leachate

	Sampling Dates	
	July 31, 1998	August 20, 1998
Barium	0.109	0.381
Cadmium	0.008	0.011
Chromium	0.004	ND
Copper	ND	ND
Lead	0.003	0.168
Manganese	0.004	ND
Mercury	0.002	ND
Nickel	0.03	0.236
Selenium	0.002	0.004
Silver	0.008	0.009
Zinc	ND	0.022
pH	9	9

ND = Non detectable (concentrations that could not be detected through correct measurement)

(2) Waste oil treatment

Wastes that undergo waste oil treatment are thinner, alcohols, used oils from refineries, lubricant and so on. Special hermetic trucks are used to carry these substances in order to prevent spilling and evaporation during transportation and the equipment to prevent damages in case of an accident was installed. The transportation routes are fixed, each truck is equipped with emergency devices, and the drivers are well trained according to GENCO.

The collected waste oil is stored in temporary holding tanks. SS is filtered out and constituents are compounded to achieve a uniform combustion heat, and then sold to cement plants.

3.5.2 Evaluation of Industrial Waste Treatment by GENCO

(1) Malodors

According to interviews with officers of Map Ta Phut Municipality, foul odor were emitted from waste oil treatment by GENCO, and complaints occurred from a nearby hospital and local residents. While strong odor was not detected during the visit of the facilities, the emission of such foul odor can be expected based on the fact that equipment was observed to lie bare outdoors when the waste oil treatment facilities were inspected from outside.

(2) Water pollution

(i) Pollution inside waste disposal site bottom liner

The BOD concentration of the polluted water accumulated inside the waste disposal site bottom liner is extremely high, but this polluted water cannot be treated due to the lack of treatment facilities inside the GENCO site. As a result, it must be carried to the small scale sewage treatment plant managed by IEAT located inside the Map Ta Phut Industrial Complex. However, the fact that the BOD concentration of this polluted water exceeds the acceptance standard (1000mg/l) for sewage treatment plant is a problem.

(ii) Ground water contamination

The pollution sources of the ground water near GENCO are not known. If GENCO is the source of pollution, this could mean that the waste disposal site bottom liner are ripped, or that rain water accumulating on the landfill area seeps in and flows outside the landfill area. In any case, a prompt investigation of the pollution source is needed.

(3) Possibility of methane gas emission

Since organic substances including polluted sludge are also buried in the landfills, there is a possibility of emission of methane gas putrefied in underground. Although the IEAT does not confirm gas emissions, a prompt investigation is needed.

3.5.3 Suggestions About Industrial Waste Treatment by GENCO

(1) Promptly implement countermeasures for foul odor from the waste oil treatment facilities (such as installation of odor eliminating facilities, etc.).

(2) Promptly establish water treatment facilities capable of processing the highly contaminated water inside the waste disposal site bottom liner within the GENCO site.
Moreover, promptly identify the source of pollution of ground water.

(3) Confirm methane gas emission, and if present, devise safety measures as well as countermeasures for foul odor.

4. Pollution Countermeasures at Visited Plants

I visited 10 plants located in the Map Ta Phut Industrial Complex and interviewed the officers in charge of environment about the status of countermeasures of pollution. Most of the plants we visited were foreign affiliated, and they appeared to satisfactorily implement anti-pollution measures using technologies of their respective country, and to have sufficient capabilities to implement measures. If there is monitoring, adequate countermeasures could be taken for points that will need improvement in the future and guidance to each plant regarding pollution countermeasures by IEAT. For the status of pollution countermeasures and the issues of each plant, refer to Attachment 1.

5. General Comments

The Map Ta Phut Industrial Complex houses principally oil refineries and petrochemistry that use abundant natural gas, as their main fuel and/or raw material, so that the complex is in a very different circumstances from that of Japan in the past with regard to environmental pollution, mainly by dust and sulfur oxides. The temperatures are high throughout the year in Thailand, and do not greatly change like in Japan. Therefore, the high atmospheric and water temperatures in the summer of Japan are equivalent to normal temperatures in Thailand.

Under these conditions, the main problems are those of foul odor and water pollution. The problem of odor has been greatly improved through the efforts of the IEAT and the plants in the complex, and it is believed that they will soon be settled. In the light of this achievement, while continuous attention needs to be paid to the sources of foul odor and facilities in general, many plants have either obtained the ISO 14001 certification or are in the process of obtaining it, and foreign-affiliated plants are fully implementing the technologies of their respective countries. The national character of the Thai, that is to say, cooperative attitude of residents, the government, and plants can be added to such a background.

With regard to the water quality, pollution is getting worse. Since there has been no direct complaint from residents, once water pollution starts, stopping its spread is rather difficult. A plant in the Map Ta Phut Industrial Complex made a target of water quality that fish can live for its treated wastewater. The attainment of an environment in which fish can live in small rivers and canals through the implementation of such efforts on a large scale would greatly soften the concerns of the residents living in the vicinity of the industrial complex.

With regard to the sea, it cannot be said that the beautiful south sea coast scenery has visibly worsened due to pollution. Red tides occur only in a very limited area and within a little distance from the industrial area, most areas present wonderful waterside sights. To preserve this beauty, however, it is important to implement measures quickly to prevent its worsening and the spreading of pollution.

With regard to the industrial waste, as the volume will be increasing in the future, its treatment will be a big issue. At present, GENCO is a sole waste treatment operator in the area. Since the technical level of GENCO is rather high, it is expected that GENCO would cope with the issues addressed in this report.

Lastly, it is sincerely wished that Thailand achieve the successful coexistence of such a large-scale industrial complex and scenic south sea areas. By achieving this, Thailand would of course become an advanced nation in this field, and certainly serve as an important model for the other developing nations.

① Equipment preventing odor at a factory in Map Ta Phut Industrial Complex

② View from IEAT office in Map Ta Phut Industrial Complex