No. 38

THE STUDY ON THE AIR QUALITY MANAGEMENT PLANNING FOR THE SAMUT PRAKARN INDUSTRIAL DISTRICT IN THE KINGDOM OF THAILAND

FINAL REPORT

JANUARY, 1991

JAPAN INTERNATIONAL COOPERATION AGENCY

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PREFACE

In response to a request from the Government of the Kingdom of Thailand, the Japanese Government decided to conduct a study on the Air Quality Management Planning for the Samut Prakarn Industrial District and entrusted the study to the Japan International Cooperation Agency (JICA).

JICA sent to Thailand a study team headed by Dr. Takeshi Yamada, Industrial Pollution Control Association of Japan, five times between January 1988 and October 1989.

The team held discussions with the officials concerned of the Government of the Kingdom of Thailand and conducted field surveys. After the team returned to Japan, further studies were made and the present report was prepared.

I hope that this report will contribute to the promotion of Air Quality Management Planning for Samut Prakarn Industrial District and to the enhancement of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Kingdom of Thailand for their close cooperation extended to the team.

January 1991

Kensuke Yanagiya

Kensuke Yanagiya
President
Japan International Cooperation Agency

LIST OF ABBREVIATIONS

AAS; Atomic Absorption Spectrometry
ASTM; American Society for Testing Materials
BACT; Best Available Control Technology
CAA; Clean Air Act
CMB; Chemical Mass Balance Method
COCA; Clearliness and Orderliness of Country Act
DIW; Department of Industrial Work
E-C; Elemental Carbon
EGAT; Electricity Generating Authority of Thailand
EIA; Environment Impact Assessment
EPA; Environment Protection Agency
FAC; Factory Act
FP; Flame Photometry
GDP; Gross Domestic Product
HC; Hydro Carbon
IC; Ion Chromatography
ICNEQA; Improvement and Conservation of National Environment Quality Act
IEAT; Industrial Estate Authority of Thailand
IEATA; Industrial Estate Authority of Thailand Act
INAA; Instrumental Newtron Activation Analysis
JICA; Japan International Cooperation Agency
JIS; Japanese Industrial Standard
LAER; Lowest Achievable Emission Rate
MEA; Metropolitan Electricity Authority
MOC; Ministry of Commerce
MOI; Ministry of Industry
NAAQS; National Ambient Air Quality Standard
NEA; National Energy Administration
NEB; National Environment Boad
NEPO; National Energy Policy Office
NESDB; National Economic and Social Development Boad
NESHAP; National Emission Standards for Hazardous Air Pollutants
NO; Nitrogen Oxide
NO_2; Nitrogen Dioxide
NO_x; Nigrogen Oxides
NSPS; New Source Performance Standard
O-C; Organic Carbon
ONEB; Office of the National Environment Boad

PAA; The Poisonous Articles Act
PHA; Public Health Act
PPP; Polluter Pays Principle
PSD; Prevention of Significant Deterioration
SO_2; Sulphure Dioxide
SP; Spectro Photometry
SPM; Suspended Particulate Matter
T-C; Total Carbon
TDRI; Thailand Development Research Institute
TSP; Total Suspended Particulate
XRF; X-ray Fluorescence Analysis

LIST OF UNITS

A; ampere
Å; angstrom
°C; centigrade
cal·cm^{-2}·h^{-1}; calories per square centimeter per hour
cal·cm^{-2}·min^{-1}; calories per square centimeter per minute
cm; centimeter
g; gram
g/cm^2; grams per square centimeter
h; hour
Hz; hertz
kcal/ℓ; kilocalories per litter
kg; kilogram
kℓ; kilolitter
km; kilometer
ℓ/min; litters per minute
m; meter
m^3; cubic meter
mA; milliampere
mg/m^3; milligrams per cubic meter
mm; millimeter
mmHg; millimeters hydrogram (mercury)
mmH_2O; millimeters hydrogen oxide
m/s; meters per second
nm; nanometer
Nm^3/kg; normal cubic meters per kilogram
Nm^3/ℓ; normal cubic meters per litter
ppb; part per billion
ppm; part per million
s; second
μg; microgram
μg/m^3; micrograms per cubic meter
μm; micrometer
W/m^2; watt per square meter

SUMMARY AND CONCLUSION

1. Introduction

1.1 Objectives of the Survey

This survey has two objectives: one, that the Japanese government provide the Thai government with the data and advice necessary for the latter to formulate an environmental control plan for air pollution (with respect to SO_2, NO_2, and suspended particulate matters) primarily accompanied by industrial activities in the Samut Prakarn district of the country; and two, that the survey team on behalf of the JICA accomplish technology transfer concerning the survey work to the ONEB (Office of the National Environment Board), the counterpart agency of Thailand, while this survey is under way.

1.2 Outline of the Survey

In order to furnish the necessary data useful for planning the environmental control of air pollution, the team firstly measured the atmospheric concentration levels of pollutants and meteorological variables as well as the amounts of air pollutants exhausted from the sources across the district. Secondly, the team investigated the correlation between the emission volumes and ambient pollutant concentrations by using air diffusion simulation models, thus clarifying the contributions of individual sources to the environment. In order to induce the necessary advice for planning environmental control measures, the team also compared the current ambient pollutant concentrations with the environmental standards; screened the target emission sources that required remedial actions based on the contribution rates of such sources; studied the methods of depleting the emission sources (including such measures as reduction of emissions, installation of higher stacks, and improvement of fuel quality); estimated the costs required for abatement of emission sources; assessed the possible impact of such source improvements on production cost and national economy; predicted the future ambient pollutant concentrations after such remedial measures are implemented to sources; and confirmed the compliance of the improvements with the environmental standards. The team furthermore reviewed the monitoring system of sources and ambient pollutant concentrations and collected various relevant data that lead to the improvement of legislative and administrative structures involved in environmental conservation, thus making comprehensive suggestions for formulation of the environmental control plan while considering the social and economic situations of Thailand.

Figure 1 illustrates the outline of the survey and the job relationships.

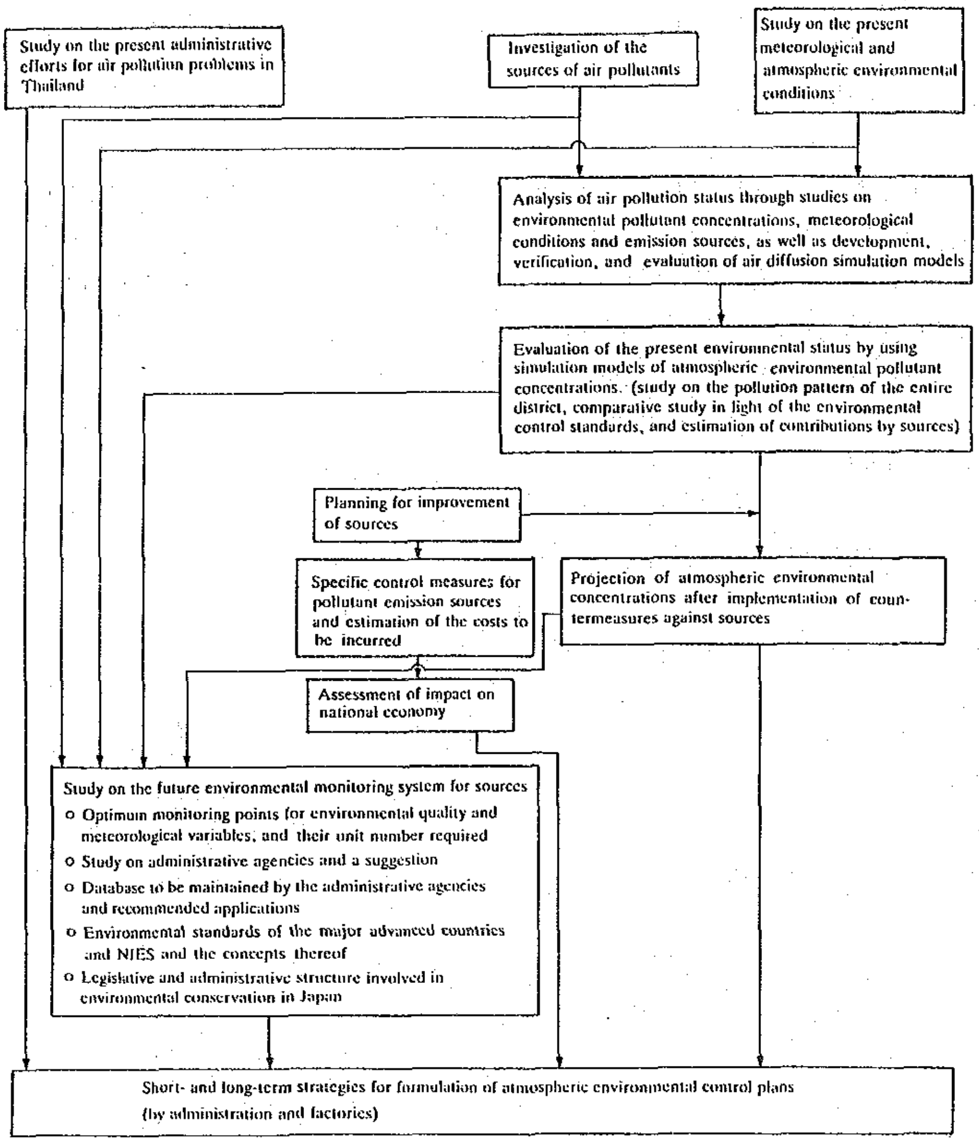


Figure 1 Flow Chart of the Entire Survey

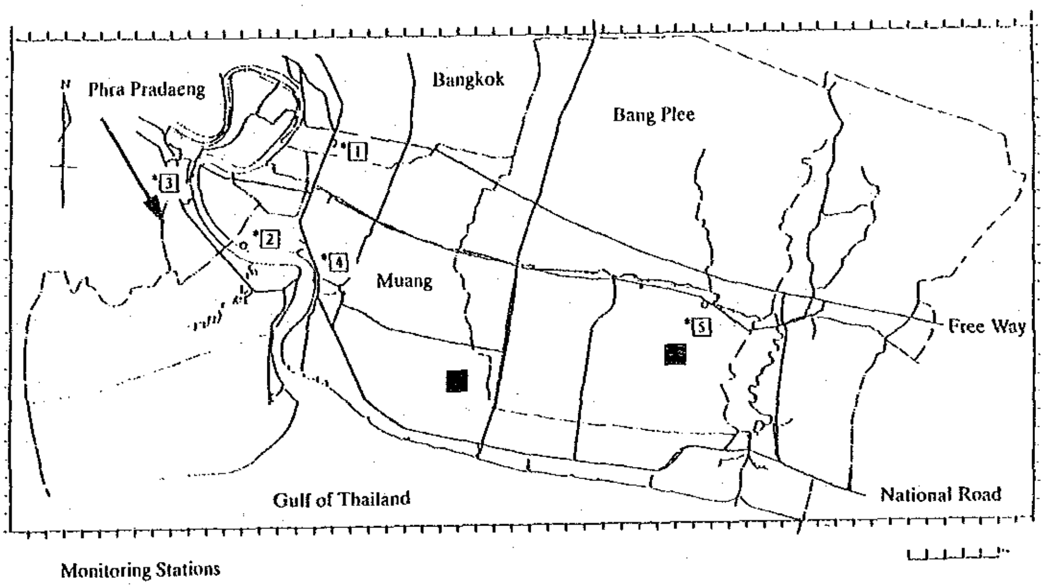
1.3 Survey Area

Samut Prakarn Province is situated on the south side of the metropolitan region of Bangkok, comprising the counties of Phra Pradaeng, Muang, and Bang Plee. This survey covers, as shown in Figure 2, an area of about 60 km from east to west and about 30 km from south to north including these counties and part of Bangkok City.

1.4 General Statement of the Area

(1) Geographical features

Samut Prakarn Province is situated in latitudes 101° East and 14° North and on the south side of the metropolitan region of Bangkok, and is an industrial area having an area of about 890 km^2. The south side of this province is facing the Gulf of Thailand as shown in Figure 2, with the Chao Phraya River flowing nearly in the center of Muang, and is nearly flat across its whole area, the maximum elevation of which is less than 20 m.



Monitoring Stations
* MS1 ONEB Station
* MS2 Power Plant, EGAT
* MS3 Mineral Department Office
* MS4 Samut Prakarn Provincial Office
* MS5 Housing and Industrial Estate

Figure 2 The Regional Map of Samut Prakarn Province

(2) Climate

There is little change in temperature throughout the year, and the annual average temperature is 28°C to 30°C. Humidity also stays at 75% to 80% the year round, characteristic of a typical tropical climate. The climate is divided into three seasons, the Hot season (March to June), the Rainy season (July to October), and the Cool season (November to February) by wind type and by rainfall frequency. The wind maintains a mostly S direction in February to August, and an N direction in November to December, but no consistent direction in the other months. The wind velocity is around 1 m/s to 3 m/s, often less than 1 m/s.

(3) Distribution of sources

There are about 2,500 small and large factories located in Samut Prakarn Province, most of which are concentrated in Phra Pradaeng, the central area of Muang, and the south banks of the Chao Phraya River. Outside of these counties, the factories are sporadically located in Bang Poo Industrial Park and Bang Plee Industrial Park, and along the expressway of Bang Plee.

The trunk roadways in these provinces are expressways, and state and provincial roads, the total length of which reaches over 200 km with a daily average traffic volume of about 500 to 75,000 cars (including motorbicycles) depending on the routes.

The other emission sources of air pollutants include ferryboats and ships. About 150 ships per day with tonnages of several hundreds to over 10,000 are sailing along the Chao Phraya River. In addition, the ferryboats are in service between both banks of the Chao Phraya River running through Phra Pradaeng, with their number at about 1,300 a day (which accounts for the frequency of services between three landing spots for the boats).

(4) Plan for development

Two industrial parks, Bang Poo Industrial Park and Bang Plee Industrial Park have been developed in the province to attract factories from within Thailand and from abroad. Bang Plee Industrial Park is inland based and has a short history since its development, and at present about 20% of the site is occupied by factories. Bang Poo Industrial Park, on the contrary, has been well developed, enjoying about 1/3 usage of the 600 ha industrial park area being used by a variety of factories in operation including foodstuffs, chemicals, metals, textiles, plastics, rubber, and clothes. In the future, the whole site of the park is likely to be occupied as more factories are moving in.

2. Present Status of the Ambient Pollutant Concentrations

In order to understand the status quo of the concentrations of air pollutants {such as SO_2, NO_2, suspended particulate matters (SPM), total suspended particulates (TSP)} and also to clarify the meteorological pattern of the district and to grasp the conditions of air diffusion, the study team placed monitoring stations at 5 spots in the target district, as agreed upon between both governments and thus monitored air pollutants and meteorological variables year-round. The team also identified all the sources (including factories, cars, ships, and ferryboats) which emit air pollutants, and quantified the ambient concentrations of SO_2 and NO_2 in the district as a whole by means of the air diffusion models. The result of the survey and the current ambient concentrations of pollutants in Samut Prakarn Province are described as follows.

2.1 Contents of the Survey

(1) Field survey of atmospheric pollutant concentrations and meteorological variables

With the monitoring stations installed at 5 spots in Samut Prakarn Province, the ambient pollutant concentrations and meteorological conditions shown in Table 1 were monitored for the period from January 17, 1988 through January 16, 1989. Furthermore, the team clarified the composition of the chemical components in the particulate matters, and then analyzed 39 chemical components in TSP by the neutron activation analysis and others for the purpose of estimating the percentage contributions of particulate matter by sources using the CMB (chemical mass balance) method. In addition, in order to determine the chemical compositions of sources of particulate matter, the team conducted chemical analysis on soil, roadway dust, and gasoline.

Table 1 Items to be Monitored at Monitoring Stations

Measurements	Station#	Period of monitoring	Instruments applied
SO_2	1, 2, 3, 4, 5	1 year	Ultraviolet-fluorescent-automatic-continuous measuring instrument (instantaneous and an hour average)
NO_x (NO, NO_2)	1, 2, 3, 4, 5	1 year	Chemiluminescence-automatic-continuous measuring instrument (instantaneous and an hour average)
SPM	1, 2, 3, 4, 5	1 year	β-ray absorption automatic continuous measuring instrument (an hour average)
TSP	1, 2, 3, 4, 5	1 year	Low volume samplers (a month average with two times filter replacement, 15 days/filter) Two samplers in use are one with a quartz filter and the other with a polyfluorocarbon filter.
TSP size distribution	1, 2, 3, 4, 5	3 seasons rainy, dry, mid-term	Andersen sampler 15 days average
Wind velocity direction	1 (3-dimensional) 2, 5 (2-dimensional)	1 year	2- and 3-dimensional ultrasonic automatic continuous anemometer 10 minutes moving average
Solar radiation Radiation balance	1	1 year	Automatic continuous measuring instrument (instantaneous and an hour average)
Air turbulency	1	1 year	3-dimensional ultrasonic anemometer (horizontal and vertical direction)

(2) Investigation of the sources of air pollutants

1) Factories

The amounts of SO_2 and NO_x exhausted from factories were estimated in principle based on the results of the questionnaire survey. As for those minor factories to which no questionnaire was sent and those from which no response to the questionnaires was received (572 factories), we set the base unit of fuel consumption per employee utilizing the data from the responding factories who reached to 208, and thus estimated the fuel consumption and emission volumes of SO_2 and NO_x of the former factories.

2) Cars

The team calculated the amounts of SO_2 and NO_x exhausted from cars running on the roads with the total length of 243 km based on the traffic volume by type of car and data on driving speeds as well as the emission factor of non-emission controled cars established by Japan's Ministry of Construction.

3) Ships and ferryboats

We estimated the amounts of SO_2 and NO_x exhausted from the ships navigating along the Chao Phraya River and the ferryboats in service between both banks of the Chao Phraya River running through Phra Pradaeng, based upon the survey of the number of ships, the emission factor of ships established by Japan's Ministry of International Trade and Industry and the results of the analysis which was separately conducted on the sulfur contents of fuels.

(3) Simulation of air pollutants

1) SO_2 and NO_2

In this survey, it was thought necessary to calculate under various meteorological conditions the ambient pollutant concentrations across the whole area of Samut Prakarn Province, having a huge number of sources. Furthermore, since the topographic effect on the state of diffusion is considered negligible due to the flat configuration of the ground in the area, the study complied with the manual of the ambient SO_x and NO_x prediction method in comprehensive environmental assessment issued by Japan's Ministry of International Trade and Industry, thus calculating the long-term average concentrations (yearly average concentrations) of SO_2 and NO_2 by using a plume-puff model.

2) TSP

The simulation of the atmospheric concentrations of particulate matters involves various problems such as the diversity of sources, modeling of the production of secondary particles and modeling of the precipitation and deposition of particles, making it difficult to use an air diffusion model. Relying on the chemical mass balance method (CMB method) which has recently drawn worldwide attention, the team estimated the contribution rates of particulate matters by type of source (i.e., sea salt particles, soil and roadway dust, diesel cars, gasoline cars, the iron and steel industry, the glass industry, and oil combustion).

2.2 Outline of Survey Results

(1) Concentrations of air pollutants

1) Present status of ambient pollutant concentrations

When the concentrations of SO_2 and NO_2 (Table 2) measured in Samut Prakarn Province are compared with the national air quality standards of Thailand (Table 3), it can be seen that all of the monitoring stations have satisfied the standards. As compared with the environmental standards of other countries (Table 4), however, the value of SO_2 at MS 3 exceeds the standard values of England, France, Canada, Australia, and Japan. As for NO_2, the values at MS 1 and MS 4 exceed the standard level of West Germany, and further, the value at MS 4 exceeds the standards of Taiwan, Korea, Australia, and Japan.

With respect to SPM, no standard value has been established in Thailand. When compared with the standard values of the U.S. and Japan where the environmental standards have been stipulated, it is found that Thai values, except for the measurement at MS 5, are all found to exceed the U.S. and Japanese standards.

2) Daily variations of the concentrations of air pollutants

As for SO_2, although the concentrations at MS 2 and MS 3 are relatively higher than at the other monitoring stations, all the stations show high concentrations during the time frame from night until early morning, and low concentrations in the daytime.

Regarding NO_2 and NO_x ($NO + NO_2$), the concentrations at MS 1 and MS 4 along the trunk road are higher than those at the other stations, but all stations exhibit a double-peak type pattern having a peak at 7:00 to 8:00 and 19:00 to 21:00, respectively.

The values of SPM do not show very significant differences among stations, indicating the same double-peak pattern as in NO_2 and NO_x.

Table 2 Measured Values of Air Pollutants

Item Code (unit)	Station	Effective monitoring days (days)	Monitoring hours (hrs)	Yearly Average	Yearly Geometric Average	Maximum values of hourly data	Maximum values of daily average data	Values of 98% cumulative daily average
SO_2 (ppb)	MS 1	362	8684	7	4	109	23	19
	MS 2	354	8515	12	8	112	34	30
	MS 3	352	8502	24	16	199	71	60
	MS 4	360	8562	5	3	79	20	14
	MS 5	296	7225	3	2	48	21	8
NO_2 (ppb)	MS 1	354	8560	16	12	138	49	33
	MS 2	316	7763	9	6	69	32	20
	MS 3	276	6805	13	10	81	41	30
	MS 4	289	7097	15	10	150	69	46
	MS 5	315	7640	5	3	48	16	14
NO_x (ppb)	MS 1	354	8558	38	23	497	176	112
	MS 2	316	7763	18	14	132	56	40
	MS 3	270	6674	24	18	251	75	62
	MS 4	289	7092	34	22	343	180	105
	MS 5	315	7639	9	6	127	36	25
SPM ($\mu g/m^3$)	MS 1	348	8399	60	46	477	156	130
	MS 2	344	8419	56	42	870	169	125
	MS 3	355	8579	63	50	702	157	132
	MS 4	350	8504	68	49	605	201	162
	MS 5	343	8322	43	32	661	119	103

Note) An effective monitoring day has 20 monitoring hours or over

Table 3 Thailand's Environmental Control Standards for Air Pollutants

Pollutant		Standard of air pollution (mg/m^3)	Standard of air pollution (ppm)
SO_2	Daily average	0.30	0.117
	Yearly geometric average	0.10	0.039
NO_2	Hourly data	0.32	0.173
TSP	Daily average	0.33	—
	Yearly geometric average	0.10	—

3) Seasonal variations of the concentrations of air pollutants

While the concentration of SO_2 somewhat varies from one monitoring station to another, it is generally high during the dry season (November to April) and low during the rainy season (May to October). As for NO_2 and NO_x, on the other hand, the stations except for MS 1 show high concentrations from the rainy season to the dry season (August to December), whereas the concentrations at MS 1 are high during the rainy season (May to October). Regarding SPM, the concentration is high from November to March, but all stations show low concentrations from May through August representing the rainy season.

Table 4 Environmental Air Quality Control Standards of Major Countries

Country	SO_2	NO_2	Particulate matter
England France	Permissible limits ($\mu g/m^3$) Yearly average (of daily average values) IF SMOKE<34 0.042 ppm IF SMOKE≧34 0.028 ppm Winter average (of daily average values from October to March) IF SMOKE<51 0.063 ppm IF SMOKE≧51 0.045 ppm Yearly peak (of daily average values) IF SMOKE<128 0.122 ppm IF SMOKE≧128 0.087 ppm Guideline value Yearly average (of daily average values) 0.014~0.021 ppm 24-hour value 0.035~0.052 ppm		SMOKE* environment standard Permissible limits Yearly average (of daily average values) 68 $\mu g/m^3$ Winter average (of daily average values from October to March) 111 $\mu g/m^3$ Yearly peak (98% value of daily average concentration) 213 $\mu g/m^3$ Guideline value Yearly average (of daily average values) 34~51 $\mu g/m^3$ 24-hour value 85~128 $\mu g/m^3$ *SMOKE: A portion in particle diameter of less than 15 μm of soot and dust exhausted by fossil fuel combustion.
West Germany	30-min value 0.350 ppm 24-hour average value 0.105 ppm	30-min value 0.098 ppm 24-hour average value 0.049 ppm	30-min value 300 $\mu g/m^3$ 24-hour average value 200 $\mu g/m^3$ Yearly average value 100 $\mu g/m^3$
Italy	Yearly average value of daily average concentrations 0.028 ppm 98% value of daily average concentration during a year 0.087 ppm	Arithmetic mean of one-hour average concentrations 0.070 ppm (The value should not be maintained longer than one hour per day.)	Yearly arithmetic mean of daily average concentrations 150 $\mu g/m^3$ 95% value of daily average concentration during a year 300 $\mu g/m^3$
Nether-lands	50% value of 24-hour average concentration 0.026 ppm 95% value of 24-hour average concentration 0.070 ppm 98% value of 24-hour average concentration 0.087 ppm 24-hour average value 0.175 ppm One hour average value 0.290 ppm	50% value of 24-hour average concentration 0.024 ppm 95% value of 24-hour average concentration 0.049 ppm 95% value of one-hour average concentration 0.054 ppm 98% value of 24-hour average concentration 0.059 ppm 98% value of one-hour average concentration 0.066 ppm 24-hour average value 0.073 ppm One hour average value 0.146 ppm 4-hour average value* 0.016 ppm The mark * is for the protection of fauna and flora, and the other is for the protection of human health.	50% value of 24-hour average concentration 30 $\mu g/m^3$ 95% value of 24-hour average concentration 75 $\mu g/m^3$ 98% value of 24 hour average concentration 90 $\mu g/m^3$ 24-hour average value 150 $\mu g/m^3$
South Africa	0.02 ppm (Shall not exceed 0.04 ppm) Averaging time is unknown.		Dependention chemical and physical property of substance and threshold value Example Asbstos 0.02 fibers/cc (max. 0.04), Nuisance dust 0.3 mg/m^3 (max. 0.2)
Taiwan	(Non-industrial district) (Industrial district) Yearly average value of one-hour values: 0.05 ppm or less, 0.075 ppm or less Daily average value of one-hour values: 0.1 ppm or less, 0.15 ppm or less One-hour value: 0.3 ppm or less. 0.5 ppm or less	(Non-industrial district) (Industrial district) Daily average value of one-hour values: 0.05 ppm or less, 0.1 ppm or less Daily average value which exceeds this standard shall be less than 10% of yearly data.	(Non-industrial district) (Industrial district) Diameter of particle: 10 μm or less Monthly average value: 210 $\mu g/Nm^3$ or less, 240 $\mu g/Nm^3$ or less Yearly average value: 140 $\mu g/Nm^3$ or less, 160 $\mu g/Nm^3$ or less Including a portion in with a particle diameter of 10 μm or more Monthly average value: 260 $\mu g/Nm^3$ or less, 290 $\mu g/Nm^3$ or less Yearly average value: 170 $\mu g/Nm^3$ or less, 190 $\mu g/Nm^3$ or less Monthly average value which exceeds this standard must be less than two times per year.
Korea	Yearly average value: 0.05 ppm or less Daily average value: 0.1 ppm or less (Shall not exceed three times per year.)	Yearly average value: 0.05 ppm or less One-hour average value: 0.15 ppm or less (Shall not exceed three times per year.)	Yearly average value: 150 $\mu g/m^3$ Daily average value: 300 $\mu g/m^3$ (Shall not exceed three times per year.)
Australia	(Victoria) Acceptable level Detrimental level One-hour value 0.17 ppm 0.34 ppm 24-hour value 0.06 ppm 0.11 ppm	(Victoria) Acceptable level Detrimental level One-hour value 0.15 ppm 0.25 ppm 24-hour value 0.06 ppm 0.15 ppm	
U.S.A.	(Primary) Yearly arithmetic average: 0.03 ppm 24-hour average 0.14 ppm (Secondary) 3-hour average 0.5 ppm	Yearly average 0.053 ppm	SPM environmenta standard Yearly average (arithmetic average): 50 $\mu g/m^3$ 24-hour average: 150 $\mu g/m^3$
Canada	(1) Desirable level a) Yearly arithemetic average value 0~0.010 ppm b) 24-hour average concentration 0~0.052 ppm c) One-hour average concentration 0~0.157 ppm (2) Acceptable level a) Yearly arithemetic average value 0.010~0.021 ppm b) 24-hour average concentration 0.052~0.105 ppm c) One-hour average concentration 0.157~0.315 ppm (3) Tolerable level Average concentration measured continuously for 24 hours or more 0.105~0.280 ppm	(1) Desirable level a) Yearly arithemetic average value 0~0.029 ppm (2) Acceptable level a) Yearly arithemetic average value 0~0.049 ppm b) Average concentration for 24 hours or more 0~0.098 ppm c) Average concentration for one hour or more 0~0.195 ppm (3) Tolerable level Average concentration measured continuously for one hour or more 0.195~0.488 ppm	(1) Desirable level a) Yearly geometrical average 0~60 $\mu g/m^3$ (2) Acceptable level a) Yearly geometrical average 60~70 $\mu g/m^3$ b) Average concentration for 24 hours or more 0~120 $\mu g/m^3$ (3) Tolerable level Average concentration for 24 hours or more 120~400 $\mu g/m^3$
Japan	Daily average value of one-hour value: 0.04 ppm or less One-hour value: 0.1 ppm or less (98% value)	Daily average value of one-hour value shall be within the zone of 0.04 ppm to 0.06 ppm or less.	Daily average of one-hour values shall be 100 $\mu g/m^3$ or less. One-hour value 200 $\mu g/m^3$ or less (98% value) Particulate matter with a diameter of 10 μm or less (SPM)

(2) Meteorological Structure

1) Wind direction and wind velocity

The wind pattern in Samut Prakarn Province is uniform despite the fact that this district covers a wide area of 60 km from east to west and 30 km from south to north, and does not exhibit any presence of a local wind pattern. The wind velocity is generally low, with the yearly average recorded as about 2 to 3 m/s, and it is rare to experience a wind velocity of 6 m/s or higher. As for the daily variations of wind velocity, it is high in the daytime, and low in the nighttime. In addition, there is little seasonal variation in the wind velocity. The wind direction, on the other hand, has a noticeable seasonal feature in that it is S system from February to August, N system in November and December, and not fixed in the months of January, September, and October, which represent the turning of the seasons.

2) Atmospheric turbulence and the conditions of diffusion

The degree of turbulence in the horizontal and vertical directions, which exerts effects on the advection and diffusion, becomes dominant when daytime radiation is strong with good conditions of diffusion, whereas it is depressed during the nighttime with no radiation, accompanied by poor conditions of diffusion. There is a general tendency, furthermore, that the turbulence size becomes larger as the wind velocity becomes greater.

(3) Emission Volume of Pollutants

The amount of SO_2 currently emitted from the whole area of Samut Prakarn Province is 21,134 tons/year; 18,330 tons/year (86.7%) of which is attributable to factories; followed by 1,330 tons/year (8.2%) to ships and ferryboats; and 1,474 tons/year (7.0%) to cars. The amount of NO_x exhausted from the whole area is 18,502 tons/year; which is broken down into 8,820 tons/year (47.7%) from factories; 7,812 tons/year (42.2%) from cars; and 1,870 tons/year (10.1%) from ships and ferryboats.

(4) Ambient Pollutant Concentrations in the District obtained by Air Diffusion Simulation

1) SO_2 and NO_2

Using the emission volumes of SO_2 and NO_2 and the meteorological conditions as input data, the team calculated the yearly average concentrations of SO_2 and NO_2 in the target district using air diffusion simulation models. The evaluation of the diffusion models (the compliance between measured and calculated values) made based on the criteria of Japan's Environment Agency is rated both in terms of SO_2 and NO_2 at A rank, supporting a finding that the air simulation models adopted in this survey had a satisfactory precision.

When the ambient concentrations of SO_2 and NO_2 in the district were compared with the environmental standards of Thailand, the team found no spot that showed a value in excess of the said environmental standards and that the whole district met the environmental standards in the year of 1988.

As for top eight points with higher yearly average concentrations, a high SO_2 appears near MS 3, and NO_2, near MS 1. The rate of contribution by sources is calculated as follows: in the case of SO_2, 77.1 to 88.1% by factories; 3.8 to 5.6% by cars; 5.4 to 11.2% by ships; and 0.05 to 8.0% by ferryboats; and in the case of NO_2, 2.9 to 8.5% by factories; 28.7 to 74.5% by cars; 2.4 to 12.3% by ships; and 0.07 to 28.3% by ferryboats; thus showing a large contribution by factories in SO_2, and by cars in NO_2.

In regard to the rate of contribution by factory stack, small sources with a stack height of about 10 m are placed at higher ranks in both SO_2 and NO_2, whereas there is no single emission source which has a contribution as great as tens of percentage.

2) Particulate matters

As the sources of particulate matters, the team targeted sea salt particles, soil and roadway dust, diesel cars, gasoline cars, the iron and steel industry, oil combustion, and the glass industry, and calculated the rate of contribution by these sources using the CMB method. The rates of contribution of natural and artificial sources vary depending on the measured spots and seasons. Among the artificial sources, the highest contribution rate is found in diesel cars (with black smoke in exhaust gas), while those of oil combustion and the iron and steel industry are relatively small with several percent. These contribution rates are found in good agreement with those of similar areas which have been estimated in various countries of the world.

3. Countermeasures for Sources, Effects and Influences on Economy

3.1 Future Atmospheric SO_2 and NO_2 Concentration when No Source Countermeasure is Conducted

Since adverse impact on the environment was forecasted if the 6th economic/social development and the following economic development would be progressed, the atmospheric SO_2 and NO_2 concentrations in future (1992 and 1999) were estimated in the case of the economic development without the execution of any countermeasures for emission source of pollutants. As a result, it was found that the concentration of SO_2 would not exceed the environmental standards for the above years, but that NO_2 would exceed the standard in 1999.

3.2 Improvement of Emission Sources and Consideration of its Effect

As mentioned above, atmospheric SO_2 concentration will not exceed the environment standards. For furnishing Thai Government with useful information to conduct emission control in the future, however, we predicted the atmospheric SO_2 concentration when emission control for factories/plants would be implemented. The reasons why factories became to be target for emission control are as follows:

① Factories take a large contribution rate at high SO_2 concentration points in range of 80–90 percent.

② Problems related to unfair competition may result from an imbalance among factories related to SO_2 emission volume.

We predicted also the atmospheric NO_2 concentration when NO_x emission control for cars is introduced in Thailand in future as cars share most contribution rate of NO_2 at the points where it exceeds the environment standards.

(1) Countermeasures for factories (SO_2 emission controls)

As a result of the discussion with ONEB on which type of controls would be best if SO_2 emission controls were to be introduced for factories in Thailand, we reached the conclusion that the concept of Japan's K-value control should be introduced. From this conclusion, we estimated atmospheric SO_2 concentration if SO_2 emission controls were introduced in 1999. This K-value control is a landing concentration restriction, and can be executed by making stack higher or reducing SO_2 emission volume. From the points of view of economy and feasibility, however, we estimated atmospheric SO_2 concentration on the basis of adopting plans whereby stacks would be made higher. As a concrete K-value, the value of 13 was determined by referring to the K-value set for industrial areas in Japan which are similar to Samut Prakarn district in the SO_2 emission volume per unit area. As a result, if SO_2 emission controls were introduced in Samut Prakarn district, it was found that 49 stacks could not meet the K=13 standard, and that current stack heights of 10 to 15 meters would have to be increased to about 20 meters.

(2) Cars

Because the reason that NO_2 environmental standard will be exceeded in future is mostly occupied by cars (contribution rate: 80 through 90%), the NO_x volume emitted from cars should be reduced to achieve NO_x environmental standard. Thus the introduction of NO_x emission controlled cars was considered and it was made evident that in 1999, the NO_x emission control just like the 1978 controlled car in Japan should be introduced.

(3) Environment air concentration after implementation of countermeasures

Although atmospheric SO_2 concentration will not exceed the environmental standards even if countermeasure will not be taken in the future, we estimated the atmospheric SO_2 concentration based on the assumption that countermeasure (introduction of higher stacks at factories) will be introduced in 1999. As a result, it was clear that the atmospheric SO_2 concentration would be lower than if emission controls were not implemented. If NO_x emission controlled car was introduced in 1999, we found that the atmospheric NO_2 concentration in the Samut Prakarn district would not exceed the environmental standards, even if the current economic/social development plans are carried out.

3.3 Estimate of Cost for the Improvement of Emission Sources

We estimated the actual cost for the implementation of SO_2 emission control for factories. Although the proposed countermeasure to meet emission control value was the method of making stack higher, the costs for energy saving, desulfurization of fuel oil, fuel conversion to natural gas and desulfurization of flue gas were also estimated. Consequently, the cost for the making stack higher of 49 stacks was estimated to be about 115 million bahts. The costs for energy saving at the 49 stacks, desulfurization of fuel oil (processing volume: 3,500 barrels/day for use by 49 stacks), fuel conversion at the 49 stacks and desulfurization of flue gas at the 49 stacks were estimated to be 160 million, 880 million, 83 million, and 540 million bahts respectively.

3.4 Influences of the Countermeasures on the Economy of Thailand

(1) Influence of making stack higher on the GDP of Thailand

Since the production amount of manufacturing sector in Samut Prakarn district occupies 12% of the overall production amount of manufacturing sector in Thailand, it was assumed that the cost for making stack higher in Thailand was borne at the same rate. Consequently, the slow down of the growth rate of GDP from 1992 to 1999 were estimated at, when calculated on the yearly basis, 0.07% (case A that the measure starts in 1993), 0.05% (case B that the measure starts in 1995) and 0.03% (case C that the meaure starts in 1997). Concerning the reduction of GDP amount in 1999, the case A, B and C indicate the reductions by 12.07 billion bahts (0.42%), 8.63 billion bahts (0.30%) and 5.18 billion bahts (0.18%) toward the case that no making stack higher measure is conducted. From this, it was evident that the measure would make little influence upon the economy of Thailand.

(2) Investment on energy saving in Samut Prakarn district and its effect

The investment on energy saving and its effect were estimated assuming that energy saving would progress at a constant growth rate of 2.81% per year from 1993 to 1999. As a result, the energy saving amount from 1993 to 1999 should be 65,549 kl (fuel oil), and judging by the unit price of fuel oil of 3,960 bahts/kl in 1999, about 260 million bahts could be saved—about 1.6 times the investment amount on energy saving (160 million bahts).

(3) Investment on energy saving in Thailand and its effect

The fuel oil consumption of the plants in Samut Prakarn district requiring countermeasures occupies 16% of the total in the district if SO_2 emission control is introduced. Thus the effect of energy saving when investment on energy saving is conducted by plants corresponding to 16% the fuel oil consumption of manufacturing sector in Thailand was considered. As a result, the energy saving amount of manufacturing sector in Thailand and investment on energy saving were estimated to be 314,000 kl and 546 million bahts respectively. In addition, those of the overall industries in Thailand were estimated to be 666,000 kl and 998 million bahts respectively. Considering the difference between the consumptions before and after the energy saving measure, the effect of energy saving of manufacturing sector in 1999 was estimated to be 1.2 billion bahts and that of the overall industries was estimated to be 2.6 billion bahts.

(4) Influence of energy saving on the GDP in Thailand

The influences of the investment on energy saving by executing energy saving meaure and export of surplus energy on the GDP in Thailand was investigated. Consequently, it was estimated that, if only the manufacturing sector invested on energy saving, the GDP would increase by 1 billion bahts and in the case of the entire industries, it would increase by 2 billion bahts. Namely, it is considered that the GDP of Thailand increases by conducting energy saving measures and converting surplus energy to export.

4. Legal and Administrative Framework for Future Environment Control in Thailand

Although the atmospheric SO_2 concentration in the Samut Prakarn district does not currently (1988) exceed the environmental standards, and it will not exceed the standards in the future (1992 and 1999), there is some anxiety about the effects on the environment if economic and social development plans, including and after the sixth economic/social development plan, are implemented. Furthermore, Thailand does not currently have any SO_2 emission control for factories, and it is believed that the problem of fairness will be developed because of the imbalance in SO_2 emissions among factories. Because of these factors, it is felt that SO_2 emission control for factories will be necessary in the future. With regard to the atmospheric NO_2 concentration, the estimates show that it will exceed the environmental standards in the future (1999), so that countermeasures for emission sources are necessary. We, therefore, summarized the environment control and pollution regulation system desired from the administrative viewpoint to make the countermeasures to be executed by the Thai Government feasible.

First, we analyzed the current legal and administrative framework for the pollution control in Thailand so that we could propose the recommendations to improve some constrains existing in it. Second, we introduced the legal system related to the air pollution control in Japan and concepts of environmental standards and emission standards in foreign countries for the Thai Government to refer to executing environment control administration. Further, we proposed the desirable surveillance system and monitoring methdos from the technical viewpoint to observe environment air quality and emission sources. Our recommendation on the improvement of legal and administrative framework related to pollution control in Thailand are as follows.

(1) In Thailand the basic policy of the environmental preservation is determined by the National Environment Board (NEB) based on the Improvement and Conservation of National Environmental Quality Act (ICNEQA) and implemented by the Office of the National Environment Board (ONEB). In this respect, the unification of the environmental administration has been established and the implementation of the consistent policy has been possible, like that in other countries. We, however, recommend the following revisions must be made in ICNEQA to strengthen ONEB's power.

① The laws must be improved and expanded so that the ONEB can carry out policies related to the environmental air quality control planned and determined by the NEB and ONEB smoothly by virtue of the ONEB's administrative power.

② The administrative subject must be clarified in each stage of control and administration in the legal system, and the administration organization system must be improved and expanded based on the stipulation of the laws in order to realize the environmental air quality control administration effectively, and the responsibility of entrepreneurs must be stipulated so that the regulators and the regulated can participate in environmental control systematically. Namely, the responsibility (power and duty) of the environmental administration in the local government (provincial or municipal) must be clarified, and the obligations of the local government must be newly provided as a legal support. Further, to promote smooth and efficient environmental administration implemented by the national and local governments, the law must be amended to clarify the entrepreneur's duty and responsibility as a pollutor; (i) to cooperate with the government's activities, (ii) to make efforts for pollution prevention, and (iii) to share the expenses of pollution prevention work.

③ In the knowledge that the vital point of the environmental air quality control administration is to set an administrative goal and to carry out mutual check of the validity of the goal and administrative measures and the progress, the establishment of the "mutual check" system must be stipulated in the legal system and the implementation system must be improved and expanded. That is, it is necessary to clarify the environmental standard serving as the core of environmental quality control and stipulate the responsibilities of national and local governments of Thailand to always supervise the environmental quality.

(2) Although the basic laws for fulfilling the environmental administration in Thailand is established, the laws to execute air pollution control have not been arranged yet. Namely, concrete matters, who shall control according to what law and standards, have not been specified. Thus, to aim at effective air pollution prevention, it is considered necessary to establish an air pollution control law and arrange the following items legally.

① To clarify the scope of the substances and facilities (depending on scale of facility and substance emitted) to be regulated

② To clarify regulation method (by an emission facility and emission standard for each substance)

③ To clarify the responsibility of emission sources (responsibility of measuring pollutant, etc.)

(3) It is expected that the administrative organization to carry out the air and environmental quality control is improved and expanded of its own accord through the improvement and expansion of the ICNEQA and air pollution regulation laws. It is necessary, however, to train public servants to be experts in environmental administration and technical staff and increase the staff in each stage of the administration to give satisfactory management results. Among others, it is of urgent necessity to establish environmental departments and sections in the local self-governing bodies. For this reason the training of experts in administration and technical staff must be conducted urgently.

5. Prospect of Short- and Long-Term Strategy for Environment Air Quality Management Planning

Although the atmospheric SO_2 and NO_2 concentration in the Samut Prakarn district of Thailand meet the environmental standards of Thailand at the present time (1988), it was found that the atmospheric NO_2 concentration would exceed the standards at 31 mesh points in 1999 if the economic and social development plans of the Thai Government are carried out. If, however, countermeasures are taken to reduce emissions from cars, such as the introduction of NO_x emission controlled car, we found that it would be possible to maintain the levels of NO_2 so that it meet the environmental standards even in the future. Even though the atmospheric SO_2 concentration will not exceed the environmental standards in the future (1992 and 1999), the contribution rate of stationary emission sources is high at 80 to 90 percent and there is no existing SO_2 emission controls for factories at the present, so that on apprehension about the effects of SO_2 on the environment is predicted if economic and social development plans are continued from and after the sixth economic/social development plan. Therefore, it is believed that establishment of SO_2 emission control will be necessary in the future (1999 or after). Whether the concentration of total particulate matters satisfies the environmental standard is not clear because the measuring method used in this study is different from the standard measuring method used for the evaluation of environment in Thailand. As a result of the calculation of the contribution rates of such sources as sea salt, soil, road dust, diesel vehicles, gasoline vehicles, iron works, oil burning and glass industry as the sources of pollutant by using the CMB method, however, it was demonstrated that the contribution rates of natural and artificial generation sources share about half each, and any countermeasure for artificial generation sources would not have enough effect.

As for the costs of the countermeasures for stationary emission sources to meet emission standard value, it was estimated that the application of making stack higher costs about 115 million bahts and desulfurization of fuel oil costs 880 million bahts, and if making stack higher are applied all over Thailand at the same scale of Samut Prakarn, the economy of Thailand is affected little so that the reduction of GDP is 0.42 through 0.18%. If SO_2 emission control was to be implemented, 49 stacks which can not meet the environment standards come into view. The investment volume was estimated to be 160 million bahts in case that such 49 stacks requiring countermeasures adopt an energy saving measure, it was made clear, however, that about 260 million bahts could be saved by implementing energy saving at the investment rate of 2.81% from 1993 to 1999. Further, the effects of energy saving when such a scale energy saving are spread all over Thailand was estimated to total 2.6 billion bahts for all industries and by making the effective use of surplus energy saved by energy saving, the GDP of Thailand will increase by about 2 billion bahts.

To grasp the current legal and administrative framework related to the pollution control in Thailand, we collected the concerned laws and interviewed with the officials of the governmental agencies concerned. As a result of our study based on the collected information, we found out that the legal system for executing air pollution control was currently incomplete though the basic laws for fulfilling environmental administration were established.

From what are mentioned above, we propose the following short- and long-term strategies for the environment air quality management planning in Thailand.

(1) Prospect of short-term strategy (objective for 1992)

1) Establishing technical methods for surveillance system for emission sources

In 1992, atmospheric concentraiton levels of SO_2 or NO_2 will not exceed the environmental standards of Thailand at any point, however, it goes without saying that surveillance of emission sources is importrant for the development of an environmental air quality management plan. In this study, questionnaires were sent to 577 factories as an effort to collect the information about emission volume in Samut Prakarn District and about 36 percent of the questionnaires were returned. It was also found later that there were 422 remaining factories to which the questionnaires were not sent although they have combustion facilities. To fill this deficiency, the unit fuel consumption per employee was calculated from retrieved data and then used for extrapolation to approximate the fuel consumption of these factories and the emission volume of SO_2 and NO_x. Even in the retrieved sheets there were quite a few missing data with respect to the emission volumes of SO_2 and NO_x and thus, the method applied is one in use in Japan for estimation of exhaust gas volume and NO_x emission volume that uses the exhaust gas factor and the NO_x emission factor. Therefore, the reporter would like to draw special attention to the fact that this investigation result on the air pollutant emission volume in the Samut Prakarn district is not based on the actual measurements but on said estimation efforts.

In Japan, the responsible party for the emission of soot and smoke is obliged to measure the exhaust gas volume or emission concentration. Furthermore, from 1978 on, questionnaires have been sent by the Environmenta Agency and the Ministry of International Trade and Industry to all factories, as done in the Samut Prakarn prefecture this time, every three years for soot and dust and every year for SO_2 and NO_x to measure the quantity of air pollutants and the effort was found to be useful for succeeding corresctive actions.

It is our belief, therefore, that surverllance of emission sources is important to: Smoothly execute management of the environment; estimate air pollutant emission volume increases with progress of economic geowth; estimate air pollutants volume when emission control is to be established in the tufure; and estimate air pollutant volume in areas other than the Samut Prakarn district.

As the short-term strategy for achieving such objectives, ONEB has to acquire technical methods to measure concentration and volume of pollutants emitted from plants. Further, ONEB should be asked to prepare datas on air pollutants volume in areas other than Samut Prakarn, by using the method of questionnaire which is conducted in this study.

2) Monitoring system of environmental air concentration

What is important for fulfilling the environment air quality management is to grasp atmospheric pollutant concentration levels as well as to obtain emission volume of pollutant at target areas accurately. Although we think that the investigation in Samut Prakarn district this time has satisfied this requirement, it is necessary to continue monitoring air quality in future, in order to grasp the change of air pollutants concentration with a passage of time. In addition, to proceed with the environment air quality management of Thailand, it is necessary to grasp the air pollutants concentration of other places than Samut Prakarn district.

(2) Prospect of long-term strategy (objective for 1999)

1) Achievement of environmental standard

According to our estimation, atmospheric NO_2 concentration will exceed the environmental standards of Thailand at many points in 1999. To solve this problem, it is necessary to set the NO_x emission control corresponding to the 1978 controlled car in Japan. For this purpose, revision of the concerned laws as mentioned later will be required.

2) Implementing SO_2 emission controls for factories

Although atmospheric SO_2 concentration will not exceed the environmental standards in the Samut Prakarn district in the future (1999), problems related to unfair competition may result from an imbalance among plants related to SO_2 emission volume since Thailand currently does not have any SO_2 emission control system, and if such situation may be continued. Because of this, we feel that SO_2 emission controls for factories will become necessary in the future. Our estimates of costs for countermeasures to be taken if SO_2 emission controls are implemented are by no means cheap at 115 million bahts for making stacks higher and 880 million bahts for desulfurization of fuel oil; however, because the effect of these investments have little effect on the GDP, we feel that SO_2 emission controls must be implemented from the long-term point of view.

3) Intensification and expansion of legal and administrative framework related to environment

To fulfill the environment air quality management smoothly, it is desired to improve the administrative organization and law system. It is considered necessary, in particular, to expand the ONEB administrative authority based on ICNEQA serving as the basic law of the environmental control in Thailand, and clarify the following items in ICNEQA; (i) the allocated responsibilities of governmental agencies related to environmental administration; (ii) local government's responsibility of participation to environmental administration; (iii) roles to be conducted by administrative offices (for example; (iv) responsibility of measurement of pollutant and publication of environment condition to public); and (v) responsibility of enterprises as a pollutor. In addition, it is considered indispensable to arrange the execution law for conducting air pollution control, that is, establish the legal basis for promoting air pollution countermeasures and arrange the related regulations and standards. Our recommendation is as follows.

① Clarification of substances and facilities objective for restriction, establishment of the emission standard of SO_2 and NO_2 for stationary emission sources and the emission standard of NO_2 mobile emission sources.

② Establishment of the prior-notification system concerned with the facilities objective for restriction.

③ Establishment of the improvement order for flue gas emitting facility.

④ Clarification of the responsibilities which the emission source should conduct (responsibility of measurement of pollutant, etc.)

⑤ Intensification of vehicle inspection system for motor-vehicle exhaust gas control.

4) Improvement and expansion of the administrative organization

It is expected that the administrative organization to carry out the air and environmental quality control is improved and expanded of its own accord through the improvement and expansion of the ICNEQA and air pollution regulation laws. It is necessary to train public servants to be experts in environmental administration and technical staff and increase the staff in each stage of the administration to give satisfactory management results. Among others, it is of urgent necessity to establish environmental departments and sections in the local self-governing bodies. For this reason the training of experts in administration and technical staff must be conducted urgently.

A broad scope of knowledge as specified below is required to execute administration for ambient air pollution control.

① Thorough knowledge of the present legal structure and administrative organs related to the control of air pollution

② Present situation of air pollution

③ Generating mechanism of air pollution

④ Adverse effects of air pollution

⑤ Control of combustion

⑥ Techniques for prevention of air pollution

⑦ Dispersion of pollutants in the air

⑧ Techniques for environmental assessment

⑨ Measuring techniques of air pollutants (environment and sources)

Although environmental administrative specialists may not have to be knowledgeable about the details of the above items ⑤ to ⑦, they will need to know them in general. For that purpose, first of all, it will be necessary to prepare a textbook entitled, for example, "The Fundamental Knowledge of Environmental Preservation Countermeasures," with which comprehensive education and training for execution of administration for ambient air pollution control will be provided not only to the administrative officials of central government, but also to those of the bureaus and departments fully in charge of environmental administration, which may be established on a local government basis in the future.

In addition, while technical staff are required to have high expertise concerning the above ③ to ⑨, not all of them need to have the whole knowledge. Namely, it is necessary to foster technical staff specializing in the individual items. In Thailand, presently, courses related to the above ③ to ⑨ have been started at Chulalongkorn University and various other universities. In order to increase the number of technical staff, however, it will be necessary to begin more courses as well as complete them. Especially for learning about the techniques for combustion control and prevention of air pollution, it will be a good idea to invite visiting professors from developed industrial countries or send students to such countries.

5) Knowledge of Pollution Prevention

The postures taken by enterprises in tackling pollution prevention are greatly forced by such external impacts as legal restrictions and social responsibility, whereas the effect of these impacts is limited. Since the enterprises are in a position to be able to know best about the occurrence of industrial pollution, it is essential for them to establish their positive postures of dealing with the prevention of pollution by their own voluntary will. From this point of view, in order to make environmental preservation effective, the enterprises must become to think of the pollution prevention as an essential element of corporate management in terms of management philosophy. Furthermore, the enterprises must improve their constitution so as to be able to work out scientific and rational countermeasures for pollution prevention and complete the corporate organization so as to be able to implement effectively the above countermeasures.

In line with the above described enterprises' efforts to prevent pollution, it is a matter of course that central and local governments need to educate and spread the knowledge of pollution prevention and take measures to provide subsidies required for execution of pollution control countermeasures. In order to specifically establish a setup to educate and spread the knowledge of pollution prevention, it will be first necessary that central and local governments give seminars on the knowledge of pollution prevention to enterprises' responsible personnel or the like and, moreover, that if employees in charge of pollution control are assigned in the enterprises in the future, the said governments should take a measure to hold technical seminars on more professional pollution prevention for the above employees. In addition, an environment center has presently been established in Thailand, and it will be beneficial to train private sector engineers who are in charge of pollution prevention at this center. For the future, in addition, it is expected that the pollution control organization system in the specified factories will be introduced into Thailand as explained in the paragraph 2.1.3 of the Part VIII.

6) Execution of countermeasures for energy saving

Because energy saving not only saves and makes the effective use of energy but also provides effects on the environmental aspects (reduction of SO_2 and NO_x emission volume), it is necessary to stand on a long-term perspective upon the execution of this countermeasure.

CONTENTS

PART 1 INTRODUCTION

PART II STUDY ON CURRENT ATMOSPHERIC POLLUTANT CONCENTRATIONS AND METEOROLOGICAL CONDITIONS

PART IV ANALYTICAL STUDY ON CURRENT EMISSION VOLUME OF ATMOSPHERIC POLLUTANTS (SO_2 and NO_x)

PART V ANALYTICAL STUDY ON CURRENT AMBIENT POLLUTANT CONCENTRATIONS BY USING ATMOSPHERIC SIMULATION MODELS

PART VI REMEDIAL EFFORTS AGAINST EMISSION SOURCE IMPROVEMENTS AND THEIR EFFECTIVENESS

PART VII SPECIFIC REMEDIES FOR EMISSION SOURCES, COST ESTIMATION, AND ANALYSIS OF ECONOMIC IMPACTS

PART VIII DESIRABLE SURVEILLANCE SYSTEM FOR ENVIRONMENT QUALITY AND EMISSION SOURCES IN FUTURE

PART IX PROSPECT OF SHORT- AND LONG-TERM STRATEGY FOR ENVIRONMENT AIR QUALITY MANAGEMENT PLANNING

PART 1 INTRODUCTION

1. Background and Objectives of the Survey

1.1 Background of the Survey

Thailand has stepped forward its industrialization by enforcing the 1953 National Enterprise Establishment Act and 1954 Industry Encouragement Act, and such industrialization has achieved an epochmaking industrial growth through the first to fifth stages of its economic and social development 5 year plans. Even in the current sixth development plan under way, the way towards further industrialization is considered to be the core part of the program.

Under the circumstances, environmental problems have gradually become the central issue of public concern that requires urgent remedial actions. On the enactment of the 1975 National Environmental Quality Improvement and Preservation Law, Thailand established the National Environment Board (NEB), which is to undertake interministerial coordination and the designing and planning of environmental policies, and the Office of the National Environment Board (ONEB), began secretarial work as an acting end of NEB.

Although many environmental policies have been put into force since the start of NEB, no environmental measure for Samut Prakarn Province, Thailand's largest industrial province located in the southern part of the Bangkok metropolitan area, has been implemented in an extensive manner because of financial and technical constraints. In view of the situation and future expansion of industry in this district, the Thai government requested the Japanese government in August 1986, to extend its technical assistance related to the formulation of an environmental control plan for air pollution in the district.

In response to this request, the Japanese Government sent a preliminary survey team in March, 1987, to confirm and to discuss the contents of the request and thus concluded an agreement with ONEB on the details of implementation of a full-scale survey, which started from December 1987.

1.2 Objectives of the Survey

This survey has two objectives: one, that the Japanese government provide various data and materials which are necessary for the Thai government to formulate an environmental control plan for prevention of air pollution caused by the industrial activities in the Samut Prakarn district, coupled with advice thereon and two, that the Japanese team present ONEB with the technical transfer of survey operations during this survey period.

2. Outline of the Survey

The 7 items listed below were surveyed for the purpose of furnishing the necessary data to formulate an environmental control plan for air pollution in the Samut Prakarn district of Thailand and advice on the planning. The relationships among these survey items are illustrated in Fig. 2-1.

① Investigation of the sources of air pollutants, such as SO_2 and NO_x.

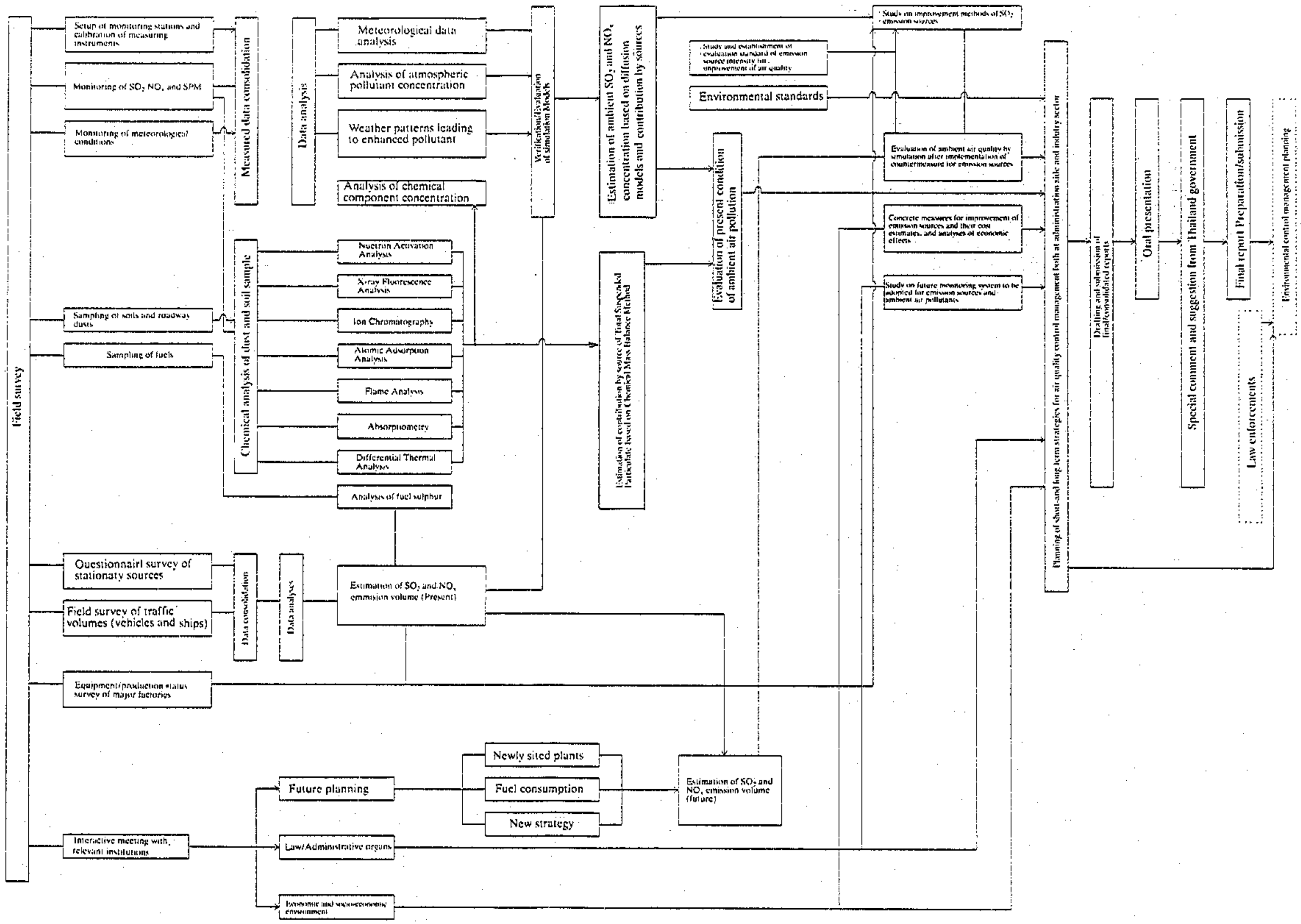


Fig. 2-1 Flow Chart of the Survey

② Identification of the present meteorologic and atmospheric pollutannt concentrations.

③ Analysis of air pollution through the analyses of ambient pollutant concentrations, meteorology and emission sources, and the development, verification, and evaluation of air diffusion simulation models.

④ Specific methods of reducing pollutants and the required cost estimation, and the impact assessment on the economy.

⑤ Study on administration efforts for prevention of air pollution in the Kingdom of Thailand.

⑥ Study on emission sources and proper environmental monitoring system in future in the Kingdom of Thailand.

⑦ Short- and long-term strategies for formulation of air quality management planning.

2.1 Survey Area

The target area of this survey encompasses an area as shown in Fig. 2-2, which represents about 60 km from east to west and about 30 km from south to north, including the whole district of Samut Prakarn Province and part of Bangkok City.

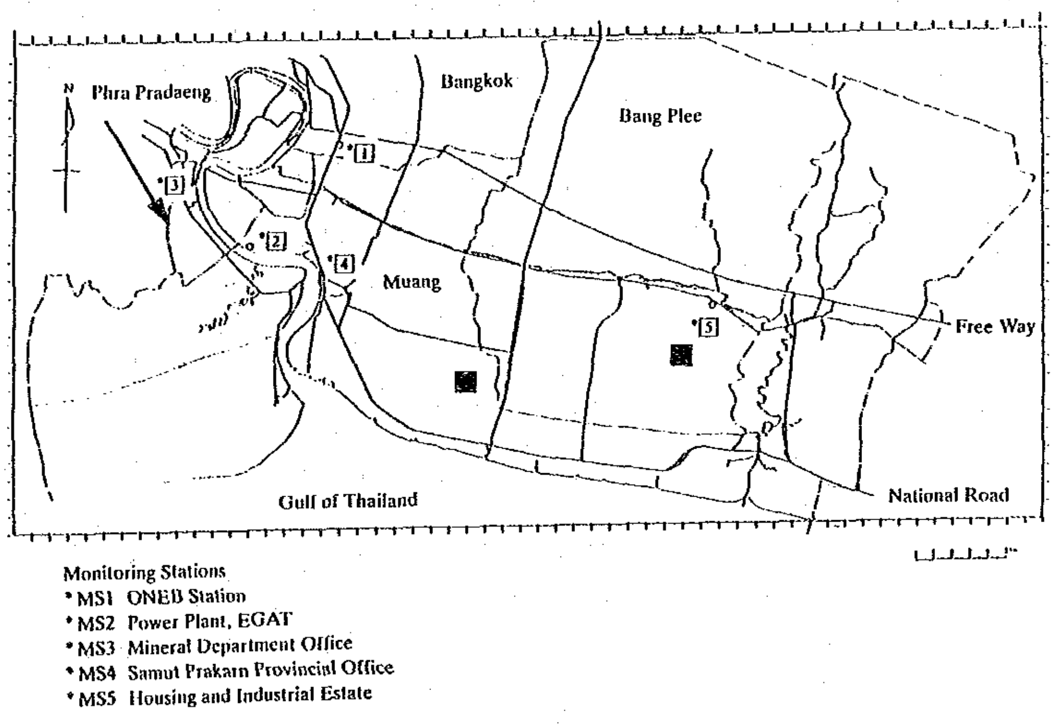


Fig. 2-2 Survey Area

2.2 Contents of the Survey

The contents of the survey are as follows:

(1) Preliminary investigation

The following items were discussed and agreed upon between ONEB and the preliminary survey team in December, 1987:

① Presentation of the Inception Report to ONEB.

② Confirmation of the location of the monitoring stations, and arrangements on the transport of measuring instruments.

③ Confirmation of the location of measuring instruments (a bonded warehouse)

(2) Field measurement of ambient pollutant concentrations and meteorological variables

With the monitoring station established at 5 spots in the surveyed district as shown in Fig. 2-2, atmospheric pollutant concentrations and meteorological variables were measured.

1) Long-term field measurement

From January 17, 1988 to January 16, 1989, a long-term field survey was conducted to measure continuously one hour intervals of SO_2, NO, NO_2, SPM, wind direction & velocity, atmospheric turbulence and solar radiation & net radiation flux by using automated continuous measuring instruments. These measured values were recorded on the record paper at each monitoring station. Further, the hourly average values automatically picked up once every one hour at each monitoring station were transmitted to the master station installed at ONEB via telephone cable and were automatically recorded with a telemetric printer. This automatic data transfer is called the "Data-logger" system. Data of solar radiation, net radiation flux, and atmospheric turbulence, however, were omitted from this system.

In regard to the maintenance of these measuring instruments, the daily check-ups were undertaken by ONEB staff, and the full-scale maintenance was carried out in coopereation between ONEB and the field survey team during the following periods: the first field survey from January 17 to 30, 1987, in the dry season; the second from March 11, to 24, 1988, in the intermediate period between the rainy and dry seasons; the third from July 4 to 28, 1988, in the rainy season; and the first to third maintenance of instruments (from April 24 to May 5, 1988; from September 11 to 21 of the same year; and November 13 to 23 of the same year).

In the long-term monitoring, incidentally, total particulate matters were measured with low-volume samplers in addition to the automatic continuous measuring instruments. For this measurement, 2 low-volume samplers per station were used, with a polyfluorocarbon fiber filter mounted on one unit for analyzing elements and ions, and with a quartz fiber filter mounted on the other unit for analyzing carbon. With these filters replaced once every half month, the yearly concentrations of total particulate matters were measured. During the first, second and third field surveys, however, the measurement was carried out by the Japanese survey team, while the measurement for the remaining 10.5 months was carried out by ONEB.

The data measured with the automatic continuous measuring instruments were checked with those from the recording paper and those recorded in the data logger, and were compiled into the monthly reports.

2) *Short-term field survey*

In the short-term field survey, the concentrations of total particulate matters by particle size were measured with an Andersen sampler to identify the distributions of the particle sizes of total particulate matters during the first, second and third field surveys.

3) Calibration and inspection of measuring instruments and technical training on measuring instruments to ONEB staff members

Prior to the start of the first, second and third field surveys, the calibration of measuring instruments was carried out jointly with ONEB using the English instruction materials for handling that had been prepared beforehand, leading to technical transfer related to the handling and calibration of measuring instruments. After the start of monitoring, moreover, the measurements made at each time were inspected with reference to the instruction manual and the additional technical transfer of methods of maintenance and repair for the measuring instruments was also performed for ONEB staff members.

4) *Presentation of measuring instruments*

All the measuring instruments were put in order by the Japanese survey team during the fourth field survey — from January 17 to 28, 1989 — and were donated to ONEB from the Japan International Cooperation Agency (JICA). The donation ceremony was attended by the following people:

ONEB: Mr. Pravit Ruyabhorn (General Secretary)
Mr. Sirithan Pairoj-boriboon (Director of Environmental Quality Standard Division)
Mrs. Noppaporn Panich (Environmental Officer)
Other concerned staff of ONEB

Japanese Embassy in Bangkok:
Mr. Shoichi Ikuta (First Secretary)

JICA: Yukihisa Sakurada (Deputy Manager of JICA Bangkok)
Tatsuo Suzuki (JICA Bangkok)
Reibun Nagaoka (Division of Industrial Research, JICA Headquarters)

Survey team:
All 5 members including Leader Takeshi Yamada

The ceremony was presided over by Mr. Sirithan Pairoj-boriboon, who explained the background and outline of this project using a slide projector, followed by the speeches of Mr. Yukihisa Sakurada, Deputy Manager of JICA Bangkok and Mr. Pravit Ruyabhorn, General Secretary of ONEB. Then, the ceremony concluded with the exchange of presentation certificate and a receipt thereof between Mr. Pravit and Mr. Sakurada.

(3) Analysis of chemical components in particulate matters and other analyses

1) Analysis of chemical components in particulate matters

In order to clarify the chemical compositions of particulate matters and determine the contributions rates of dust sources by the chemical mass balance method (CMB), we analyzed 39 chemical components in the particulate matters collected with the low-volume samplers and the Andersen samplers during the first to third field survey periods by such methods as instrumental neutron activation analysis, X-ray fluorescence analysis, ion chromatography, atomic absorption spectrometry, flame photometry, and spectrophotometry in Japan. As for the dust collected with the low-volume samplers, in addition, the analyses of elemental carbon and organic carbon were carried out by pyrolysis. In regard to the dust collected with the Andersen samplers, the analysis was performed with particles divided into fine particles (less than 2.1 μm) and coarse particles (2.1 μm or more).

2) Chemical analysis of soil, roadway dust, and gasoline

In order to investigate a source matrix (the chemical compositions of sources) which was necessary to estimate the contribution rates by source of dust, we sampled two kinds of soil, one kind of roadway dust, and two kinds of gasoline respectively in this district during the first field survey, and analyzed the chemical components by the methods described in the above (1) in Japan. As for the samples of gasoline, we limited our work to the analysis of 23 components by the neutron activation analysis and the X-ray fluorescence analysis as no other analysis was possible because of the liquid samples.

3) Analysis of sulfur contents in fuels

In order to investigate sulfur contents in the fuels which are usually being consumed in this district, we collected four kinds of heavy oil, two kinds of light oil, and four kinds of gasoline during the first field survey, followed by the analysis of sulfur contents in Japan.

(4) Analysis of data measured in the field

The analyses specified below were performed in order to clarify the present concentrations of air pollutants and meteorological structure in the district.

1) Analysis of long-term field survey data

① Meteorological analysis

- Seasonal and hourly classification
- Monthly and hourly average wind velocity
- Occurance frequency of wind velocity rank
- Wind rose
- Correlation coefficients of wind direction and wind velocity vectors
- Monthly and hourly solar radiation and net radiation flux
- Atmospheric stability
- Analysis of horizontal wind fluctuation σ_A and vertical wind direction fluctuation σ_E

② Analysis of the ambient pollutant concentrations (SO_2, NO_2, NO_x, and SPM)

- Monthly and diurnal variations of concentration
- Resemblance among monitering stations by cluster analysis and principal component analysis
- Resemblance among atmospheric pollutants
- Cumulative frequency distribution of ambient pollutant concentrations
- Comparisons of measured pollutant concentrations with ambient air standards

③ Analysis of TSP concentrations by Low-volume sampler

- Comparison of the TSP concentration measured by polyfluorocarbon-fiber filter and quartz-fiber filter
- Monthly average concentrations of TSP
- Comparison of the concentration of TSP measured by Low-volume sampler and the SPM concentration measured by β-ray dust analyzer
- Resemblance among monitoring stations by cluster analysis and principal component analysis based on correlation coefficients among ambient pollutant concentrations

④ Analysis of polluting meteorology

- Concentrations of air pollutant by wind direction and by wind velocity level
- Average pollutant concentration by wind velocity range and by atmospheric stability
- Analytical study on high pollutant concentrations (one hour value and daily average value)

2) Data analysis of short-term field surveys

① Analysis of ambient pollutant concentrations

- TSP concentrations by rank of particle size
- Particle sizes distribution of TSP
- Comparisons of particulate matters concentrations measured by different instruments

② Relationship between the meteorological conditions and the ambient pollutant concentration

- Dependence of air pollutant concentration during the short term field surveys by wind direction
- Dependence of air pollutant concentration during the short term field surveys on wind velocity ranks
- Dependence of air pollutant concentration during short term field surveys on atmospheric stability

3) Data analysis of chemical components contained in particulate matter

- Average concentrations of chemical components
- Spatial distributions of chemical components
- Comparisons of the concentrations of chemical components between monitoring stations
- Resemblance among monitoring stations by cluster analysis based on correlation coefficients of chemical component concentrations
- Relationships between chemical components

- Resemblance among the chemical components by duster analysis based on correlation coefficients of chemical component concentrations

(5) Survey of the sources of air pollutants

1) Stationary sources

A questionnaire survey on stationary sources was conducted in order to identify the amounts of SO_2 and NO_x emitted from the factories located in the Samut Prakarn industrial district. ONEB selected 577 factories as emission sources of SO_2 and NO_x from among the 2,456 factories registered in this district, and the survey was carried out on these factories. The number of responding factories was 208 and the response rate was 36%. Since we could not accurately estimate the amounts of pollutants emitted with that number of respondents, we reconducted the survey (confirming the presence of pollutant-emitting facilities by phone calls or visits). As a result, the Japanese survey team found: (i) 167 of the non-responding factories had pollutant-emitting facilities, (ii) 130 factories which were unknown about possession of pollutants-emitting facilities, (iii) 275 factories to which no questionnaire was sent were existing and (iv) these 275 factories had pollutant-emitting facilities. For this reason, as for the responding factories, the amounts of SO_2 and NO_x were calculated based on the fuel consumption and the emission factor set by Japan's Ministry of International Trade and Industry. In regard to the factories from which no questionnaire were collected 572 factories (167+130+275), in addition, the amounts of SO_2 and NO_x were calculated based on fuel consumption estimated by setting the base unit of fuel consumption per employee based on the data from the responding factories and the emission factor.

In calculating the emission volume of SO_2 and NO_x in future years (1992 and 1999), we used the growth rate of G.D.P. and the elasticity rate of energy in Thailand.

2) Cars

In order to estimate the emission volumes of SO_2 and NO_x emitted from the cars running on the roads in Samut Prakarn district, a traffic volume survey and a driving speed survey based on the classification of cars into four types were carried out at nine spots on the main trunk roads. The Japanese survey team conducted these traffic surveys on two dates: the first traffic survey at four locations on January 13, 1988 during first field survey program and the second traffic survey at five locations on July 13, 1988 during third field survey program, thus investigating the traffic volume and driving speed for 24 hours in both lane directions. Based on these values and the emission factor by type of car and by driving speed for cars without emission controls set by Japan's Ministry of Construction, we calculated the amounts of SO_2 and NO_x emitted from cars.

Five routes or so were targeted for the calculation of the emission volumes of SO_2 and NO_x in the initial schedule, but since it was also important to accurately figure out the emission volumes of SO_2 and NO_x from cars in order to formulate the environmental control plan, the team relied on the existing data to calculate the traffic volume by type of car for the routes not covered by this survey, thus obtaining the emission volumes of SO_2 and NO_x on 31 routes in total.

The emission volumes of SO_2 and NO_x from cars running in the future years were calculated by estimating the number of cars in 1992 and 1999 based on the Forecast of the Number of Car Holdings in Samut Prakarn Province published by the Research Institute for Asian Economics and then multiplying the above estimated values by the emission factor.

3) Ships

In order to identify the emission volumes of SO_2 and NO_x from ships sailing in the Chao Phraya River and ferryboats crossing the Chao Phraya River flowing through Phra Pradaeng, the number of ships and boats was surveyed at two spots in the involved district during the first and third field survey programs. By using on the collected data, the data of sulfur content in fuel and the NO_x emission factor from ships developed by Japan's Ministry of International Trade and Industry, the Japanese survey team calculated the emission volumes of SO_2 and NO_x by type of ship, tonnage class, and navigation during anchorage. The number of ships was estimated in the same manner as in the case of factories based on a view that the growth rate of the number of ships would be proportional to that of G.D.P. in Thailand, so that the emission volumes of SO_2 and NO_x in the future years were calculated by multiplying the above estimated number of ships by the emission factor. In the case of ferryboats, supposing that the number of navigating ferryboats would be in proportion to the number of cars, the amounts of SO_2 and NO_x were calculated by applying the rate of increase in the number of cars.

(6) Evaluation of the present status of air pollution and Forecast of future by simulation of atmosphere

1) SO_2 and NO_2

Using the atmospheric diffusion model, we calculated the ambient concentrations of SO_2 and NO_2 in the whole Samut Prakarn district under the present situation, proceeding to comparisons of the measured values with the environmental standards of Thailand as well as calculation of the rate of contribution by sources. In the calculation, we examined the conformity of the measured and calculated values obtained by those monitoring stations at which the ambient pollutant concentrations were being carried out, thus evaluating the models. As the diffusion parameter, moreover, we adopted a parameter which was calculated by the atmospheric turbulence measured in the district.

The future concentrations of SO_2 and NO_2 were forecasted in the two cases in which countermeasures for sources would be taken and when they would not, and compared the values in the respective cases with the environmental standards.

2) TSP

The rates of contribution by sources of particulate matters (including sea salt particles, soil, roadway dust, diesel cars, gasoline cars, the iron and steel industry, and the glass industry) were estimated with the chemical mass balance method (CMB method). The calculations were carried out by individual cases such as the first to third field surveys and monitoring stations. Furthermore, since forecasting the future could not be done with the CMB method, we only estimated the contribution rates by sources under the present status.

(7) Survey of countermeasures for sources

In order to clarify the present countermeasures for air pollution in Thailand, we visited 28 factories in 17 industrial sectors as shown in Table 2-1 during the field surveys. Based on the results, we studied the present status of the countermeasures taken for pollution and the possible ways of taking countermeasures against the sources in the future.

We found that, if economic and social development continues in Thailand without any countermeasures being taken, atmospheric NO_2 concentration will exceed the environmental standards at certain area in 1999, and automobiles took a large contribution rate of this concentration. We, therefore, recommended the concept of automobile emission controls.

Although atmospheric SO_2 concentration will not exceed the environmental standards in the future even if countermeasures are not taken, because factories are mainly accountable for the atmospheric SO_2 concentration at the high concentration points and because problems related to unfair competition will result from an imbalance among factories related to SO_2 emissions volume, we discussed the best control methods to be taken with ONEB if SO_2 emission controls for factories were implemented in the future. As a result, ONEB agreed that, if Thailand should adopt SO_2 emission controls in the future, the concept of K-value regulation used being adopted in Japan should be introduced in Thailand. Since K-value regulation controls concentration at ground level, reduction of concentration can be managed by either making stacks higher or reducing the SO_2 emission volumes. In regard to the 49 stacks which cannot clear the regulated K-value (K=13), therefore, we made estimates for capital investment, fixed costs and variable costs for either higher stacks or desulfurization (reducing the amount of sulfur contents in fuel oil) as well as the effects on production costs. Incidentally, since more serious emission controls for stationary sources should be required after 1999, the team calculated the costs to be incurred for the switch of heavy oil fuel to natural gas and the desulfurization of exhaust gas at an individual source.

We introduced SO_2 and NO_x reduction technologies for stationary emission sources. We also introduced the optimum filtering equipment for particulate matter for the various types of smoke generating facilities.

Table 2-1 List of Factories Visited

Type of Industry	Name of Factory
1. Chemical industry	(1) Siam Chemicals Co., Ltd. (2) Thai Asahi Caustic Soda Co., Ltd. (3) Thai Chemical Corporation Ltd. (4) Thai Kawaken Co., Ltd.
2. Plastic materials and synthetics industry	(1) Thai Plastic & Chemical Co., Ltd. (2) Asia Fiber Co., Ltd.
3. Paints industry	(1) Thai kansai Paint Co., Ltd.
4. Plastic products manufactory	(1) Daiaglass Co., Ltd.
5. Iron and Steel basic industry	(1) GS Steel Co., Ltd. (2) The Bangkok Iron and Steel Works
6. Leather tanning and finishing industry	(1) Central Point Co., Ltd.
7. Flavoring manufactory	(1) Ajinomoto Co. (Thailand) Ltd. (2) Thai Churos Co., Ltd.
8. Electric Power generation	(1) South Bangkok Power Plant
9. Confined livestock feeding industry	(1) Srithai Pasusuk Co., Ltd.
10. Paper industry	(1) Thai Union Paper Co., Ltd.
11. Seed oil manufacturing	(1) Thai Castor Oil Industries Co., Ltd.
12. Glass products manufacturing	(1) Thai Asahi Glass Co., Ltd.
13. Textile industry	(1) Soonthorn Printing Co., Ltd. (2) Luckytex (Thailand) Ltd. (3) Century Textile Co., Lte. (4) Thai Industries Development Co., Ltd. (5) Sinsaenee Co., Ltd. (6) Gusawas Industry
14. Vegetable oil manufacturing	(1) Tanakorn Vegetable Oil Co., Ltd.
15. Tyre manufacturing	(1) Siam Tyre Co., Ltd.
16. Non-ferrous metal basic industry	(1) Thai Tin Plate Manufacturing Co., Ltd.
17. Oil refinery	(1) The Bangchak Petroleum Co., Ltd.

(8) Economic analysis

Since a good knowledge about the degree of impact of environment prevention investment on the economy is important to establish the air quality management planning, therefore, the team conducted economic analysis as specified below:

① To estimate the amount of investment and the annual operating expenses to be required in implementing the countermeasures for prevention of air pollution in the Samut Prakarn district.

② To estimate the amount of investment and the annual operating expenses when the same countermeasures for prevention of air pollution as those in the Samut Prakarn district are extended all over Thailand.

③ To analyze what impacts the implementation of such countermeasures for prevention of air pollution could have on the economy, industries, export and import, etc. of the Samut Prakarn district or the whole country of Thailand.

In the first survey, as a consequence, the team explained to ONEB about methods of the cost estimation when the countermeasures for improvement of air pollution are taken in the Samut Prakarn industrial district, as well as the forecast of impacts on the entire economy of Thailand, the method for such forecast and the required forecast data. The team also discussed with ONEB various topics including the ways of collecting the required data, the collection deadline, and proper approaches to the concerned government agencies. As for the required data, ONEB confirmed responsibility for collecting such data by the time the Japanese second survey team would visit Thailand. The data listed below 1) were given by ONEB to the second survey team. In addition, ONEB's arrangements enabled the Japanese survey team to approach the Thai government agencies mentioned below 2):

1) Data collected
   - Kcal/kl or Kcal/kg by fuel being consumed in Thailand
   - Market prices by fuel being consumed in Thailand
   - Energy consumption by industry in Thailand (1982 to 1986)
   - Contents of the Thai government's 6th 5-year economic plan
   - Import volumes by oil product in Thailand (1981 to 1986)
   - Other reference data and materials

2) Government agencies interviewed
   - Department of Industrial Works, Ministry of Industry
   - Fuel Oil Division, Ministry of Commerce

Analyzing the collected data and materials described above clarified the following findings:

① The data collected by ONEB are those primarily targeted for Thailand as a whole as expected, not satisfactorily serving as those on the Samut Prakarn district.

② There are independent plans for energy and the Samut Prakarn district other than Thailand's 6th 5-year economic plan as earlier expected.

Consequently, we visited the agencies concerned shown below 1) during the third field survey and could obtain the data specified below 2).

1) Concerned agencies visited
   - National Economic and Social Development Board
   - National Energy Administration
   - Industrial Estate Authority of Thailand
   - Electricity Generating Authority of Thailand
   - Thailand Development Research Institute
   - Ministry of Commerce
   - Petroleum Authority Thailand
   - National Energy Policy Office
   - Metropolitan Electricity Authority

2) Collected data

①	Urban and Specific Areas Development	NESDB
②	The Sixth National Economic and Social Development Plan (1987 to 1991)	
③	Bangkok Metropolitan Regional Development Proposals	Metropolitan Planning Project (NESDB, IBRD, USAID) June 1986
④	Recommended Development Strategies and Investment Programs for the Sixth Plan (1987 to 1991)	
⑤	Guideline of the Main Industrial Estates	IEAT, 1988
⑥	Company's Names in the Main Industrial Estates	IEAT, 1988
⑦	The Guideline of North Industrial Estate	IEAT, 1988
⑧	Energy Development and Environment	EGAT, Feb. 1987
⑨	Annual Report of EGAT 1986	EGAT, 1987
⑩	GDP by Industrial Sectors	TDRI, 1988
⑪	Opportunity and Challenges for Environment Management in Thailand	TDRI, 1988
⑫	Natural Resources Profile THAILAND	TDRI, May 1987
⑬	New Electric Rate	MEA, July 1988
⑭	MEA's Load Forecast Results July 1988	MEA, July, 1988
⑮	Total Picture Status of Energy in Thailand in the Future	NEPC, Jan. 1988
⑯	Thailand Energy Sector Review	NEPC, June 1988
⑰	Energy Development Plan During the Sixth National Economic and Social Development Plan (1987 to 1991)	NESDB
⑱	Million Baht Business Information Thailand (1987)	

During the third field survey, in addition, the team reported the analytical results of the data obtained up until the point of the second field survey, and also confirmed the values of input data which were necessary to perform the economic analysis simulation.

After the third field survey, the team arranged and analyzed the information and data obtained in the survey, and estimated the amount of investment and the annual operating expenses required for the countermeasures for sources as well as the amount of investment and the annual operating expenses when the same countermeasures for prevention of air pollution would be extended all over Thailand. Furthermore, the team assessed what impacts could be given to the economy, industries, import and export, etc. of the Samut Prakarn district or Thailand as a whole when such countermeasures for prevention of air pollution would be put into practice.

(9) Outlook of short- and long-term strategies for air pollution control in Thailand

In order to learn about the laws/regulations and the administrative structure related to air pollution control in Thailand, the team visited the concerned Thai government agencies as listed below 1) during the first to third field surveys to conduct interview surveys, and also collected the relevant data shown below 2).

1) Government agencies visited

   ① Central Provincial Industrial Office, Office of the Permanent Secretary, Ministry of Industry

   ② Air Pollution Control Section, Department of Industrial Works (DIW), Ministry of Industry (MOI)

   ③ Industrial Estate Authority of Thailand (IEAT)

   ④ Quality Control Section, Fuel Oil Division, Ministry of Commerce (MOC)

2) Obtained laws/regulations related to air pollution

   ① Improvement and Conservation of National Environmental Quality Act 1975

   ② Factory Act 1969

   ③ Industrial Estate Authority of Thailand Act 1979

   ④ Public Health Act 1941

   ⑤ The City Planning Act 1979

   ⑥ The Poisonous Articles Act (PAA)

   ⑦ Cleanliness and Orderliness of Country Act 1960

   ⑧ Local Health Administration Act 1952

   ⑨ Bangkok Metropolitan Administration Act 1975

   ⑩ Provincial Administration Act 1955

   ⑪ Municipal Act 1953

   ⑫ Announcement of Revolutionary Party No.326, 1956

   ⑬ Re: Duties of Licensee to Operate Factory, Notification of The Ministry of Industry (No.2 B.E. 2513)

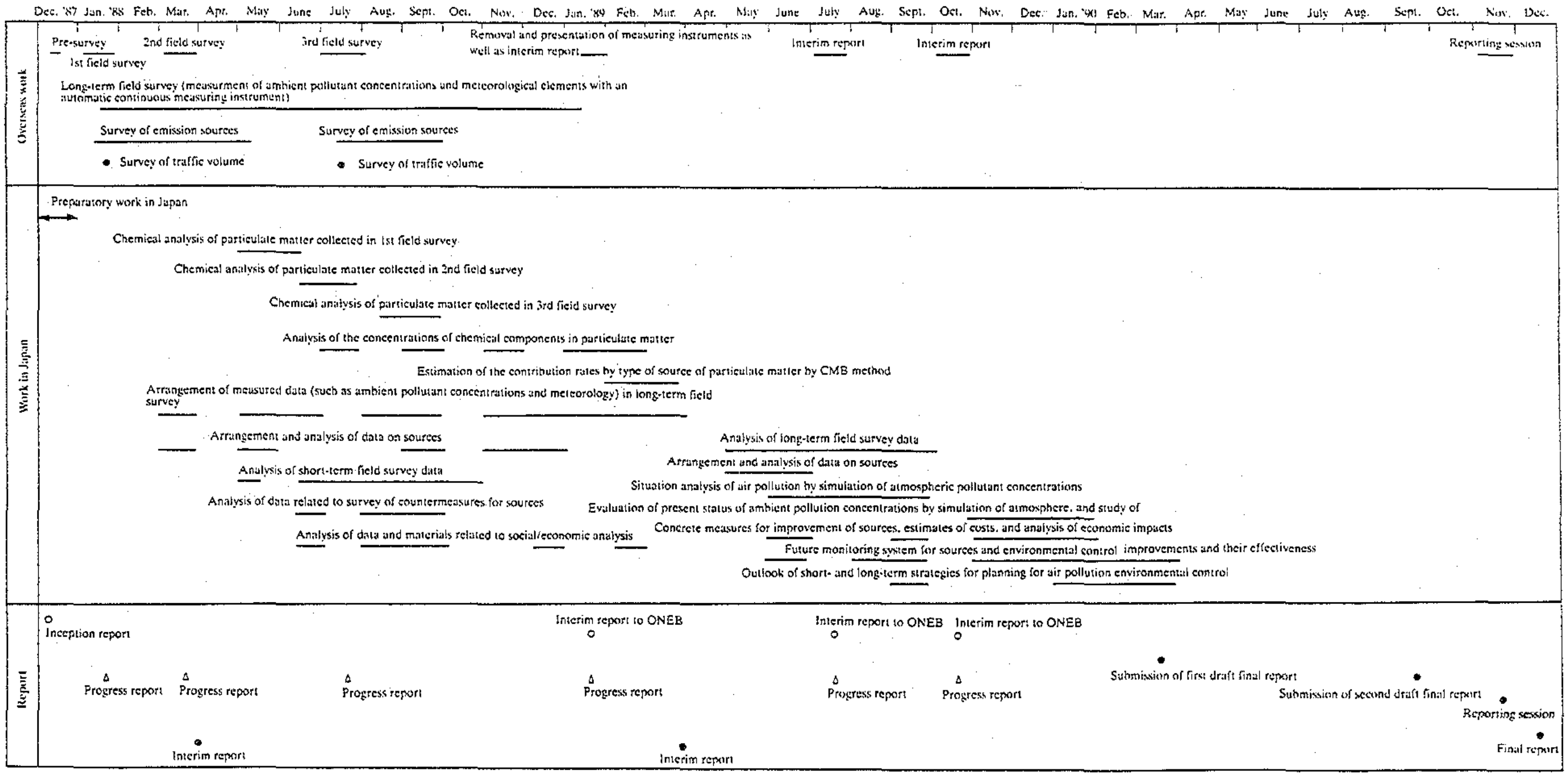
   ⑭ Re: Duties of Licensee to Operate Industrial Plant, Notification of The Ministry of Industry (No.2 B.E. 2525)

Based on analysis of the aforementioned information, the team pointed out the present status of the legislative system and the administrative structure in Thailand, and also introduced the legislation adopted in Japan. Also taking into consideration the pollution control system in other developed countries, the team made suggestions on: (i) the desirable improvement of the legislative system, (ii) the administrative actions including the cooperative relationship among the concerned agencies, and the data and observation system of emission sources and environment conditions to be kept by the concerned agencies, for executing the feasible air quality management planning in the Samut Prakarn industrial district.

3. Survey Process

The survey process in this project is as shown in Table 3-1.

Table 3-1 Survey Process



4. Setup of Survey

4.1 Survey Setup on the Part of Japan

The survey team members involved in this survey are as shown in Table 4-1.

4.2 Survey Setup on the Part of Thailand

The setup of survey on the part of Thailand in this survey was undertaken by ONEB with participation by the staff shown in Table 4-2.

Table 4-1 Survey Team Members

Name	Duty	Position
Takeshi Yamada	Overall management, team leader	Industrial Pollution Control Association of Japan
Yoshimi Umezaki	Social analysis	same as above
Yasuzo Sakurai	Survey of sources, data analysis, and social analysis	same as above
Shigeru Suda	Social analysis	same as above
Keizo Kobayashi	Field measurement, survey of sources, countermeasures for sources, data analysis, simulation, and social analysis	same as above
Setsuo Ono	Survey of sources, data analysis, simulation, and social analysis	same as above
Norihito Ono	Survey of sources, data analysis, simulation, and social analysis	same as above
Tomoyuki Inoue	Economic analysis	same as above
Yoshikazu Ota	*Survey of sources (cars and ships)*	*Chiyoda Consultant Co., Ltd.*
Isao Ono	Survey of sources (factories)	Mitsubishi Petrochemical Engineering Co., Ltd.
Makoto Takagi	Countermeasures for sources	same as above
Eiichi Okubo	Field measurement (SO_2, NO_x and SPM)	Denki Kagaku Keiki Co., Ltd.
Masanori Amano	Field measurement (SO_2, NO_x and SPM)	same as above
Shuji Kimura	Field measurement (data logger)	same as above
Mitsutaka Nagasaka	Field measurement (meteorology)	Ishikawajima Inspection and Instrumentation Co., Ltd.
Jiro Ota	Field measurement (TSP)	same as above

Table 4-2 Survey Setup on the Part of Thailand

Mr. Pravit Ruyabhorn	Secretary General
Mr. Arthorn Suphapodok	Deputy Secretary General
Mr. Suchat Mongkolphantha	Deputy Secretary General
Mr. Sirithan Pairoj-boriboon	Director of Environmental Quality Standards Division
Mr. Sangsant Panich	Acting Chief of Air and Noise Section
Mrs. Noppaporn Panich	Environmental Officer
Dr. Supat Wangwongwatana	Environmental Officer
Miss. Khantong Soontrapa	Environmental Officer
Mr. Warawut Suadee	Environmental Officer
Mr. Kanok Suksomsunk	Environmental Officer
Mr. Khunchai Kriengkrai-udom	Environmental Officer
Mr. Santad Koompalum	Environmental Officer
Mr. Suphol Cheiwkijkachorn	Environmental Officer
Miss. Potchana Wongsiri	Environmental Officer
Mr. Phunsak Tiramongkol	Environmental Officer

PART II STUDY ON CURRENT ATMOSPHERIC POLLUTANT CONCENTRATIONS AND METEOROLOGICAL CONDITIONS

1. Outline

The quality of environmental control planning is thought largely dependent on the degree of accuracy in which the status quo of environmental pollutant concentration as well as distribution is surveyed. Thus pollutants in terms of sulphur dioxide (SO_2), nitrogen oxides (NO, NO_2), suspended particulate matter (SPM) and total suspended particulate (TSP) were subject to a year long survey (long term field survey) by means of installed monitoring stations across the Samut Prakarn Industrial District. Also simultaneously surveyed were the wind profile, air turbulency, intensity and balance of solar radiation as well as emmision for same one year period since those factors were thought to influence the environmental pollutant concentrations.

Furthermore, both size distribution analysis and chemical analysis were done three times on the TSP samples, which were thought to give some informations with respect to the degree of contribution of each source (short term field survey).

2. Installation of monitoring stations

2.1 General conditions of the area

(1) Geology

Samut Prakarn Province drops on 101° in eastern longitude and 14° in northern latitude,locates to the south of Bangkok and consists of four counties, Phra Pradaeng County, Muang County and Bang Plee County and the area of which cover 890 km^2 in total. The province is well known as a highly industrialized one, the south part of which faces Gulf of Thailand as shown in Figure 2-1 and practically constitutes a flat land with the height less than 20 meters above sea level. The river, Chao Phraya flows through the central part of Muang County.

(2) Climate

The climate of the province changes little in temperature between 28–30°C on average throuhout the year and maintains that of typical tropical type with a relative humidity of 75–80%.

But the weather can be classified with respect to wind direction, rainfall and temperature into three seasons, Hot season from March through June, Rainy season for the period of July through October, and Cool season from November through February or about the wind profile, that of South wind type from February through August, that of North wind type for the period of November through December and the remaining period with non-oriented wind patterns. The wind velocity normally varies between 1–3 meters per second and often drops down to less than 1 meter per second.

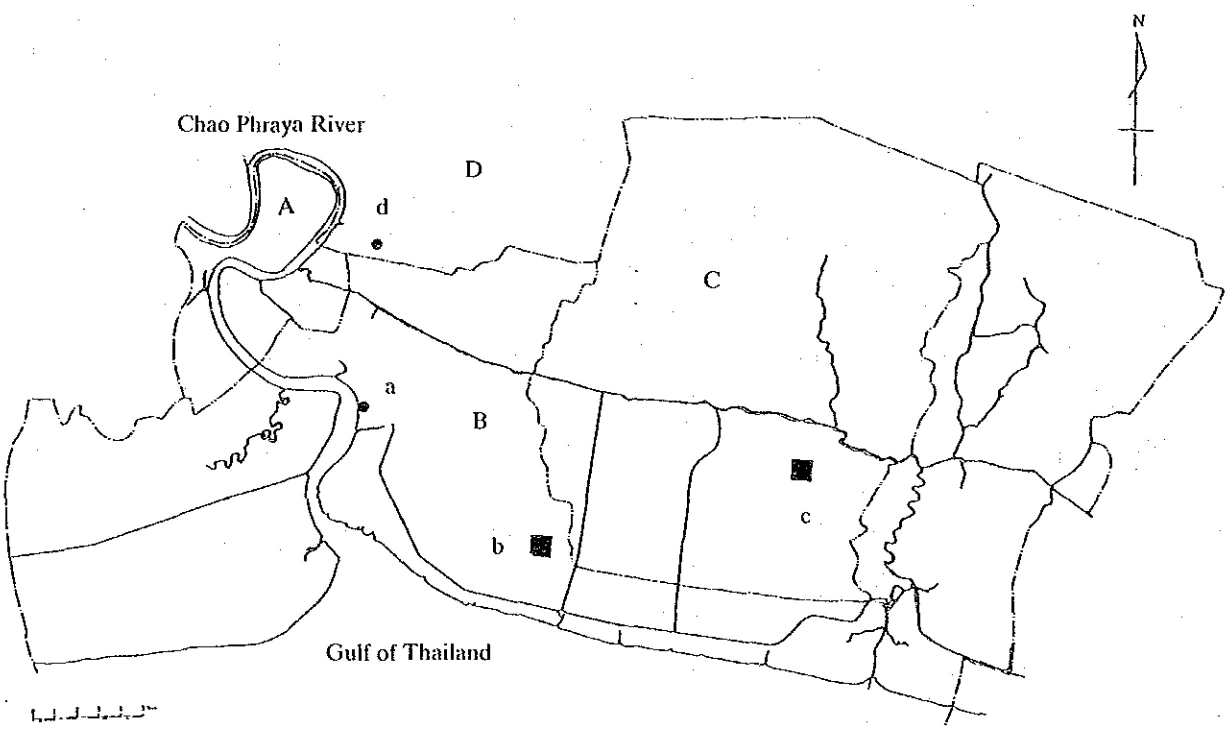
(3) Distribution of pollution sources

In Samut Prakarn Province, there are approximately 2,500 factories large and small and most of them locate in Phra Pradaeng county and also at left bank side of Chao Phraya river which flows through the central part of Muang county. Except those industrialized areas, the remaining factories exist in scattered way at Bangpoo industrial park, Bang Plee industrial park and also along the freeways in Bang Plee county.

The total mileage of trunk roads, freeways, state roads and provincial ones inclusive, comes to over 200 km and the traffic volume of vehicles (including the motorbike) was found to be between 500 and 75,000 on daily average. Besides those, ferryboats and ships in Chao Phraya river are thought to contribute to environmental pollution of the area. The ships varying in tonnage between a few hundreds to 10,000 count daily about 150 whereas the ferrying service across the both banks of Chao Phraya are available at three points and shuttling frequency was found to reach as large as 1,300 times per day.

(4) Development plan

Two industrial parks, Bang Poo and Bang Plee are developed to invite domestic as well as foreign enterprises. Though the land use of the former still remains at 1/5 of total area, about 1/3 of Bang Plee park, 600 hectares, is already occupied by various industries such as food processing, chemical, metallurgical, textile, plastics, rubber and garment industry. The remaining park area is also expecting other industies coming in near future.



A Phra Pradaeng
B Muang
C Bang Plee
D Bangkok

a Samut Prakarn Provincial Office
b Pang Poo Industrial Park
c Bang Plee Industrial Park
d Bang Na Meteorological Observatory

Fig. 2-1 The regional map of Samut Prakarn Province

2.2 Installation of monitoring stations

Prior to the installation of monitoring stations, careful studies were to be made on various factors such as the degree and status changes of pollution in the addressed area, meteorological and geographical conditions, and the distribution of pollutant sources. The objectives of measurement of atmospheric pollutant concentrations are listed as follows.

(1) Criterion of whether or not the measured concentrations comply with stipulated standards.

(2) Observation of unusual and high pollutant concentration that requires urgent countermeasures.

(3) Base data collection to effectuate the ambient air pollution abatement planning that state and local government make.

(4) Base data collection required for environmental impact assessment or projection with respect to new pollutant sources forthcoming.

(5) Evaluation of implementation of (3) and (4).

Assumed that reliable survey data are to be obtainable about the pollution status for a long period, the following other factors are thought to be considered to locate the monitoring stations while taking account of such factors as pollutant distribution, present and future land utilization and specific conditions of sources.

(1) The site where the pollutant concentration is highest.

(2) The most densely populated area, especially such one where the pollutant concentration is also high.

(3) The area which borders the neighbouring county and makes it possible to quantify the pollutants coming into the area from the neighbouring province.

(4) The site where the significant impact of future development is expected.

(5) The site where the effectiveness of air pollution control measures can be evaluated with less difficulty.

(6) The site where the obtained data represent the general status of air pollution in the area.

The basic ideas about siting of monitors are as afore-mentioned, but more specifically the following were considered prior to the selection of five monitoring sites especially where measurement data are scarce.

(1) Pollutant distribution and wind profile.

(2) A densely populated area requires more monitoring stations than a less crowded one does.

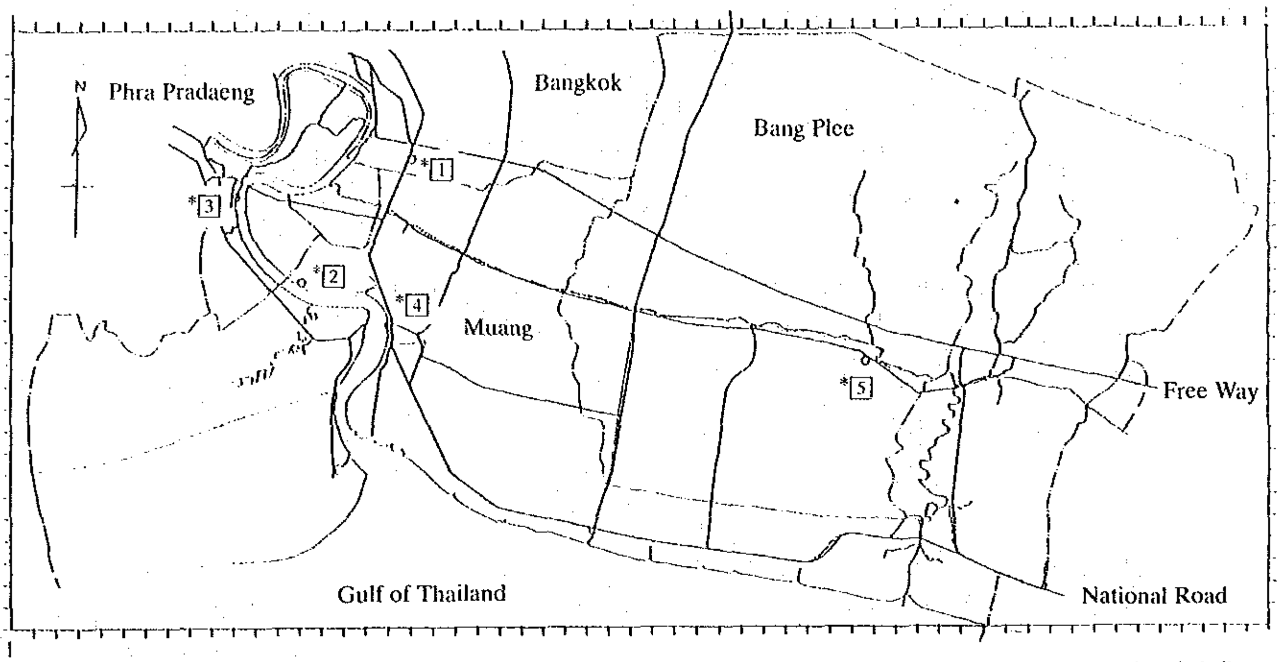
(3) The area which borders the neighbouring county requires stations to study the effect of pollutants and meteorological conditions of the neighbouring province.

(4) It is better to select the site such that the effectiveness of any countermeasure taken can be quantified.

(5) The plan for future land use is to be accounted.

(6) Generally, installation sites are to be evenly distributed.

With all conditions above combined, five monitoring station sites were selected as shown in Figure 2-2.



Monitoring Stations
* MS1 ONEB Station
* MS2 Power Plant, EGAT
* MS3 Mineral Department Office
* MS4 Samut Prakarn Provincial Office
* MS5 Housing and Industrial Estate

Figure 2-2 Installation of monitoring stations

2.3 Measured variables at monitoring stations

Variables measured at each station is as shown in Table 2-1. The automated continuous measuring instruments were employed for SO_2, NO_x and SPM detection. The measurement of TSP and that of its size distribution were done by means of Low volume samplers and Andersen samplers respectively. Also installed were a three dimensional ultrasonic anemometer for measurement of wind direction, wind velocity and air turbulency at MS1. In addition, anemometers of two dimensional ultrasonic type were set up at both MS2 and MS5 for the measurement of wind direction and velocity.

As for the Low volume sampler, each monitoring station has two sets, one with a polyfluorocarbon filter to improve the accuracy of elemental as well as ion analysis of the dust and the other with a quartz filter for carbon analysis.

Table 2-1 Measurements at monitoring stations

Measurements	Station#	Period of monitoring	Instruments applied
SO_2	1, 2, 3, 4, 5	1 year	Ultraviolet-fluorescent-automatic-continuous measuring instrument (instantaneous and an hour average)
NO_x (NO, NO_2)	1, 2, 3, 4, 5	1 year	Chemiluminescence-automatic-continuous measuring instrument (instantaneous and an hour average)
SPM	1, 2, 3, 4, 5	1 year	β-ray absorption automatic continuous measuring instrument (an hour average)
TSP	1, 2, 3, 4, 5	1 year	Low volume samplers (a month average with two times filter replacement, 15 days/filter) Two samplers in use are one with a quartz filter and the other with a polyfluorocarbon filter.
TSP size distribution	1, 2, 3, 4, 5	3 seasons rainy, dry, mid-term	Andersen sampler 15 days average
Wind velocity direction	1 (3-dimensional) 2, 5 (2-dimensional)	1 year	2- and 3-dimensional ultrasonic automatic continuous anemometer 10 minutes moving average
Solar radiation Radiation balance	1	1 year	Automatic continuous measuring instrument (instantaneous and an hour average)
Air turbulency	1	1 year	3-dimensional ultrasonic anemometer (horizontal and vertical direction)

Automatically recorded measurement data of each station were typed out on hard copies and were simultaneously converted into 1 hour average values, which were then transmitted through telephone cable to a data logger in the central observation center of ONEB. The data transmitted in this way from all stations were also printed out by using a telemetric printer except those about the amount of solar radiation, radiation balance, wind direction and velocity, and air turbulency.

Photo 2-1 shows a data logger and a telemetric printer in use.

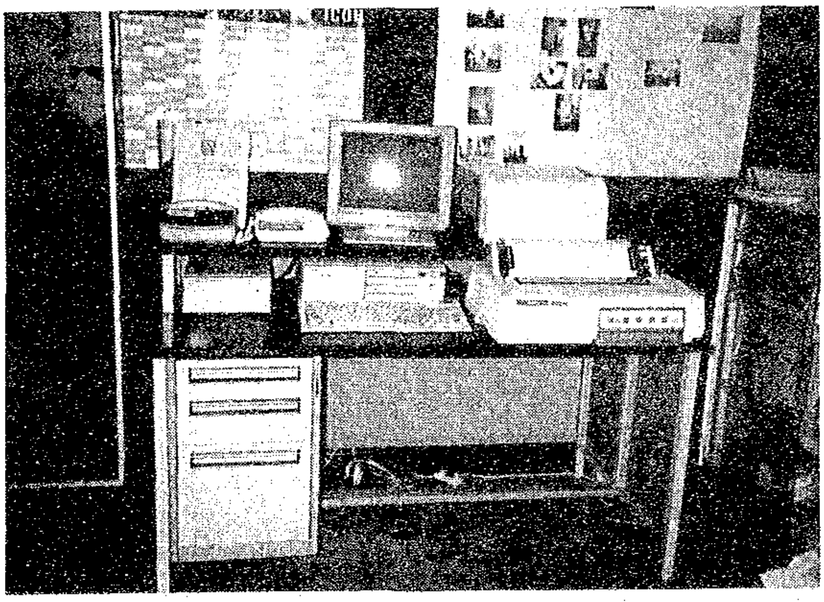


Photo 2-1 The setup of data logger and telemetric printer at ONEB

2.4 Specifications and configuration of monitoring stations

The monitoring stations, MS2 through MS5, are basicaly prefabricated rooms of special aluminum structure which were transported from Japan to Thailand. MS1 station, however, consists of an environmental measurement instruments placed in an existing room of ONEB, and meteorological instruments, detection sensing part of which is set up in a meteorological observatory tower and the data recording part of which is placed inside the ONEB office.

(1) Monitoring station MS1 at ONEB

The ONEB monitoring station locates inside a meteorological observatory in Bang Na area of Bangkok surrounded by the green belt. As seen in Figure 2-3, the area 90 m apart and to the west-north-west direction of this observatory has an expressway called SuKhumvit road (Route 3) with the daily traffic volume of 77,000 vehicles. Samely the area 660 m apart and to the north of the observatory tower is an intersection of SuKhumvit, First Stage Expressway with the daily traffic volume of about 13,000 vehicles and Bang Na-Trat Highway (Route 34) with 30,000 vehicles on daily average. The three dimensional ultrasonic anemometer was mounted on a tower 30 meters high above ground level, sited 240 m apart from the ONEB monitoring station to the north.

The amount of solar radiation and radiation balance were measured at the spot 30 m apart to the north of the tower and 1.5 m above the ground. The probing parts of these measurement instruments in use were connected by a private line to the recorder inside the office of meteorological observatory tower. The area map of MS1 station is shown in Figure 2-3.

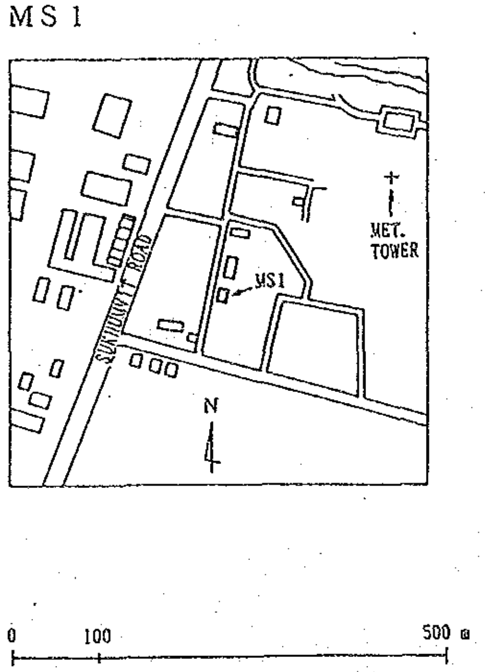
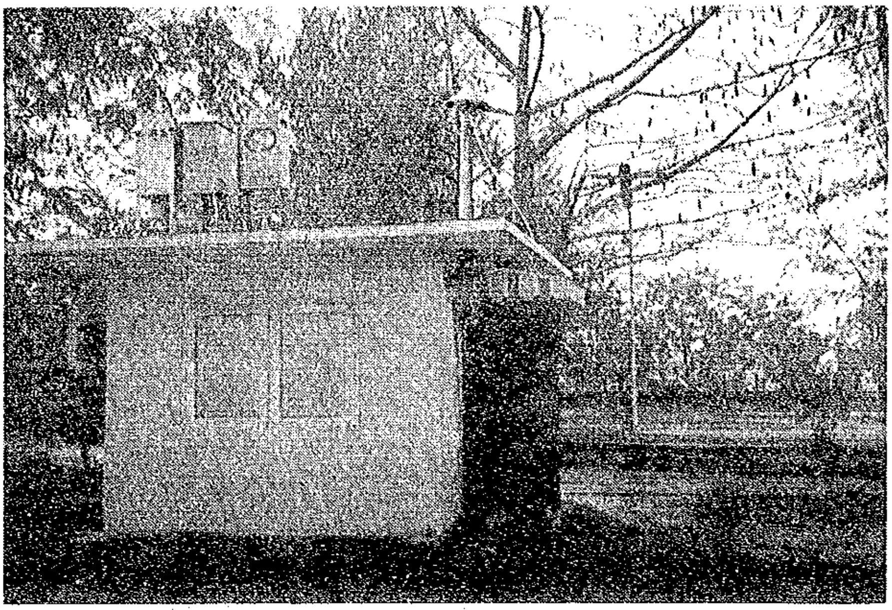
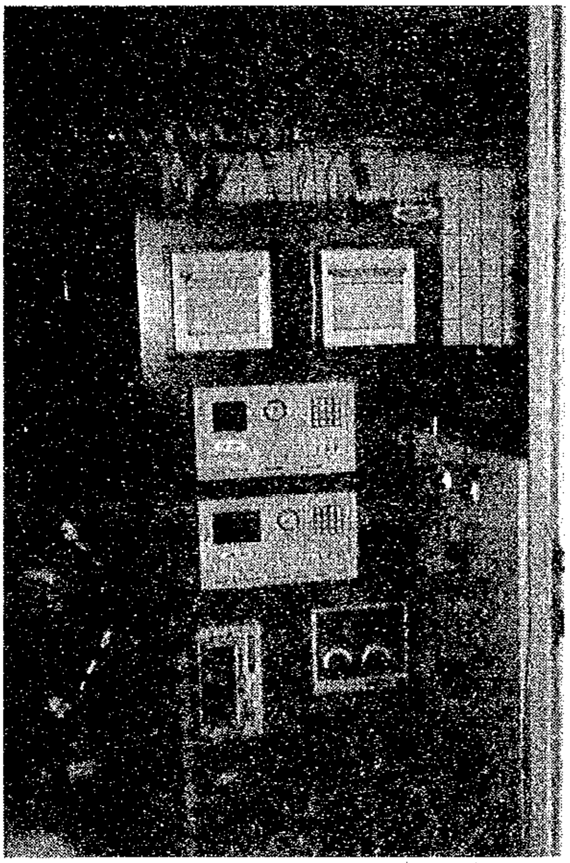
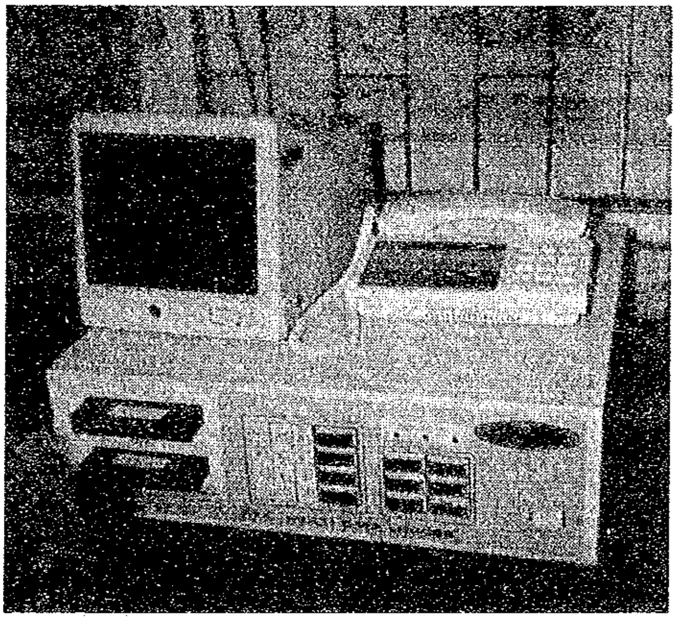


Figure 2-3 Area map of meteorological observatory



External appearance of a monitoring station with a low volume sampler
and an Andersen sampler mounted on the station roof

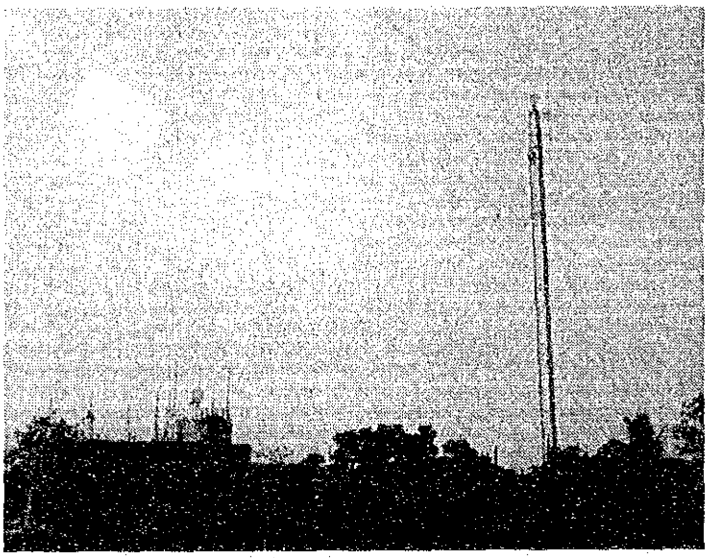




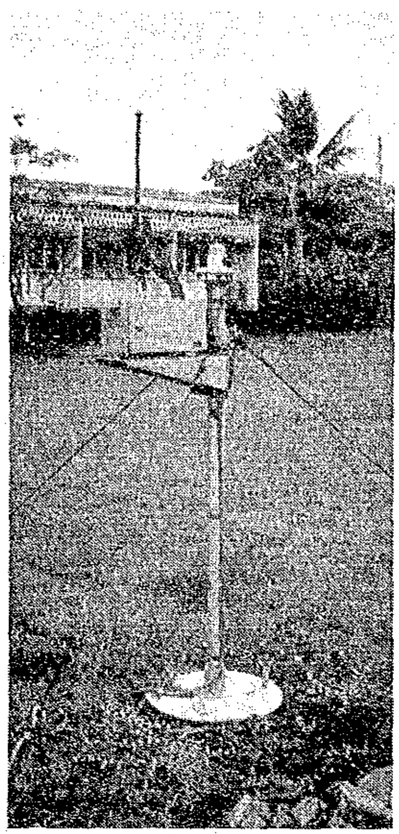
Data logger

SO_2, NO_x and particulate measuring instrument

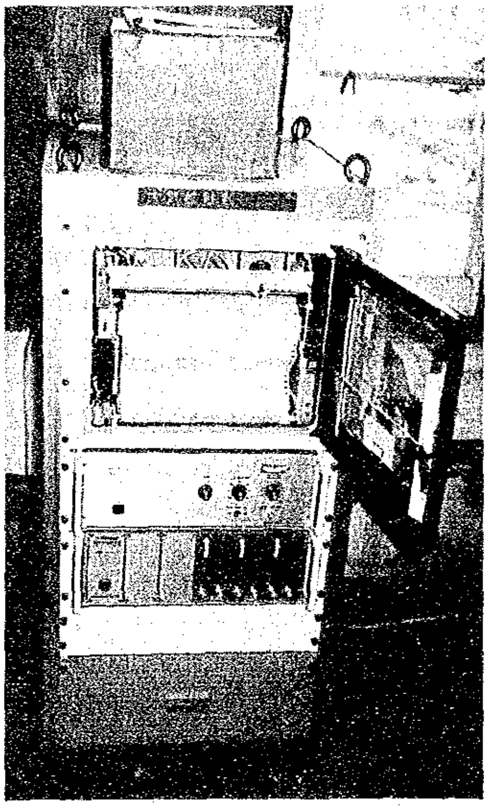
Photo 2-2 (1) Snapshots of MS1 station



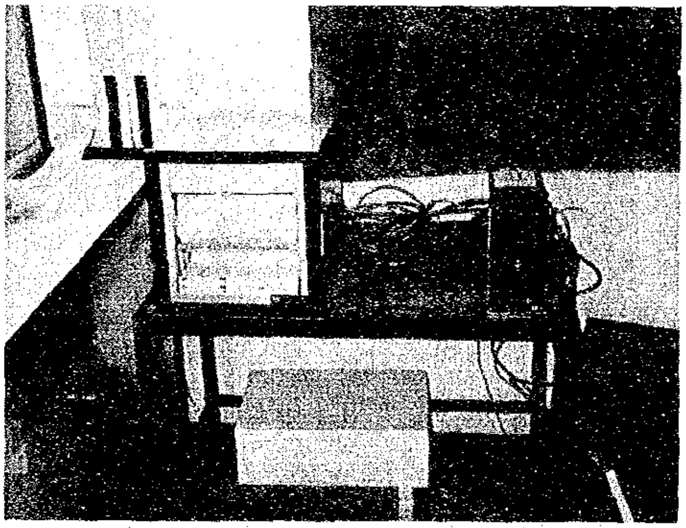
Three dimensional ultrasonic anemometer mounted on a 30 m high steel structure tower



The solar radiation meter and radiation balance meter



Three dimensional ultrasonic anemometer recording part



The recording part of solar radiation and radiation balance meters

Photo 2-2 (2) Snapshots of MS1 station

(2) South Bangkok Power Plant (MS2)

This power plant locates at a point to the southwest of and 7 km apart from the meteorological observatory tower and Chao Phraya river flows close to the south and southwest end of the power plant. There are a number of plants including Asahi Beer on the other side of Chao Phraya to the west and south of the power plant, though there is none to the northeast through west within 2 km radius range. Accordingly it is hard to find roads with a significant traffic volume in the vicinity of the power plant but Suksawat road (Route 303) runs at 1.2 km apart and on the opposite side of Chao Phraya river. The traffic volume of Route 303 is estimated as 55,000 vehicles per day.

The monitoring station (MS2) was placed inside the power plant, at a position about 300 m apart from 102 m high stacks and to the southeast of them as shown in Figure 2-4.

Air quality measurement instruments were placed inside the station and an anemometer was mounted on a supporting pole 10 m in height above the ground level as shown in Photo 2-3 (1).

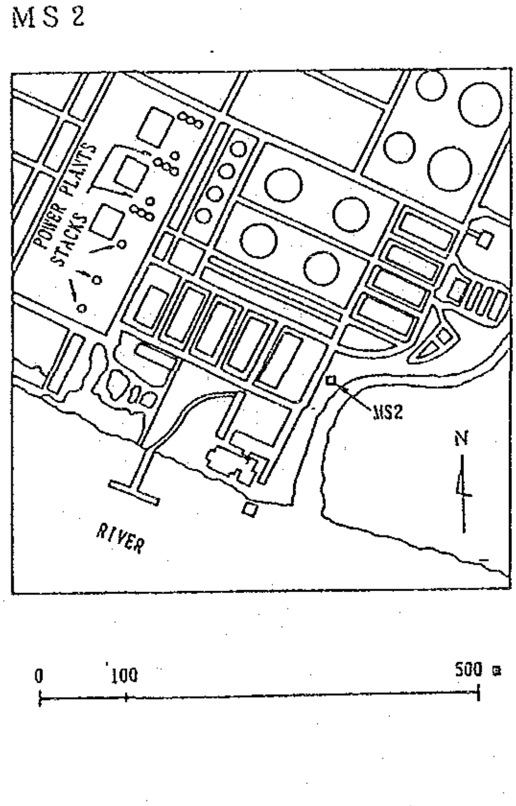
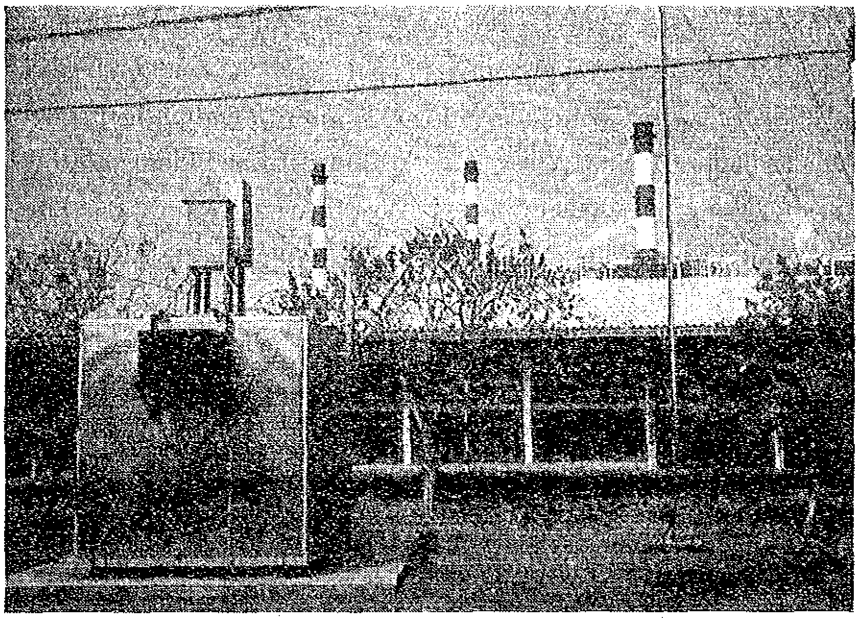
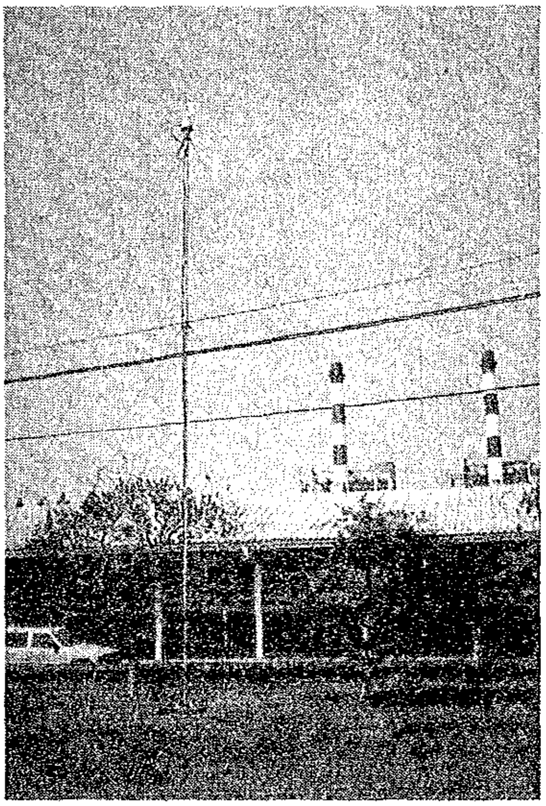


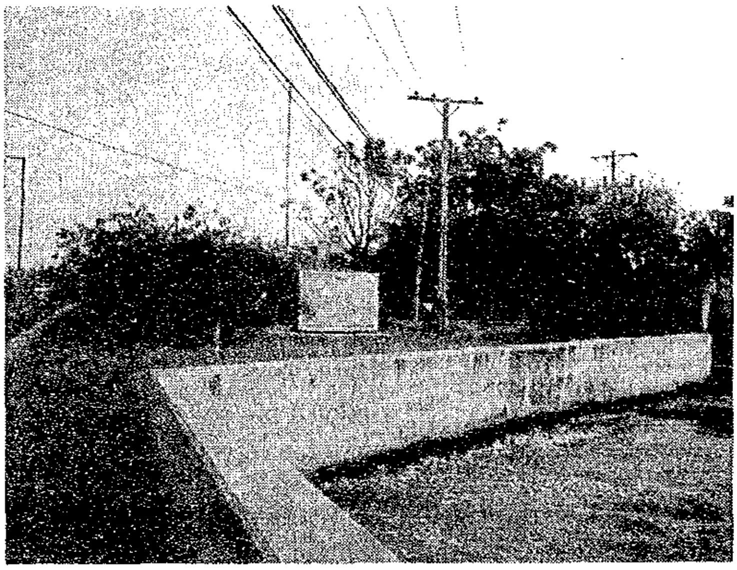
Figure 2-4 Area map of South Bangkok power plant



The external appearance of MS2 station



Three dimensional anemometer mounted on a supporting pole 10 m high



Another view of MS2 station (the thermal effluent from the power plant is seen.)

Photo 2-3 (1) Snapshots of MS2 station