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AIR QUALITY MANAGEMENT PLAN

for

THE RAYONG-MAP TA PHUT DEVELOPMENT PLANNING AREA THAILAND

by

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to

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1. INTRODUCTION

Air pollution has increasingly plagued man as a consequence of his economic and social development. Concern for air pollution control and the need to protect human health and the ecosystems upon which man depends has become an important consideration in the formulation of national growth and development policies. Incorporation of air quality management principles in national economic and social plans provides a practical basis for realizing and maintaining clean air in harmony with national development goals. Progress in prevention and control of air pollution is dependent on developing an ethic in which air pollution control is recognized as a positive component of growth and development rather than a deterrent. A direct and effective way of implementing the ethic is to include air quality as an integral component in national comprehensive economic and social planning.

The Fifth Economic and Social Development Plan (1982-1986) of the Royal Thai Government (RTG) recognized the importance of improved efficiencies in the utilization of natural resources and the need to support environmental conservation programmes. The Rayong - Map Ta Phut Development Planning Area (DPA) was specified as the location of a new industrial complex to serve as a new growth centre in accordance with the Fifth Plan objective of systematic decentralization of economic and industrial activities to the regions. The Fifth Plan also calls for concurrent measures to control environmental pollution which may come from industrial activities and tourism, as well as proposing projects to plant perennial plants such as rubber and fruit trees instead of soil debilitating field crops, and to revive deteriorating forest conditions around watershed areas.

The 1982 Eastern Seaboard Study made for the RTG National Economic and Social Development Board by Cooper $ Lybrand Associates (CLA) affirms the Fifth Plan environment pollution control policies and identifies actions to be taken to protect the environment in the DPA (Appendix 1).

2. PRESENT AND POTENTIAL AIR POLLUTION PROBLEMS

The planned development of the Rayong - Map Ta Phut area over the next decade provides the incentive and need to evaluate the scope and severity of present and potential air pollution problems.

2.1 Description of the Development Planning Area

The Fifth Plan and CLA define the DPA to include the existing urban area of the city of Rayong and the coastal area to the west including the towns of Ban Chang, Ban Krok Tabaek and Ban Kilomet Sip Hok (See Fig. 1). The area extends north from the sea coast to Khao Krok and Khao Chom Nai. From these it extends southeasterly along the Rayong district boundary and ends with the eastern district boundary enclosing Rayong. The land forms a coastal plain gently rising to a northwesterly ridge of some 400 metres (m) and sloping southeasterly to the flood plain of the Khlong Yai.

2.1.1 Airshed and Air Quality Control Region

The described DPA occupies the southwestern portion of a larger, naturally described, topographic area all within Rayong Province which may properly represent an air basin, or airshed. The airshed is bounded on the west by the ridge formed by Khao Krok and Khao Chom Hai, and on the east by the ridge formed by Khao Yai Da, Khao Nguang Chang, and the peaks continuing to the north. The southern boundary is the coastline. There does not seem to be a clearly defined topographic northern boundary on the maps available, but it is likely to be the upper reaches of the tributaries to the Khlong Yai watershed more than 50 kilometres (km) north of the coastline. Further study of the airshed may show it to be entirely within Rayoung Province, in which case the land area contained within the airshed may be described as the Map Ta Phut - Rayong Air Quality Control Region (AQCR) and used as the administrative area for purposes of air quality monitoring, regulating emission sources, and describing applicable ambient air quality standards for health and environment protection.

2.1.2 Climate and Weather

Published summaries of climate and weather typically deal with the entire Eastern Seaboard Area. Climate reports recognize the

alternating northeast and southwest monsoon system with its moderate winds, seasonal rainfall differences, and temperature and relative humidity variations. The weather data summaries most often given are for Chantaburi, and Sattahip.

The 20 year average wind pattern in Sattahip (Meteor. Dept. ID. No. 48477) shows the 4 to 16 knot (kt) wind direction frequency percentages to be: N=15.2; NE=4.9; E=0; SE=0; S=31.8; SW=33.6; W=14.3; and NW=0. Winds of 17 to 27 kt are sometimes observed, and short gusts above 27 kt from various directions occur infrequently. Some data have been reportedly collected for winds aloft in the vicinity of the Royal Thai Naval airport at U Taphao, but have not been available for analysis and evaluation for applicability to the proposed Map Ta Phut-Rayong AQCR. Apparently there are no temperature lapse rate data for U Taphao. However, since the Sattahip station is the synoptic station of the Royal Thai Navy it is possible that some weather data may be recorded that has application to the development of regional air quality models.

The Meteorological Department has established a weather station east of Rayong (Meteor. Dept. ID. No. 48478) and wind direction and speed data have been reported since October 1980. A comparison of wind information for Rayong and Sattahip is shown in Table 1. The comparative data of record are for 3 years only and show similar average wind speeds (about 4 kt) but somewhat different average wind directions. Only surface wind data are collected and there are no data for temperature lapse rates or for winds aloft. Evaluation of the potential for air pollution in the DPA requires descriptive meteorological data on vertical atmospheric mixing heights, depth of the inversion layer, and winds aloft, and accurate information on % calm periods.

2.1.3 Agriculture, Forests, and Fisheries

Agriculture and fisheries are important industries in Rayong Province Rayong produces the largest share of the fruit and tree crops grown in the 3 Eastern Seaboard Provinces, and a substantial amount of field

crops, primarily cassava, some sugar-cane, and small quantities of rice and vegetables. Tree and fruit crops occupy 31 % of the Province's agricultural land. The dominant tree crop is rubber which is planted on 65 % of the land. Coconuts use 13 % of the land, while fruit trees use 17 %, and pineapples 4 %. Field crops occupy 55 % of the agricultural land with cassava the dominant crop planted on 80 %, and sugar-cane on 18 %

Forest resources in the 3 Eastern Seaboard Provinces have declined very significantly over the last 20 years. The most rapid destruction of forest areas has occured in Rayong. There were 1,450 km^2 in 1961 and only 153 km^2 in 1981, a reduction from 42 % cover to somewhat less than 4 %

The DPA is also an important fishing area, especially in Ban Phe on the eastern edge of the AQCR and Rayong in the central coastal area. Fisheries provided work for about 30,000 fishermen in the province and about one-half of the annual fish catch on the ESB.

Prospective air pollution impacts from industrial, urban, and transportation emission sources must consider possible adverse effects upon agricultural crops and rubber production as well as possible damage to planned reforestation areas. Consideration should also be given to the effect of collected air pollutants when they are discarded in land fills, streams, marshes or other dumping sites and subsequently transported to marine and fresh water fisheries.

2.1.4 Industry

Present industrial enterprises in the DPA are primarily related to the processing of agricultural products grown in the Province. The principal industries are cassava pellet and starch plants which use electricity, fuel oil, or rice hulls as their energy source. The only non-agriculture based industry is the Petroleum Authority of Thailand's (PTT) Natural gas dew point separation plant located in Map Ta Phut. The Thai Petroleum Industry (TPI) polyethylene plant is east of Rayong and outside the DPA.

The Department of Industrial Works lists the industries licensed for operation in the area by category and business address. The current listing method is not amenable to transposition on available topographic grids so that specific areal site locations cannot be made. Separate site visits of each listed industry may allow siting so that a distribution of present industries in the area can be properly mapped for air quality management purposes.

Industries proposed for the DPA may be easily located and sited since they are to be directly associated with the established PTT facility. A considerable change in the industrial profile will occur with the construction of a gas separation plant and proposed construction of a complex for chemical fertilizers, petrochemicals, vinyl chloride monomer, soda ash, and methanol.

2.1.5 Transportation

The DPA is well served by road transport. CLA summarized the 1981 road traffic counts for Map Ta Phut and vicinity and showed a daily count of 6122 vehicles on Route 3, 1883 on Route 36, and less than 1000 on Routes 331 and 3138. In 1981 heavy trucks made up 24 % of the daily average traffic count on Route 3 between Map Ta Phut and Ban Chang, while cars and taxis made up 23 %, and motorcycles 37 %. There was slightly more heavy truck traffic (28 %) on Route 36 between Rayong and Khao Mai Kaeo, but many more cars and taxis (36 %) and about half as many motorcycles (15 %). The 1981 traffic counts for all vehicles on Route 3 travelling between Map Ta Phut and Ban Chang was 9790. The number of vehicles travelling on Route 3 between Sattahip and Rayong in 1981 was about 6500. CLA estimate traffic counts between Sattahip and Rayong will increase to 8000 in 1986 and to 9900 in 1991, and to 12,700 in 2001. Some variations in numbers and types of vehicles will result from optional forms of commercial and industrial transport modes suggested for use between Sattahip and Map Ta Phut.

2.1.6 Urban Development

At present there is a low level of urbanisation in the DPA. The urban population was estimated to be 44,700 in 1981 with 37,300

in the municipality of Rayong, and 7,400 in Map Ta Phut but outward migration is reducing that number. Urban development and population growth will change as the DPA proposed basic industries and ancillary facilities are constructed and go into production. The 1991 urban DPA population is estimated to be 70,100, and to increase to 119,100 by 2001.

The development plan calls for the location of major industries near the PTT plant in Map Ta Phut. These industries are typically capital rather than labor intensive, use considerable land, and unless suitably designed and operated, emit considerable quantities of air contaminants. They are easily identifiable point sources amenable to efficient and affordable air pollution control. Since the industries have a low job to capital ratio, population increase, commercial development and transportation requirements will be limited and the potential for area source emission growth will be less than in other parts of the DPA. The location of lighter industries with greater labor demands will affect patterns of urbanization and determine air pollution potential.

2.2 Description of Present Air Pollution

There are no air quality measurements either in the DPA or the larger AQCR. On two field surveys in November 1982 and April 1983 several industrial point sources were observed to produce suspended particulate matter (SPM) and unacceptable smoke and fumes emissions, probably due to poor fuel combustion or poor boiler operation and maintenance. The PTT dew point plant produced a continuous, dense, and long lasting black smoke plume from its low-level, inadequately sized, waste vapor flare. Many other local SPM sources associated with rice milling and cassava processing, were observed; fugitive dust due to manufacture and goods transport is a major problem.

An appraisal of present air pollution may be made from the source emission inventory instigated by the ONEB Division of Environmental Quality Standards (DEQS). The emission inventory currently considers 717 industries in 8 categories located in 6 districts in Rayong Province. Most of the emission sources are within the AQRS. A standard inventory questionnaire (Appendix 2) is used to estimate

emissions from fuel combustion. Details of pollution controls used and their effectiveness are also noted. This initial program is a valuable first step and will prove useful in estimating current air pollution levels.

Observations of some agricultural crops and other vegetation in the DPA and AQCR showed no evidence of injury or damage from air pollution with the exception of crops, fruit trees, and ornamental and native plants about rock crushing and tapioca operations which were heavily soiled by dust deposits.

2.3 Prospective Air Pollution

The basic industrial development planned for Map Ta Phut is centered about the existing PTT facility as industries are expected to be gas-related enterprises. The present natural gas landfall operations and the olefin separation plant now under construction are integrated industrial operations. The outputs of those operations will be used in the proposed additional basic industries for manufacture of chemical fertilizers, petrochemicals, vinyl-chloride monomers, soda ash, and methanol. These heavy industries require considerable land, very little labor, and generally produce heavy pollution waste loads. The prospect for air pollution is real and significant.

Prospective air pollution may be greatly reduced by selection of resource efficient industrial manufacturing processes and by including available and affordable air pollution control systems as integral parts in the production processes.

2.3.1 Prospective Impacts

The location of polluting industries in the DPA may take advantage of some natural air transport and dispersion due to regional weather conditions, and consequently minimize pollution levels. The use of the CLA proposals for open space and planned landscaping to produce an attractive urban environment with woodlands for recreation also aids in the dissipation of air contaminants and reduces their prospective impact. However, since weather conditions are changeable and may even aggravate air quality during periods of air stagnation, provisions should be made for source emission controls and action plans for air pollution episode emergencies.

The most effective way of reducing prospective air pollution is to provide the necessary controls as integral parts of the development plan. When emission control systems are built into the production process and designed to meet Thai national ambient air quality standards, the health and environmental protection provided will be affordable and in harmony with national industrial development plans. The air quality resulting from integral controls provides for protection of the environment and economic developments such as the further promotion of rubber plantations, reforestation, as well as minimizing the prospect of contributing to acid precipitation in the ESB and the Northeast Provinces, or conversely to the Southwest Provinces.

Protection against prospective pollution for the Map Ta Phut industrial development should consider emission reduction systems which use design standards, performance standards, best practical means, or predictive intermittent controls. Most of the industries proposed for Map Ta Phut already use control systems, generally performance standards. Particular attention must be paid to adequate reductions of SPM, sulfur dioxide (SO_2), nitrogen oxides (NO_x), and volatile organic compounds (VOC and HC). It is also important to critically evaluate the need to control specific fertilizer plant losses such as nitric, phosphoric, and sulfuric acids, and fluorine compounds. Other specific pollutants to guard against are chlorine (Cl_2), hydrogen chloride (HCl), and vinyl chloride (PVC) from the proposed vinyl chloride monomer plant.

2.3.2 Prevention and Control of Air Pollution

A master plan for clean air provides solutions for present and potential air pollution problems.

The planning and management of short and long-range air pollution control programs using air quality as the basis for management requires; 1) description of the area to be controlled; 2) assessment of existing air quality; 3) meteorology of the proposed air quality control region; 4) establishment of air quality standards; 5) a source emission inventory of the described area; 6) assessment of available control technology; and 7) the development and implementation of appropriate abatement and control actions.

These several information and data requirements must be used in concert; that is, they must be used as integrated actions within an operations system. All of the integrated actions or activities should be directed towards making the DPA air quality acceptable and keeping it that way. Air quality management is the operations system to obtain and maintain air quality which meets the RTG national ambient air quality standards.

3. ASSESSING THE DPA AIR QUALITY PROBLEM

Assessing present air pollution in the DPA starts with data requirements listed in 2.3.2, Prevention and Control of Air Pollution. Prospective air pollution assessments require the same basic data with the important addition of accurate estimates of industrial expansion, urban growth, and transportation and land-use changes affecting area and point source configurations. These basic data and estimated future growth data must be considered collectively for their combined impacts using air quality predictive models which account for the spatial distribution of all significant sources and provide for time and space location of atmospheric chemical reaction products.

3.1 Air Quality Assessment Parameters

Information involving a number of important activities is basic to the development and use of the air quality management strategy. Among them is the definition of the air quality control region or area. The boundaries of the area for which a control strategy is to be formulated are usually described by its topography, weather patterns and the transport and diffusion characteristics of the pollutants commonly found throughout the area. An emission inventory is needed which accounts for air pollution sources, rates of emission by source categories, and seasonal variation for such things as fuel combustion in fixed and mobile sources, industrial processes, and burning of combustible wastes. The information may be obtained in a variety of ways ranging from estimates derived almost entirely from published census data, rapid survey techniques, and comprehensive surveys. An accurate emission data base is needed for

projecting air quality, as a guide to community planning and land-use management, for the design of air quality monitoring programs, as well as for development of control strategies. An emission source survey questionnaire for the DPA has been developed (Appendix 2).

Another important activity is the assessment of existing air quality since it aids in defining the pollution levels in the prescribed area, assists in the choice of control strategies by showing the amount of control needed, and in demonstrating the effectiveness of the controls achieved by allowing comparisons of measured levels with chosen goals. It is essential that the measurement methods and data reporting systems for the entire area be explicitly described and defined and be based on ONEB accepted standard reference methods.

Air quality predictive assessments derived from air quality dispersion or climatological models require meteorological data. These models, which provide a mathmatical relationship between air pollution emission sources and resulting air quality, yield information useful in evaluating proposed control strategies and in determining the prospect of their meeting required air quality levels.

Air quality standards and precribed measurement methods for them have been established and were published 1 December 1981 (Appendices 3 and 4). There are other toxic air pollutant emissions for which there are no RTG air quality standards, which are now or may be emitted from a limited number of sources in a limited number of places, including the proposed DPA. These additional pollutants of concern include arsenic, beryllium, cadmium, fluorine, manganese, zinc, nitric, phosphoric, and sulfuric acids, benzene, vinyl chloride, and a variety of other materials such as polynuclear organic compounds.

Control technologies and control systems for polluting processes are provided to meet emission limits for designated pollutants. The emission limit can be determined in several ways: a limit that represents the best practical control level; a limit that represents the best available control technology; or the most restrictive limit, the lowest achievable emission rate. The various limits are typically represented either as design or performance standards. The

emission limits, or emission standards are essential inputs to the predictive air quality model in judging emissions required in order to achieve the ambient air quality standards. A well developed model properly programmed makes it possible to choose a set of selective emission controls for the most important emitters instead of applying uniform emission controls on all emitters. Applying most efficient controls to the most significant sources and minimum or no controls on emission sources of least impact can result in clean air at lowest cost. Adoption of this concept implies that as emission sources increase with expansion of existing industries and urban centers, or emissions increase in amount and kind due to new industries and related activities in the modeled area, emission limits and emission standards will be made more restrictive to accommodate the desired additional economic and social development.

Abatement and control actions are based on the formulation of emission standards and their promulgation for the emission sources in the AQCR or the described control area. The success of the controls in meeting the ambient air quality standards depends on the choice of emission restrictions, the size and efficiency of the control systems, the quality of inspection, operation, and maintenance of the selected controls, and the type and quality of enforceement provided by the regional air pollution control authority.

3.2 Air Quality Management Requirements

The measures to be taken to mitigate, or prevent and control, air pollution and the monitoring or surveillance programs needed to ensure the successful implementation of the mitigation measures are identified and arranged in an ordered systems approach as shown in Figure 2. A complete set of 1981-82 USEPA regulations for all aspects of air quality management is given in the US CFR, Parts 50-87 on file in the DEQS library. Each of the required systems measures is discussed in the following 8 sections together with information needs and some recommended actions.

3.2.1 National Ambient Air Quality Standards.

Air quality standards and designated methods for their detection and measurement have been promulgated (Appendices 3 and 4).

Current air quality standards for CO, Pb, NO_2, O_3 SO_2, and SPM are applicable to all municipalities and provinces of Thailand. The standards are designed to protect health. Their effectiveness in protecting agriculture, forests, and natural and cultivated ecosystems, visibility and other qualities of the atmosphere continues to be reviewed. The standards should be periodically reviewed to consider new health protection information and changed to meet new requirements.

Recommend :

1) ONEB monitor fine particulate matter in the range of 10 um and smaller in order to physically characterize the size distribution of inhalable particles at 3 representative sites, center city, industrial-commercial, and residential. The sized particulate samples should be chemically analyzed to determine their source of origin, such as motor vehicle, fuel oil, fugitive dust, and other sources of especial concern to assess need for additional particulate standards.

2) ONEB promulgate a list of approved alternative air quality measurement methods for the RTG air quality standards and give specific details on the procedures to be used in reporting air quality data for Environmental Impact Assessment (EIA) and other purposes.

3.2.2 Inventory Source Emissions.

The organization, collection, evaluation, and compilation of an inventory of point and area source emissions is vital to the development of the air quality management plan and the establsihment of mitigation measures for the DPA and AQCR. There are few useful reports with meaningful point source emission information. The reports available to ONEB give emissions in general terms such as Kg per tonne processed without emission rates or other data with which to quantity emissions from specific emission processes or emission exit points. Reports given to the DEIE are neither organized nor planned for presentation of quantitative air quality emission information or ambient air quality assessment (Appendix 5).

There are no motor vehicle emission data. The available CO data report CO % at idle for a limited vehicle population. These data cannot be quantified because a portion of the sample reports off-scale readings and none of the tests were timed and all were for idle engine cycle. The basic motor vehicle registration data are inadequate. There is no single validated statistical source for all vehicle categories and ages, engine displacement information is wanting, and there are no driving cycle data. In the absence of any substantive RTG motor vehicle emission information, no accurate and representative pollution emission estimates are possible. For purposes of developing comparative emissions for some vehicle categories, one set of RTG statistics was selected and USEPA emission factors were used for US vehicle engine displacements, US driving cycles and average US vehicle age groups. A set of comparative emissions was estimated for vehicles using benzine, diesel, and liquified petroleum gas (LPG). These preliminary estimates suggest CO levels in Bangkok may be due largely to the motor vehicle and that fuel type and engine maintenance may significantly impact CO ambient air quality as well as HC and NO_x (Appendices 6 and 7). The comparative emission estimates for Bangkok serve as an example of how estimates may be made in the DPA.

Emission estimates for motor vehicles in Thailand will likely remain unreliable and misrepresent their actural contribution to measured pollution levels until validated motor vehicle statistics, driving cycles, and emission estimates are forthcoming.

The present licensing procedures of the Department of Industrial Works (IW) provides a comprehensive list of all industries in the DPA and AQCR by process or product category and business address. There is no current requirement for listing process emissions. The nature and detail of emission inventories for air quality management purposes is given in a USEPA 4 volume report now on file in the DEQS (Appendix 8). The DEQS is now compiling a list of all existing point sources in Rayong Province from which a detailed emission inventory can be made using the information and quidelines given in Appendix 8. An initial emission inventory questionnaire could be prepared by DEQS

for use by IW for all new industries filling for permission to construct and operate polluting enterprises in the DPA or AQCR. Detailed inventories could be subsequently prepared by DEQS for purposes of evaluating the adequacy of planned emission controls and for recommending the need for additional emission restrictions. This engineering evaluation should be considered as a reciprocal service to IW in which the DEQS receives data necessary for the maintenance of RTG air quality standards and IW receives data necessary to ensure installation of processes or controls in compliance with RTG air quality requirements.

DEQS. is staffed and performs the many programs and activities concerned with air quality management. Since DEQS is concerned with existing as well as new pollution sources, it is important that DEQS be responsible for all basic air quality information including the establishment, evaluation and storage of source emission inventories and the determination of air quality monitoring needs.

The staff is particularly well equipped to evaluate the effect of source emissions on air quality and the data gathered by DEQS should be made available to DEIE for its preparation of EIA.

The DEQS has on file an up-to-date set of USEPA emission factors and rates for estimating emissions from designated industrial processes and categories and from motor vehicles (Appendix 9). Some of the USEPA process and category emission factors are likely applicable to Thai conditions. The DEQS should determine the appropriate emission rates for categories and fuels not given by USEPA; those USEPA factors believed applicable to Thai conditions should be validated. The procedures to be followed by the DEQS when using its stack sampling equipment is given in the US Code of Federal Regulations (CFR) (Appendix 10). Since stack emission sampling is ardous and time consuming work, it is important that only priority sampling be undertaken.

The DEQS should develop a position on in-plant monitoring and reporting of selected emission sources and in-plant fuel quality and use. Detailed procedures, methods, and reporting systems should be specified. The proposed emission monitoring plan should incorporate needs of ONEB as well as other RTG agencies and should be officially promulgated.

Recommend :

1) ONEB develop with IW an addition to the present IW licensing form an item which describes specific grid site location in addition to the business address now required.

2) ONEB develop a simplified, uniform, first-level emission inventory questionnaire to be used as a supplement to the IW licensing form. The form should endeavor to obtain estimated emissions from energy development and process operations for air pollutants for which there are RTG ambient air quality standards and recognized toxic or hazardous substances which are to be vented to the atmosphere.

3) ONEB should develop a plan to acquire motor vehicle statistics necessary for the development of a vehicle emission inventory as a first requirement for the establishment of motor vehicle emission standards.

3.2.3 Local Meteorology

There is no local meteorology station in the DPA. One surface meteorology reporting station, Rayong is within the proposed AQCR east of Rayong municipality. The Rayong weather station established in 1980 collects standard weather information, surface wind direction and velocity on a fixed interrupted time schdule. Data outputs from Rayong are presently inadequate for air quality management purposes, but they presumably could be upgraded to meet AQM needs. The development of basic industries in the DPA and the establishment of a worker's urban community there calls for the location of a local meteorological station within the DPA complex to service the basic AQM requirements as well as to provide data for forecasting and operating an air pollution episode action program.

The meteorological data requirements should provide real-time wind direction and velocity, temperature lapse rates, mixing depths, and atmospheric stability information. The nearness of the Royal Thai Navy (RTN) synoptic weather service in Sattahip suggests integration of their forecast facility into the DPA weather operations and air quality

monitoring network. Given proper weather and air quality information, effective built-in industrial air pollution controls designed to meet RTG ambient air quality standards could be assured through putting into action any necessary intermittent controls called for during periods of air stagnation.

The meteorological needs of the AQCR could be met by locally gathered data using specified equipment on real-time and specified-time schedules. A number of options may be developed to provide the required meteorological information for predictive modelling. One that appears feasible now consists of upgrading the present Rayong station, establishing a meteorological station in the DPA at Map Ta Phut as an operational responsibility of PTT, and upgrading the current DEQS Mobile Laboratory to provide temperature lapse rates, mixing heights, and aloft wind speed and direction data. PTT is selected for their central position as gas supplier to DPA developments and their recognized leadership and professional capabilities. Since stability classes based on cloud cover are described for temperate and more northern latitudes, and most predictive models used for AQM are developed for climate zones experiencing 4 temperate zone seasons and without monsoon periods, it is very important that meteorological data be acquired for the DPA for purposes of modelling and determining the acceptability of integral emission control systems for the planned DPA industries.

Recommend :

1) DEQS expand its mobile air quality monitoring capability to
in include local meteorological parameters required for modelling and development of a data base suitable for transport and dispersion monitoring of atmospheric chemical reaction systems. Acquired equipemnt should include a tethered balloon with sensors and detectors for ground receiver and recorder of aloft conditions, such as pressure, temperature, time and wind direction and velocity.

2) ONEB negotiate with PTT for their installation and operation of basic air quality monitoring and meteorological parameters

as a cooperative industrial program. The outputs should serve as an integral part of ONEB's air quality surveillance responsibility as well as the control center for operation of the air pollution episode management program. Acoustical radar together with temperature and wind information may be installed at PTT operations center and make use of their communications tower or other elevated structures.

3.2.4 Local Air Quality

There are no local air quality data for the DPA or AQCR. Air quality information should be obtained by DEQS using the recently completed mobile laboratory. Plans should be made to establsih an AQCR monitoring network initially centered in the DPA for purposes of securing information on air quality before there is significant industrial development, for monitoring the effectiveness of the DPA pollution control program, and for evaluating compliance with RTG air quality standards and consideration for their possible improvement. Suggestions on analysis and evaluation of air quality monitoring data are given in Appendices 11, 12 and 13.

Measuring local air quality with DEQS mobile laboratory should also consider validation of model output as well as selection of prospective air quality monitoring network sites. It is important to determine air quality levels in areas designated for housing industrial workers and their families to make sure the exposure risk is acceptable and that it does not become an additional burden or insult to the worker's occupational exposure risk. In this regard it appears desireable to request the industry to monitor air quality on the plant site as well as on the housing sites they provide their workers. The air quality monitoring sites should be established in accordance with ONEB requirements including data submittal, and should include real time surface meteorological information appropriate for tracking plumes and accountability for local health surveillance.

Recommend:

1) DEQS start monitoring air quality in the DPA at selected sites with particular reference to NO_x, SO_2, and SPM near and

away from present industrial activity. The sites must be identified by grids. CO may be measured as a marker for plume tracking or area source detection.

2) DEQS should equip the mobile laboratory to make manual samples for detection and measurement of special air pollutants such as HCl, Cl_2, and certain HC, such as acetylene, low molecular weight olefins and some saturates. Chromatographic determinations for HC and VOC are preferred and easily adopted to space limitations of a mobile laboratory.

3.2.5 Air Quality Predictive Model.

There are a variety of stationary source models from which one appropriate to the gently rising coastal plain may be chosen. They range from single source, simple terrain, and short-term to mutiple source, complex terrain, and long-term with and without accommodation of urban areas and atmospheric chemical reactivity.

The applicability of various models to particular air quality needs and data inputs required for use of particular models are detailed in 2 USEPA publications on file in DEQS (Appendices 14 and 15). One of the simpler well tested ones is the Air Quality Display model (AQDM) which deals with multiple sources and receptors and produces annual averages for a described grid area. A single emission source made up of a collection of as many as 19 colocated stacks applicable to rural and urban uneven,,but not complex, terrain is CRSTR, which has found some use in Thailand. An evaluation and choice of preferred working models must consider not only available data inputs but computer services and programs.

Recommend:

1) DEQS staff evaluate available models in light of input data capabilities and computer services and select one which will accommodate a grid emission source inventory and a ground level concentration output compatible with RTG ambient air quality standards.

RTG ambient air quality standards.

3.2.6 Pollution Control Regulations.

Source emission limits, or source emission standards, are designed to reduce air pollution levels to the desired ambient air quality stated by the RTG air quality standards. Emission standards are usually derived from process and equipment technology and consideration of air quality needs. Pollution control regulations are the formally promulgated descriptions of the required emission limits with prescribed amounts permitted to be released in a given volume of effluent air. Regulations must be clearly written and include procedures for quick, decisive, and effective enforcement. Emission standards vary in stringency depending on expediency and need. They may be called "best practical means", "reasonably available control technology", "best available control technology", or "lowest achievable emission rate", all terms referring to increasingly restrictive emission levels using higher, usually more efficient and sophisticated control technologies.

The 5 industries planned for the DPA typically have environmental pollution controls included as integral parts of their production processes. These integral mitigation measures may be expected to be adequate for meeting RTG air quality standards. None of the DPA industries have submitted production unit plans with estimated rates of emissions; consequently the adequacy of proposed pollution controls cannot be assessed. However, a basis for assessing their adequacy is provided by judging their effectiveness against USEPA New Source Performance Standards (Appendix 10) and a 1982 USEPA compilation of selected control technologies (Appendix 16). The choice of control technologies is based on emission restrictions predicted by the air quality simulation models.

The planned basic industrial complex at Map Ta Phut and associated polluting industries in the DPA are expected to comply with emission limits especially developed for the 5 specified enterprises and ancillary activities. Further unplanned industrial development in

Map Ta Phut or in the immediate vicinity within the DPA may lead to collective emissions exceeding the air quality standards. If this kind of an uncontrolled growth situation is allowed it will then very likely be necessary to impose new and more stringent emission standards on existing air pollution sources at considerable cost.

Recommend:

1) ONEB establish a control technology technical advisory committee for the purpose of analysis, evaluation, and designation of control technologies and control systems meeting emission standard requirements for various categories of commerce and industry.

2) ONEB publish reports documenting appropriate air pollution control technologies and systems meeting emission standards requirements together with information on their removal efficiencies and operation and maintenance requirements.

3.2.7 Enforcement of Emission Standards.

Since air pollution control regulations are the central driving force to reduce air pollution to acceptable air quality levels, it is important that the emission standards be enforced. The enforcement process is a combination of activities all focused on compliance with the regulations by the public, private enterprise and government. Public education is a key part of any enforcement or compliance program. Once the public understands what is expected from the air pollution control program and control authorities follow through on public complaints, voluntary compliance, persuasion, and conciliation will do much to enforce emission control regulations. Inspection of industries by trained agency officials will disclose violations of emission standards and illegal air pollution practices. Discovery of violations requires prompt and proper action and appropriate abatement and corrective action.

Both routine and unannounced plant inspections for compliance with emission standards are useful in identifying violators and assuring that air pollution control equipment is properly operated and

maintained. Compliance can also be achieved by requiring selected industries to report stipulated emissions on a regularized schedule. Continuous source monitoring systems may also be used for reporting emissions (Appendix 17). Source monitors are also useful to in-plant production personnel in following process efficiencies.

CLA emphasizes that "adequate environmental control facilities--" can be provided in Map Ta Phut. It certainly is true the industrial waste water effluent facilities can be provided. It is less clear that the operation, maintenance and inspection of air pollution control facilities in PTT and the 5 basic industries can be effectively achieved without an in-house, industry based air pollution control unit and without a DPA-based air pollution enforcement service. Inspection and compliance with air pollution control regulations will become effective when trained personnel make periodic inspections following established operating and reporting procedures.

Recommend

1). DEQS incorporate continuous air pollution source monitoring systems as integral components of ONEB designated control technologies and systems.

2) ONEB recommend continuous air pollution source monitoring systems as the measurement method for selected emission standards and establish source test procedures for validation of installed continuous monitors.

3) ONEB prepare emission source inspection guidelines and organize and offer specialized courses and on-the-job training for industrial and government personnel responsible for enforcing emission standards and in-plant air pollution controls.

3.2.8 Evaluate and Revise Control Program

The AQM plan is judged a success if the desired air quality is achieved. Air quality monitoring provides a continuous evaluation of air quality trends as well as an appraisal of localized effects from

particular sources. General and local air quality changes give the information needed to assess the adequacy of present emission standards and regulations as well as prospective emission control requirements. The choice of additional or revised emission restrictions and appropriate technology to meet them, or the choice of intermittent controls to meet air pollution episodes, in turn are based on information outputs from the predictive model and promulgation of relevant control regulations.

Periodically, perhaps every 4 to 6 years, the air quality monitoring data should be critically evaluated to make certain data quality is acceptable, monitoring sites represent populations at risk, and that the data are reported in a format useful for national economic and social development planning. The periodic review should also assess the cost of the monitoring program and determine if useful cost savings can be made through reduction in number of monitoring sites and personnel which may be more effectively used elsewhere in the air pollution control program.

Recommend:

1) DEQS adopt the WHO/GEMS air quality monitoring data acquisition and report form and become an active collaborator in the internatinnal program.

2) DEQS reassess the need to operate and maintain the current 9 station fixed monitoring network and evaluate the prospect of performing targeted air quality measurements for particular populations at risk in market and shophouse centers, heavily used pedestrian walkways, and densely populated congested traffic ways.

4. GUIDELINES AND TASKS FOR AQM IMPLEMENTATION

The planned industrial development in the DPA provides a unique opportunity to organize, staff, and operate a regional air pollution control program in a designated AQCR. The AQM system has been described in 3.1 and 3.2 The intent of the recommendations in those sections is to stimulate interest and activity in putting the

various elements of AQM into action and to start field activities in the AQCR as soon as possible using current staff of ONEB, other RTG Agencies, and engineers and scientists in regional operating industries. The following compilation of type and scope of activities is designed to further implement AQM in the DPA and AQCR for the decade.

4.1 Health, Environment, and Air Quality Surveillance

The activities described below are to be periodically performed and the results used to determine changes attributable to industrial development in the DPA and for comparisons with areas outside of the DPA but within the AQCR.

4.1.1 Health

- o Establish and maintain a health status census for school children in the DPA using provincial health facilities and personnel.
- o Establish and maintain a health status census for DPA adult residents using existing out-patient clinic and hospital records.
- o Periodically collect, analyse and evaluate DPA health statistics and perform cohort comparisons with children and adults outside the DPA and relate the findings to measured air quality.

4.1.2 Environment

- o Establish and maintain a census of agricultural crops in the DPA.
- o Periodically analyse and evaluate agricultural crop condition and productivity with particular attention to cassava, rubber, and forests.
- o Conduct similar studies in selected crop areas outside the DPA but within the AQCR.
- o Identify environmentally sensitive indicators and make periodic status reports in which observations are related to measured air quality.

4.1.3 Air Quality

- Initiate mobile laboratory monitoring for SPM, SO_2, and NO_x on a regularly scheduled basis and CO and O_3 at selected times at identified sites.
- Develop a plan for a monitoring network appropriate to the needs of the RTC standards and establish sites by simulation modelling.
- DPA industries should actively participate in the monitoring program and be responsible for reporting air quality in the vicinity of their operations and in employee housing and community center areas.
- Special measurements should be made for selected HC and VOC, Cl_2, and other compounds representing DPA industrial activity as well as chemical analyses of SPM for toxic substances and polynuclear organic compounds.

4.2 Meteorological Data for Modelling and Air Pollution Episode Management

- Establish a synoptic forecast system in conjunction with MD and RTN capable of predicting the onset of air stagnation periods, their prospective duration, and intensity.
- Acquire detailed meteorological data for the operation of the DPA predictive model.
- Formulate an emergency abatement and control program with personnel evacuation procedures to become operative during air pollution episodes, industrial accidents, and chemical spills.

4.3 Emission Inventory

- Develop an emission inventory program which reports emissions from existing and new industries in the DPA.
- Initiate a second inventory program for area and motor vehicle sources in the DPA.
- Establish a third inventory program for stationary, motor vehicles, and area sources in the AQCR.

4.4 Modelling

- Evaluate described predictive air quality models and programs suitable for DPA and AQCR use and select one compatable with available computer services.

4.5 Emission Standards Development

- Develop emission standards specifically tailored for the 5 planned industries taking in to consideration:

  Existing air quality
  Collective emissions of the 5 industries
  Effectiveness of built-in integral control systems
  Pollution absorption capacity of the atmosphere
  Future limited planned growth
  Isolation of DPA in the AQCR
  Compliance with RTG air quality standards

- Apply performance standards or reasonable control technology to industries planned for the AQCR.
- Develop an emission standards program for the AQCR in anticipation of the need to control emissions from existing industries.
- Development of motor vehicle emission standards (see Appendix 18) for the AQCR-now appears unnecessary. When motor vehicle emission standards are required, information needs will include:

  Comprehensive and valid vehicle population statistics
  Engine capacities
  Manufacturers design criteria for CO, HC and NO_x emissions
  Representative Thai driving cycles
  Determination of motor vehicle emissions from on the road in-use vehicle

- Establish measurement methods to be used in conjunction with source emission standards.

4.6 Control Technologies

- o Select control technologies consonant with emission standards requirements.
- o Choice of appropriate control technologies should be drawn from lists of available and demonstrated technologies and control systems such as offered in Appendix 16, and those recommended by ONEB on advice of the Control Technology Technical Advisory Committee.

4.7 Rules, Regulations and Enforcement

Prepare rules and regulations which explicitly identify the emission sources for which the emission standards and air pollution controls have been developed.

- o Rules and regulations must provide for control personnel access to the control facilities, authority to inspect and perform necessary emission tests, procedures for enforcement, and authority to prevent the use of equipment in violation of Regulations.
- o Provide for review of plans for all new industrial construction to make certain that provisions are made which ensure compliance with established emission limits and other air pollution control requirements.
- o Establish an annual permit system authorizing operation of facilities which meet the required source emission controls and denying permission to operate to those which fail.
- o Institute a source emission monitoring and report system in which industries submit scheduled accounting of their emissions for review and action to air pollution control officials.
- o Develop an information program to inform potential polluting industries of clean air regulation requirements and compliance procedures.

4.8 Personnel and Facilities

Personnel are required for the region and headquarters with

facilities likewise divided. Personnel numbers are given in man years and are exclusive of clerical and other support staff.

Regional personnel

o Air quality and continuous source monitoring with concommitant specific meteorological measurement	5
o Emission source testing	3
o Emission inventory, permits, inspection and enforecement (exclusive of court action)	4
0 Air quality meteorology	4
o Data compilation and processing	3
o Surveillance	1
o Administration, management, coordination and program evaluation	2

Headquarters personnel

o Standards development for air quality and emissions from stationary and motor vehicle sources together with measurement methods and control technologies evaluation	2
o Rules, regulations and permits	2
o Modelling	2
o Surveillance	2
o Data processing, evaluation and reports	2
o Preparation of materials for public information purposes	1
o Headquarters administration	1

Regional Facilities

- o Laboratory and shop facilities for preparation of standards, analysis of emission stack test samples, and equipment calibration, conditioning, repair and mainteneance.
- o Equipment for air quality detection and measurement and emission source monitoring for all pollutants for which standards have been established.

- Gas chromatographs for specialized purposes such as testing for HC, VOC, and hazardous pollutants.
- Emission source testing equipment.
- Meteorological equipment for operations performed in conjunction with mobile air quality laboratory and ground stations.

  Equipment is needed for measurement of surface and aloft wind direction, velocity, and turbulance; temperature lapse rates by fixed tower; temperature lapse rates by tethered balloon with air to ground electronic signalling; mixing heights by accoustical radar; other facilities for detecting and reporting air stability, cloud cover and radiation.

- Data processing equipment for handling field generated data and compatible with headquarters processing requirements.

Headquarters Facilities

- Data processing and computer services necessary for compiling, storing and retrieving all generated field data and suitable for input output requirements for modelling.
- Computer programs and services as required for designated personnel, facilities, and tasks.

4.9 Liason with Other RTG Agencies

Successful air quality management requires central leadership, a closely knit working staff and collaborative assistance from private and public organizations and institutions. The AQM effort must be focussed on air pollution control in the DPA and AQCR. This means that the central administration should be in the AQCR and that headquarters operations be dedicated to supporting the regional program. The principal RTG agencies responsible for specific tasks in the AQM system are ONEB, Industrial Works Department (IW) and Meteorological Department (MD). Other agencies providing information necessary for AQM include the provincial Public Health Department (PH), the Royal Thai Navy (RTN), and the Petroleum Authority of Thailand (PTT). The responsibilities of these organizations are recognized in the following description of tasks integral to the AQM system.

- ONEB

  Air quality standard setting and surveillance to assure that standards are met.
  Modelling for selection of emission standards to meet air quality needs.
  Compilation of emission inventories for modelling regional air quality.
  Assessment of control technologies and systems.

- IW

  Approves the location and issues licenses for construction and operation of industries.
  Adopts and enforces emission standards.

- MD

  Collects and publishes meteorological data required for ONEB modelling. Provides synoptic and microscale forecasting useful for air pollution episode management. Additional synoptic meteorological information is provided by RTN.

- pH

  Collects and compiles epidemiological health service information.

- PTT

  Provides information basic to the compilation of DPA emission inventory.

Liason will be provided by integrating these service functions into a single unit under one administrator in the regional office. Liason will occur because of the commonality of the task and the interdependence of the groups using one anothers information and data input for the purposes of air pollution control. For example, of the 22 regional personnel recommended in 4.8, it is proposed that 10 be employees of ONEB, 8 be employees of IW, 3 of MD, and 1 of PH, in keeping with the above described agency tasks.

4.10 Training

ONEB should:

- Establish an environmental training center. The center should offer short courses on subjects required for air quality management. See Sections 3.1 and 3.2 Some course details, outlines and materials are listed in Appendix 19.
- Develop a proposal for submittal to UNILO in support of training for environmental protection and air pollution control for stationary and motor vehicle sources.
- Request the USAPCA Committee on International Affairs to supply training materials and instructors for AQM and inspection, operation and maintenance of air pollution control equipment.
- Develop, through a Thai or ASEAN industrial or manufacturers association, a hands-on practical training experience for air pollution control equipment operators.

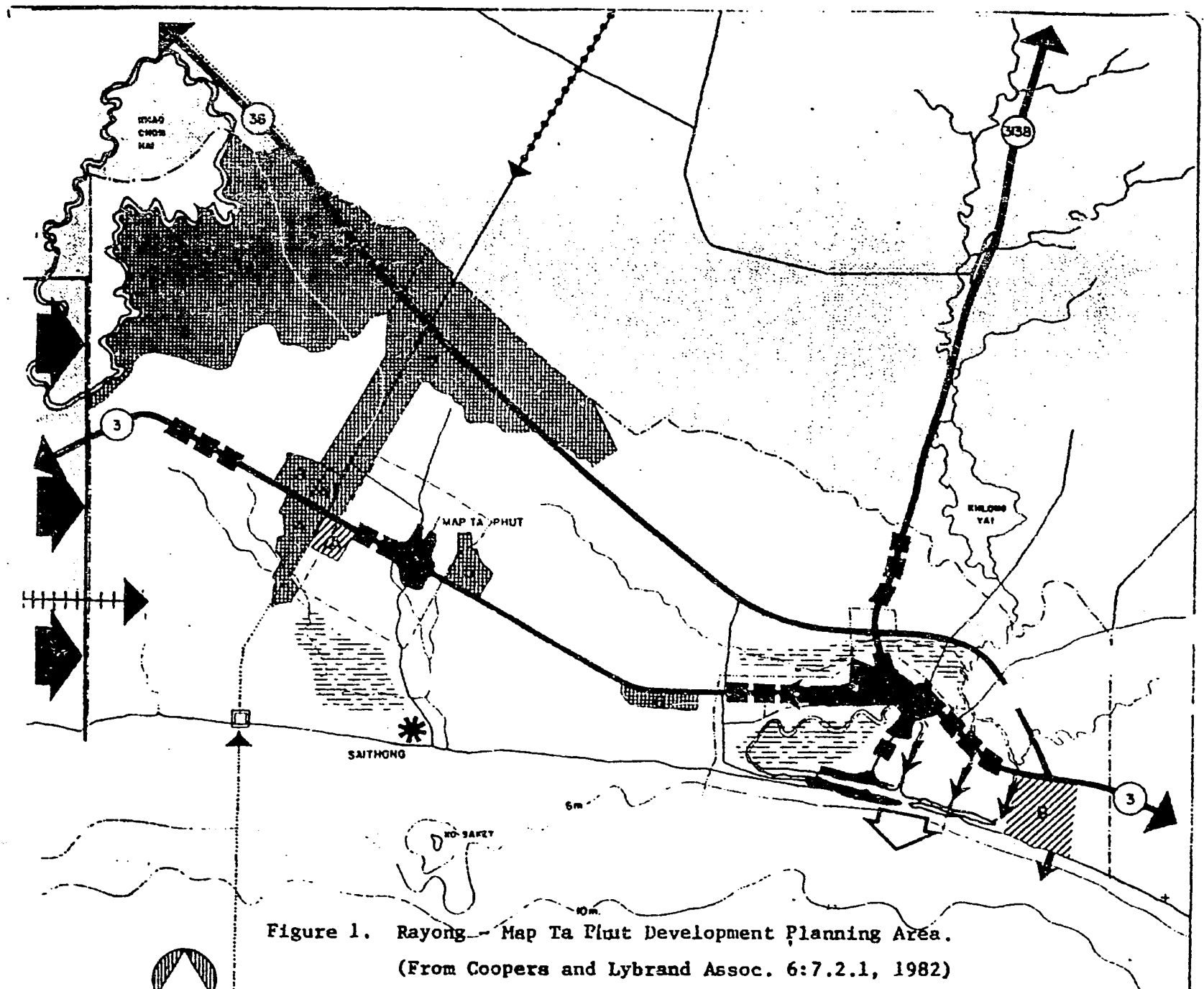

Figure 1. Rayong - Map Ta Phut Development Planning Area.
(From Coopers and Lybrand Assoc. 6:7.2.1, 1982)

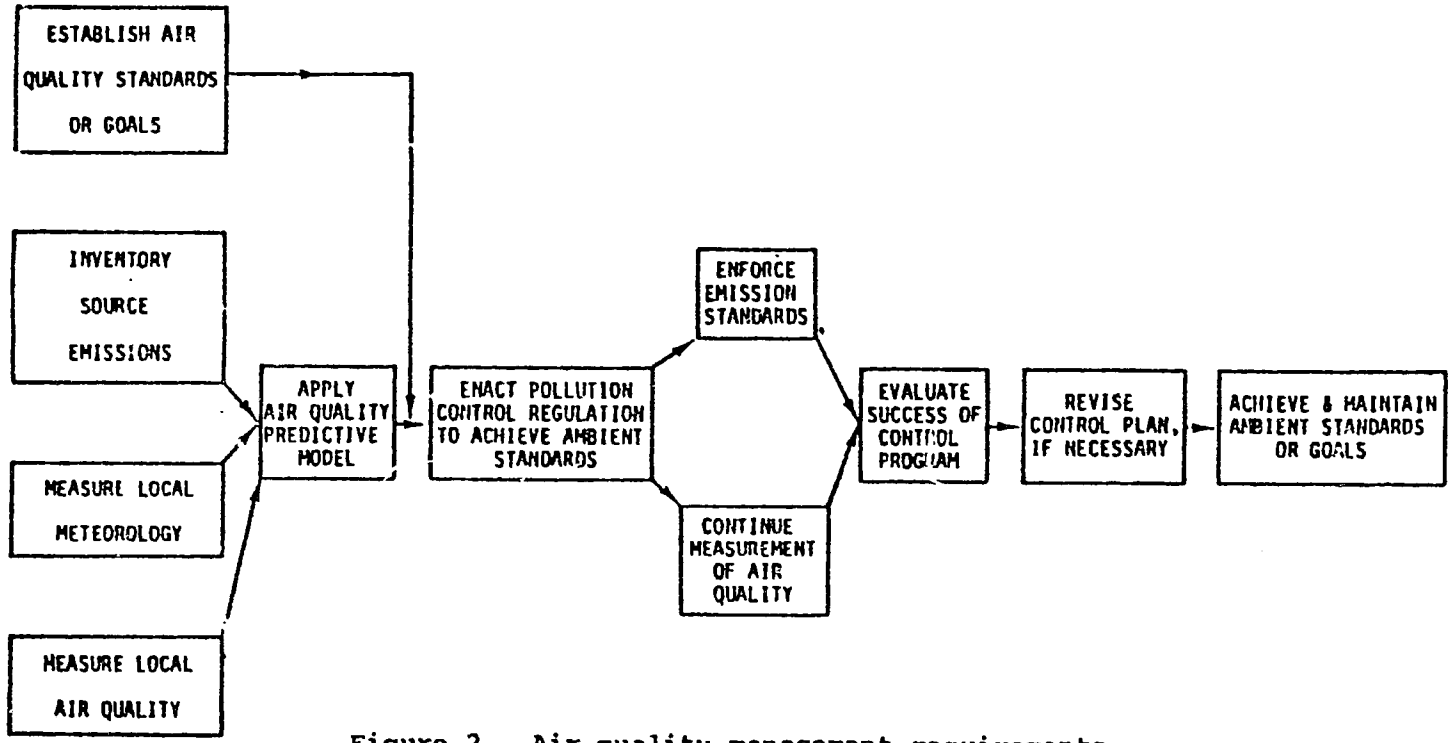

Figure 2. Air quality management requirements.

(From A.C. Stern, Air Pollution, V p. 13)

	Rayong						Sattahip						
	1980		1981		1982		1980		1981		1982		% calm
	W	S	W	S	W	S	W	S	W	S	W	S	20 Yr. avg.
Jan			NE	1.8	NE	2.4			N	4.8	N	5.2	23
Feb			W	3.7	SW	5.4			S	3.2	S	6.5	15
Mar			SW	3.9	W	5.3			S	4.9	S	7.3	9
Apr			SW	3.6	S	2.5			S	4.4	S	6.0	10
May			SW	5.0	S	3.6			S	4.0	S	6.7	11
Jun			SW	8.2	SW	9.1			W	5.8	S	7.3	4
Jul			W	6.5	SW	11.4			S	5.9	SW	7.7	8
Aug			W	8.2	SW	10.1			SW	6.4	SW	6.5	8
Sept			W	2.5	SW	6.4			S	3.4	SW	5.4	17
Oct	E	1.3	W	4.6	S	1.7	N,S	2.2	N	4.6	N	4.2	24
Nov	NE	2.1	N	1.9	N	1.3	N	3.8	N	5.0	N	4.8	18
Dec	SW	2.4	N	3.5	- -	- -	N	3.7	N	6.3	- -	- -	15

W = prevailing wind direction

S = mean wind speed in knots

Table 1. Comparative wind data for Rayong (Meteo. Dept. I. No. 48478) and Sattahip (Meteo. Dept. I. No.48477).

APPENDIX 1

John Middleton/NEB/17 December 1982

To : Deputy Secretary General

Subject : Eastern Seaboard (ESB) overview relative to preparation of an air quality management plan for the Map Ta Phut development planning area.

INTRODUCTION

An extensive review of documentation (Appendix 1) relative to the development of the ESB identifies the Rayong - Map Ta Phut zone as an appropriate growth center and well suited for the development of selected basic industries, related commercial activities, and agro-industries.

FINDINGS

The RTG Fifth National Economic and Social Development Plan (1982-1986) designates the 3 ESB Provinces of Chachoengsao, Chonburi, and Rayong as a new growth center in accordance with the ".....systematic decentralization of economic and industrial activities to the regions." In this context ESB"...will become a new industrial centre and another major employment generator in the Central region...(and) also serve the Northeast as a new gateway for its exports.". This Fifth policy plan of decentralization attempts to adjust the economic structure disperses income and economic activities to the provincial areas, and invites "...cooperation of the private sector in restructoring agriculture, industry, energy, and in export drive."

The target area covers about 123,750 rai (19,800 ha) and lies beyond the U Tapao Naval Airport, somewhat east of Ban Chang, follows the coastline to include Rayong, and the inland areas along Route 36 northwest to the forest reserve near Khao Chom Hai (419 m). The land alopes south and east from the ridge formed by Kao Khrok and Khao Chom Hai to the coast and flood plains reaching the Khlong Yai (Rayong River). The population of the area in 1981 was 73,900, with 7,400 in Map Ta Phut and 37,300 in Rayong town.

The target area is served by road transport. Map Ta Phut is located on National Highway Route 3. It may also be reached by Inter-Regional National Highway Route 36, and Provincial Highway 3138, which terminate in Rayong at Route 3 and by Secondary National Highways 331 and 332 which intersect with Route 3 West of Ban Chang. Average Daily Traffic Flows for 1981 are available for all but the short interconnecting Route 332. Flow counts pertinent to Map Ta Phut have been extracted from Coopers and Lybrand Interim Report 5, Table 2.2 (b), and presented in Appendix 2. These data show counts of 6122 on Route 3, 1883 on Route 36, and less than 1000 on Routes 331 and 3138. Heavy trucks makes up 24 to 34 % of all traffic with the lowest persentage on Route 3 and highest on Route 331.

There are no general port facilities in the target area other than for fishing vessels in the mouth of the Klong Yai. Likewise, there are no rail or air transport facilities. The urban engineering infrastructure in Rayong town is reportedly generally poor and that in Map Ta Phut considerably worse.

Two very significant industries are now operating in the Development Planning Area. The Petroleum Authority of Thailand (PTT) is responsible for the operation and maintenance of the gas separation plant in Map Ta Phut which processes and distributes natural gas collected from gas fields located in the Gulf. Thai Petroleum Industries 2 to 3 km east of Rayong started up their polyethylene bulk pellet plant earlier in the month. The high pressure reaction system is licensed from Uhde Co. and uses imported ethylene delivered to PTT jetty facilities in cryogenic vessels. Other industrial enterprises are located in the area but no listing is presently available.

Agriculture and fishing are important sectors of the regions economy, although marine fisheries production remains in a period of decline. Land for agricultural crop production in 1981 in the 3 Provinces used 5,525,000 rai of which 1,452,000 rai, or 26.3 %, were in Rayong Province. Rayong produces relatively little rice and few vegetables, but is a major producer of fruit and tree crops. Tree and fruit crops occupy 463,000 rai of the cultivated land in Rayong, with

65 % of the land used for rubber, the dominant crop. (at 65 %) The remaining rai are primarily planted to coconuts, 13 %, fruit trees, 17 %, and pineapples, 4 %. The 80,000 rai of fruit trees in Rayong are principally durian 41 %, mango, 22 %, and rambutan, 17 %. Cassava is the dominant field crop using 80 % of the 785,000 rai with sugar-cane occupying 18 %, groundnuts, maize, and miscellaneous other crops use the remaining rai.

Forest resources in the ESB Provinces have significantly declined from 5,853 km^2 (42 % cover) in 1961 to 2,087 km^2 (15 %) in 1981. The most rapid destruction of forest areas has occurred in Rayong Province. There were 1,450 km^2 of forest area in 1961, covering about 42 % of the Province. In 1981 there were only 173 km^2 remaining which leaves somewhat less than 4 % forest resource cover for timber and wood fuel supplies, wildlife habitat, watershed protection, prevention of soil erosion, reduction of siltation and climate modification.

Livestock is an important part of the agricultural economy of the ESB. Cattle are raised in all 3 Provinces with 32.4 % of the dressed meat and offal estimated to be produced in Rayong. Pigs are raised in Rayong with most farmers having herds of less than 20. Based on feedstuff consumption estimates, Rayong consumes no more than 7 % and is considered a minor ESB pork producer. Fowl are raised in limited numbers in Rayong and account for 2.7 % of the chicken and less than 1 % of the duck meat, and 6.6 % of the chicken and 3.3 % of the duck eggs in the ESB.

Fisheries account for 10 % of the rural jobs and 8 % of all employment on the ESB providing work for about 60,000 fishermen, about one-half of them in Rayong. The annual marine fish catch varied greatly over the last 10 years with a low of 48,179 tons in 1975, a high of 101,340 tons in 1977, and 82,984 tons in 1980. Fresh fish catches have also varied from a low of 219 tons in 1975 and a high in 1980 of 3,206 tons.

There are several summaries of climate and weather information, all apparently based on data from the Meteorological Department.

The weather stations most frequently used for ESB environmental impact reports are Chantaburi, Chonburi, and Sattahip, with infrequent reference to Rayong. The summaries support the recognized alternating northeast and southwest monsoon system with moderate winds, seasonal rainfall differences and temperature and relative humidity variations. The 4 to 16 knot wind pattern in Sattahip show percent wind direction frequencies of : N = 15.2 NE = 4.9, E = 0, SE = 0, S = 31.8, SW = 33.6, W = 14.3, and NW = 0. Winds of 17 to 27 knots are sometimes observed, and occasional very short gusts exceed 27 knots from various directions. Limited data are given on coastal tides and currents as well as wave and current influence on silt and sand transport.

The Fifth Plan explicitly deals with policy and formulation of action plans for an environmental conservation program which is one of 3 subjects incorporated with agriculture restructuring and improvements in efficiency of natural resources' utilization. Conservation of natural resources and the environment is viewed as a need to :1) protect farmlands from urban expansion and soil quality and prevent for soil erosion; 2) provide remedial measures for environmental effects caused by construction of dams and reservoirs, allocate water in main river basins to ensure sufficient water to drain away polluted water and prevent salt water intrusion consistent with alleviation of flooding problems, and manage water resources to avoid pollution damaging to agriculture and marine life; and 3) achieve restoration of 40 million rai of forest watershed in north and northeast, conserve 15 of the 17 million rai of existing national parks, and expand the present 21 wildlife conservation areas from 11.5 to 12.8 million rai.

The Fifth Plan gives considered and detailed attention to "Conservation and Rehabilitation of Environment" (pp.187-191) in the Chapter dealing with "Population, Manpower, Moral and Environmental Development Strategies". In this context, environmental problems resulting from rapid population growth, unorganized patterns of human settlements, and use of inappropriate technologies in production processes have negative impacts on the well-being of people, and further

deplete the country's natural resources resulting in serious environmental imbalance. Pollution is cataloged in 5 categories: 1) Water pollution, 2) Air pollution, 3) Solid waste, 4) Noise, and 5) Toxic substances.

The air quality statement from "Conservation and Rehabilitation of Environment" (p. 187) follows : "(2) Air pollution is attributed primarily to the emission of toxic substances from motor vehicles and industrial factories in certain areas and at certain time periods. This problem is extremely critical in the Bangkok Metropolitan Area. A recent survey carried out along traffic routes in the major business areas showed the carbon monoxide averages of 30-40 milligrammes per cubic meter." A target for air quality improvement is given (p. 188): "Accelerate the establishment of an air quality monitoring system in the Bangkok metropolis and control the air quality in urban centers and industrial areas." A further target in conjunction with natural resources and off-shore mining practices has relevance to air quality"-Adopt a programme to conserve the ecological system and control the utilization of resources in Songkhla Lake, the sea of Phuket Phang-nga and the Eastern Seaboard."

Development measures the Fifth Plan identified for controlling Environmental pollution include effective systems for monitoring and controlling government and private sector activities concerned with solving environmental problems, use of town-planning and fiscal-monetary measures to prevent the spread of urban areas into agricultural zones, and designation of areas where environmental quality will be controlled. Considerable emphasis is also placed on the value of creating environmental units in appropriate government agencies, establishing public education programs, promulgation of laws needed to require participation of the private sector in preventing and solving environmental problems, as well as improving and revising existing laws to meet environmental standards related to land use, town planning building permits, sanitation, traffic congestion, and land holding. The measures identified also call, for environment curricula in the multi-tiered education system, as well as for short-term specialized training, and a broad range of research tasks and a system for environmental surveillance.

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Environmental quality management for the target area on the ESB is described in varying detail in most ESB reports. A general statement is made in the Fifth Plan : "A research study will be undertaken to determine measures, preconditions, and projects necessary for the control of environmental pollution which may stem from the growth of industrial activities." Coopers and Lybrand associates present a more focused view beginning with the value of open space and landscaping to produce a better urban environment as well as urban woodlands for recreation. They propose an ESB monitoring system to be executed by NEB f the continuous surveillance of sensitive resources and for assuring environmental quality goals and standards are met.

Air pollution is recognized as an inevitable component of the planned Map Ta Phut "heavy industry, polluting industry and construction materials" center. Five concerns voiced by ESB citizens are degradation of beaches, oil spills, serious disruption of marine ecosystems, new slums without proper sanitation facilities, serious air pollution problems.

Coopers and Lybrand Associates report the wastes from all industries planned for Map Ta Phut "...can be readily managed by alternative plans" which include available and affordable process control systems. They also point out the practicality of controlling air pollutants from a limited number of major industries and the difficulties of controls from numerous homes, commercial establishments, shops, and motor vehicles.

Control of adverse impacts from industrial air pollution in the Map Ta Phut ESB development are expected to be most effective if proper process controls are built into and become an integral part of the design, construction. operation, and maintenance of the industrial enterprise. This key concept for environmental protection is advanced and well documented in ESB Planning Project, Final Report, Section on Environmental Analysis prepared by Dr. Harvey F. Ludwig. Effectiveness of the concept is supported by observations of the Esso refinery in

Siracha where air pollution control systems are an integral part of in-plant operations and air quality is in compliance with environmental controls required by the international corporation. The report also states that some of the planned industries at Map Ta Phut, particularly fertilizer and petrochemical enterprises, can cause serious air pollution unless available and affordable emission controls are included as an integral part of the process at time of construction. Local meteorology and the use of air quality simulation models adapted to ESB regional air quality requirements are reported to be useful in the choice of emission rates appropriate to the protection of the general public health and that of workers and their families located in the neighborhood of the industrial sites.

There are several industry reports which discuss some of the industrial processes likely to be used in the ESB and the Map Ta Phut site. These reports typically identify the pollutants to be generated and means for their control. The United States Steel-UEC report prepared for the Ministry of Industry is an example of one in which air pollution control techniques and process control systems are presented. These presentations sometimes do not give air pollution control technologies because a specific process has not been proposed, and an appropriate specific control technology cannot be described. Extensive information for the control of emissions from all the major categories of industry is available from government as well as industrial trade associations thus providing a choice of controls at acceptable capital and operating costs.

Implications of Overview Findings

Preparation of an air quality management plan for the Map Ta Phut-Rayong development planning area (DPA) relies upon reasonable estimates of categories and production sizes for planned basic, smaller polluting industry, and construction materials manufacture. The categories planned at Map Ta Phut include gas related industries, a petrochemical complex, including olefin separation, vinyl chloride

monomer, chemical fertilizer, soda ash, and methanol production units. No sizing or production output units are given although transportation and utility sizing needs are presented. The worker and housing unit requirements are listed and area source pollution values may be derived. Weather data for emission transport and dispersion are meager at best and appear inadequate for development of a regional air quality model. Ambient air quality and emission rate source data do not appear in any reports and the available environmental impact evaluations, while qualitatively useful, have no quantitative value for critical environmental impact analysis. Motor vehicle transportation information provides reasonable traffic estimates which may be converted to motor vehicle pollution unit.

The overview does give an excellent description of categories and location of potential air pollution receptors. This data base may permit assessment of receptor sensitivity to selected industry and urban produced air pollutants and their direct and indirect impact on people, property, agriculture, fisheries, and various ecosystems.

The data resources determined from the overview are valuable in defining the study parameters, scope of tasks, personnel requirements, and idenfifying environmental protection needs as well as Thai agencies authorized to deal with them in an integrated program with NEB.

Implicated Tasks

- A spatial emission inventory for existing air pollution sources:
  1) point sources by process categories
  2) area sources
     (a) urban housing
     (b) motor vehicles
        i) benzin
        ii) diesel
     (c) agricultural waste burning

- Develop a realistic emission inventory for planned point and area sources.
- Detailed meteorology for Map Ta Phut - Rayong DPA by month or season.
- Prepare example point emission trajectories.
- Receptor category sensitivity to selected pollutants:
  1) Urban population by age groups
  2) Occurrence and distribution of 10 WHO most prevalent diseases and angina pectoris.
  3) Economically important agricultural crops and livestock.
  4) Fisheries response to discharge of solid or liquid waste collected emissions.
- Define information and data requirements for the determination of categories and their location for present and prospective targets at risk.
- Estimate levels of control technology sufficient to eliminate risk to the public health, agriculture, ecosystems, and the environment.
- Evualuate the prospect of available control practices meeting estimated levels of control technology.
- Outline control strategy options and requirements for ambient air quality and emission monitoring and surveillance.

Appendix 1. Information Sources Used for 17 December 1982

Newspaper

_____. " Eastern Seaboard Development Plan". Bangkok Post (August 6, 1982) :5

_____. " Eastern Seaboard Development Plan (Day 2)". Bangkok Post (Ausgust 7, 1982) :7

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Sheet

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Appendix 2. Average Daily Traffic Flows in the ESB Map Ta Phut Target Area, 1981. (From Coopers and Lybrand Associates, extracted from Dept. of Highways, Traffic Volumes and Flow Maps, 1981)

Type of Vehicle	Route 3 N3 Map Ta Phut-Ban Chang	Route 36, L36 Khao Malkaeo-Rayong	Route 331, P351 Sattahip-Khao Song-Hong	Route 3153, MM Ban Khai-Hua Chuat
Car & Taxi	1420	637	150	41
Light Bus	1160	76	68	67
Heavy Bus	423	88	40	43
Light Truck	2049	588	196	368
Medium Truck	566	398	85	121
Heavy Truck	504	46	90	67
Motor Cycles	3668	322	237	1032
Total	9790	2205	866	1742
Percent (Exclusive of motor cycles)				
Car & Taxi	23.2	36.5	23.8	6.2
Heavy Vehicles	24.4	28.3	34.2	32.5
Percent Motor cycles	37.5	14.6	27.4	59.2

APPENDIX 2

DEQS Emission Inventory Questionnaire

ชื่อโรงงาน_____

ที่ตั้ง _____

_____

ประกอบกิจการ _____

จำนวนหม้อน้ำ_____ เครื่อง ๑. เป็นแบบ _____

๒. เป็นแบบ _____

๓. เป็นแบบ _____

อายุของหม้อน้ำ ๑._____ ปี สร้างโดยบริษัท ◯ ต่างประเทศ ◯ ในประเทศ

๒._____ ปี สร้างโดยบริษัท ◯ ต่างประเทศ ◯ ในประเทศ

๓._____ ปี สร้างโดยบริษัท ◯ ต่างประเทศ ◯ ในประเทศ

ความดันใช้งานสูงสุด (Max Working Press) ๑._____

๒._____

๓._____

อัตราการผลิตไอ ๑._____ แรงม้าหม้อน้ำ _____

๒._____ แรงม้าหม้อน้ำ _____

๓._____ แรงม้าหม้อน้ำ _____

ชนิดของเชื้อเพลิงที่ใช้ ๑._____ ปริมาณการใช้ / หน่วยเวลา _____

๒._____ ปริมาณการใช้ / หน่วยเวลา _____

๓._____ ปริมาณการใช้ / หน่วยเวลา _____

ขนาดของปล่องไฟ ๑._____

๒._____

๓._____

ลมช่วยในการเผาไหม้ ๑. ◯ ลมธรรมชาติ ◯ พัดลม ขนาด_____

๒. ◯ ลมธรรมชาติ ◯ พัดลม ขนาด_____

๓. ◯ ลมธรรมชาติ ◯ พัดลม ขนาด_____

APPENDIX 3

RTG Air Quality Standards

(สำเนา)

ประกาศสำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติ

ฉบับที่ ๒ (พ.ศ.๒๕๒๔)

เรื่อง กำหนดมาตรฐานคุณภาพอากาศในบรรยากาศ

โดยที่เป็นการสมควรกำหนดมาตรฐานคุณภาพอากาศในบรรยากาศโดยทั่วไปขึ้นไว้เพื่อให้หน่วยงานของรัฐซึ่งเกี่ยวข้องกับการควบคุมคุณภาพอากาศใช้เป็นมาตรการสำหรับตรวจสอบ และควบคุมดูแลให้สภาพแวดล้อมของบรรยากาศเหมาะสมกับการดำรงชีพของมนุษย์และสิ่งมีชีวิตอื่น ๆ เพื่อถ้าหากคุณภาพของอากาศในบรรยากาศโดยทั่วไปได้แปรเปลี่ยนไปในทางที่อาจจะก่อให้เกิดอันตรายแก่มนุษย์และสิ่งมีชีวิตอื่น ๆ แล้ว หน่วยงานของรัฐที่เกี่ยวข้องกับการควบคุมคุณภาพอากาศอาจจะต้องทำการแก้ไขปรับปรุงมาตรฐานคุณภาพอากาศที่ยินยอมให้ระบายออกจากแหล่งกำเนิดให้เหมาะสมกับสภาพแวดล้อมโดยส่วนรวมของบรรยากาศ เพื่อประโยชน์ในการดำรงชีวิตของมนุษย์และสิ่งมีชีวิตอื่นสืบไป

ฉะนั้น สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติ จึงเห็นควรออกประกาศกำหนดมาตรฐานคุณภาพอากาศทั่วไปในบรรยากาศไว้เพื่อให้หน่วยงานของรัฐที่เกี่ยวข้องกับการควบคุมคุณภาพอากาศนำไปใช้เป็นแนวทางประกอบการแก้ไขปรับปรุงมาตรฐานคุณภาพอากาศที่ยินยอมให้ระบายออกจากแหล่งกำเนิดดังต่อไปนี้

ข้อ ๑ มาตรฐานของก๊าซดังต่อไปนี้ ในบรรยากาศโดยทั่วไปในช่วงเวลาหนึ่งเวลาใดให้เป็นไปตามค่าเฉลี่ยที่กำหนดไว้ คือ

(๑) ค่าเฉลี่ยของก๊าซคาร์บอนมอนอกไซด์ในเวลาหนึ่งชั่วโมงจะต้องไม่เกินกว่า ๔๐ มิลลิกรัมต่อลูกบาศก์เมตร และจะต้องไม่เกินกว่า ๒๐ มิลลิกรัมต่อลูกบาศก์เมตรในเวลาแปดชั่วโมง

(๒) ค่าเฉลี่ยของก๊าซไนโตรเจนไดออกไซด์ในเวลาหนึ่งชั่วโมงจะต้องไม่เกินกว่า ๐.๓๒ มิลลิกรัมต่อลูกบาศก์เมตร

(๓) ค่าเฉลี่ยของก๊าซซัลเฟอร์ไดออกไซด์ในเวลาหนึ่งชั่วโมงจะต้องไม่เกินกว่า ๐.๓๐ มิลลิกรัมต่อลูกบาศก์เมตร และค่ามัชฌิมเรขาคณิต (Geometric Mean) ของก๊าซดังกล่าวในเวลาหนึ่งปีจะต้องไม่เกินกว่า ๐.๑๐ มิลลิกรัมต่อลูกบาศก์เมตร

(๔) ค่าเฉลี่ยของก๊าซไอเสียในเวลาหนึ่งชั่วโมงจะต้องไม่เกินกว่า ๐.๒๐ มิลลิกรัมต่อลูกบาศก์เมตร

ข้อ ๒ มาตรฐานของสารต่อไปนี้ในบรรยากาศโดยทั่วไปในช่วงเวลาหนึ่งเวลาใดให้เป็นไปตามค่าเฉลี่ยที่กำหนดไว้ คือ

(๑) ค่าเฉลี่ยของตะกั่วในเวลายี่สิบสี่ชั่วโมงจะต้องไม่เกินกว่า ๐.๐๑ มิลลิกรัมต่อลูกบาศก์เมตร

(๒) ค่าเฉลี่ยของฝุ่นละอองในเวลายี่สิบสี่ชั่วโมงจะต้องไม่เกินกว่า ๐.๓๓ มิลลิกรัมต่อลูกบาศก์เมตร และค่ามัวเฉลี่ยบรรยากาศของสารดังกล่าวในเวลาหนึ่งปีจะต้องไม่เกินกว่า ๐.๑๐ มิลลิกรัมต่อลูกบาศก์เมตร

ประกาศ ณ วันที่ ๖ พฤศจิกายน ๒๕๒๔

เกษม สุนิตวงศ์ฯ

เลขาธิการคณะกรรมการสิ่งแวดล้อมแห่งชาติ

<u>หมายเหตุ</u> (ประกาศในราชกิจจานุเบกษา เล่มที่ ๙๘ ตอนที่ ๑๙๗ วันที่ ๑ ธันวาคม ๒๕๒๔)

APPENDIX 4

RTG Measurement Methods for Air Quality Standards

(สำเนา)

ประกาศกระทรวงวิทยาศาสตร์ เทคโนโลยีและการพลังงาน

ฉบับที่ ๒ (พ.ศ.๒๕๒๔)

เรื่อง กำหนดวิธีการวัดคุณภาพอากาศในบรรยากาศ

อาศัยอำนาจตามความในมาตรา ๑๗ (๓) และมาตรา ๒๘ แห่งพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ พ.ศ.๒๕๑๘ ซึ่งแก้ไขเพิ่มเติมโดยพระราชบัญญัติส่งเสริมและรักษาคุณภาพสิ่งแวดล้อมแห่งชาติ (ฉบับที่ ๒) พ.ศ.๒๕๒๑ และมาตรา ๑๓ แห่งพระราชบัญญัติโอนกิจการบริหารบางส่วนของสำนักนายกรัฐมนตรี กระทรวงเกษตรและสหกรณ์ กระทรวงพาณิชย์ กระทรวงศึกษาธิการและกระทรวงอุตสาหกรรม พ.ศ.๒๕๒๒ รัฐมนตรีว่าการกระทรวงวิทยาศาสตร์ เทคโนโลยีและการพลังงาน โดยคำแนะนำของคณะกรรมการสิ่งแวดล้อมแห่งชาติ ออกประกาศกำหนดวิธีการวัดคุณภาพอากาศในบรรยากาศไว้ ดังต่อไปนี้

ข้อ ๑ ในประกาศนี้

"เครื่องวัดระบบนันดิสเปอร์ชัฟ อินฟราเรด ดีเทคชั่น (non-dispersive infrared detection)" หมายความว่า เครื่องมือวัดค่าก๊าซคาร์บอนมอนอกไซด์ โดยใช้รังสีอินฟราเรด

"เครื่องวัดระบบเคมีลูมิเนสเซน (Chemiluminescence)" หมายความว่า

(๑) เครื่องมือวัดค่าก๊าซไนโตรเจนไดออกไซด์โดยใช้ก๊าซโอโซนทำปฏิกิริยากับก๊าซไนตริกออกไซด์ ซึ่งถูกเปลี่ยนมาจากก๊าซไนโตรเจนไดออกไซด์ แล้ววัดความเข้มของแสงซึ่งเกิดจากปฏิกิริยานั้น ณ ที่ความยาวคลื่นที่สูงกว่า ๖๐๐ นาโนมิเตอร์ (Nanometer) หรือ

(๒) เครื่องมือวัดค่าก๊าซโอโซนโดยใช้ก๊าซเอธีลีนทำปฏิกิริยากับก๊าซโอโซน แล้ววัดความเข้มของแสงซึ่งเกิดจากปฏิกิริยานั้น ณ ที่ความยาวคลื่นระหว่าง ๓๕๐ ถึง ๕๕๐ นาโนมิเตอร์

"ระบบพาราโรซานิลีน (Pararosaniline)" หมายความว่า การวัดค่าก๊าซซัลเฟอร์ไดออกไซด์ โดยการดูดอากาศผ่านสารละลายโปตัสเซียม เตตราคลอโรเมอคิวเรต (Potassium Tetrachloromercurate) เกิดเป็นสารไดคลอโรซัลฟิโต เมอคิวเรต คอมเพลกซ์ (Dichloro sulfito mercurate Complex) ทำปฏิกิริยากับสารพาราโรซานิลีนและฟอร์มัลดีไฮด์ (Pararosaniline and Formaldehyde) เกิดเป็นสีของพาราโรซานิลีน เมธิล ซัลฟอนิก แอซิด (Pararosaniline Methyl Sulfonic Acid) ซึ่งจะถูกวัดความสามารถในการดูดซึมแสง ณ ที่ช่วงคลื่น ๕๔๙ นาโนมิเตอร์

"เครื่องวัดระบบอะตอมมิก แอบซอบชั่น สเปกโตรมิเตอร์ (Atomic absorption spectrometer)" หมายความว่า เครื่องมือวัดปริมาณของตะกั่วโดยใช้เปลวไฟอะเซทิลีน (Acetylene Flame) ที่ความยาวคลื่น ๒๘๓.๓ หรือ ๒๑๗ นาโนมิเตอร์

"ระบบกราวิเมตริก (gravimetric) หมายความว่า การวัดค่าฝุ่นละออง โดยการดูดอากาศผ่านแผ่นกรอง ซึ่งมีประสิทธิภาพในการกรองฝุ่นละอองขนาด ๐.๓ ไมครอน (Micron) ได้ร้อยละเก้าสิบเก้า แล้วหาน้ำหนักฝุ่นละอองจากแผ่นกรองนั้น

ข้อ ๒ การวัดค่าเฉลี่ยของก๊าซคาร์บอนมอนอกไซด์ในเวลาหนึ่งชั่วโมง หรือในเวลาแปดชั่วโมง ให้ใช้เครื่องวัดระบบนันดิสเปอร์ชิฟ อินฟราเรด ดีเทกชั่น หรือระบบอื่นที่สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติให้ความเห็นชอบ

ข้อ ๓ การวัดหาค่าเฉลี่ยของก๊าซไนโตรเจนไดออกไซด์ในเวลาหนึ่งชั่วโมง ให้ใช้เครื่องวัดระบบเคมีลูมิเนสเซน หรือระบบอื่นที่สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติให้ความเห็นชอบ

ข้อ ๔ การวัดหาค่าเฉลี่ยของก๊าซซัลเฟอร์ไดออกไซด์ในเวลายี่สิบสี่ชั่วโมงหรือในเวลาหนึ่งปี ให้ใช้วิธีการวัดตามระบบพาราโรซานิลีน หรือระบบอื่นที่สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติให้ความเห็นชอบ

ข้อ ๕ การวัดหาค่าเฉลี่ยของก๊าซโอโซนในเวลาหนึ่งชั่วโมง ให้ใช้เครื่องวัดระบบเคมีลูมิเนสเซน หรือระบบอื่นที่สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติให้ความเห็นชอบ

ข้อ ๖ การวัดหาค่าเฉลี่ยของตะกั่วในเวลายี่สิบสี่ชั่วโมงให้กระทำโดยการเก็บอากาศผ่านแผ่นกรองในเครื่องเก็บตัวอย่างอากาศชนิดโวลุ่ม (high volume air sampler) สกัดตะกั่วออกจากแผ่นกรองโดยใช้กรดไนตริกและกรดเกลือ แล้วนำไปวัดค่าของตะกั่วโดยใช้เครื่องวัดระบบอะตอมมิก แอบซอบชั่น สเปกโตรมิเตอร์ หรือระบบอื่นที่สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติให้ความเห็นชอบ

ข้อ ๗ การวัดหาค่าเฉลี่ยของฝุ่นละอองในเวลายี่สิบสี่ชั่วโมงหรือในเวลาหนึ่งปี ให้ใช้วิธีการวัดตามระบบกราวิเมตริก หรือระบบอื่นที่สำนักงานคณะกรรมการสิ่งแวดล้อมแห่งชาติให้ความเห็นชอบ

ข้อ ๘ การวัดหาค่าเฉลี่ยของก๊าซหรือสารอย่างหนึ่งอย่างใดตาม ข้อ ๕ ถึงข้อ ๖ ให้ทำในบรรยากาศทั่ว ๆ ไป และต้องสูงจากพื้นดินอย่างน้อย ๓ เมตร แต่ไม่เกินกว่า ๖ เมตร

การวัดหาค่าเฉลี่ยของฝุ่นละอองตามข้อ ๗ ให้ทำในบรรยากาศทั่ว ๆ ไป และต้องสูงจากพื้นดินอย่างน้อย ๑.๕๐ เมตร แต่ไม่เกินกว่า ๖ เมตร

ข้อ ๙ ประกาศนี้ให้ใช้บังคับตั้งแต่วันที่ให้ประกาศในราชกิจจานุเบกษา เป็นต้นไป

ประกาศ ณ วันที่ ๒๗ ตุลาคม ๒๕๒๔

นาวาอากาศโท หินกร ศันสุกระวี

รัฐมนตรีว่าการกระทรวงวิทยาศาสตร์

เทคโนโลยีและการพลังงาน

<u>หมายเหตุ</u> (ประกาศในราชกิจจานุเบกษา เล่มที่ ๙๘ ตอนที่ ๑๙๗ วันที่ ๑ ธันวาคม ๒๕๒๔)

APPENDIX 5

Comments on Adequacy of Data for Air Quality Assessment

To : Sirithan Boriboon

Subject : Comments on Esso Sriracha Refinery letter and Documentation of 14 December 1982 and Environmental Impact Statement.

The following comments are made in response to your interest in the SO_2 data supplied you by Esso Standard Thailand Ltd. as given in their letter, attachments, and Environmental Impact Statement. The ppm SO_2 is given for 6 stations representing 8 locations, due to the abandonment of the original location for stations # 4 and # 6 and their relocation in Ban Laem Chabang (#4) and about 2.5 km east of the refinery (#6) where they are stated to be located at maximum SO_2 ground level concentrations.

SO_2 is determined by lead peroxide candles (PbO_2) and reported as ppm SO_2 on a monthly basis. No statistical analyses are performed and the data are not summarized or reported in terms of published ONEB ambient air quality standards and measurement methods. ONEB SO_2 ambient air quality standards are expressed for 2 averaging times, 24 hours, and 1 year. The measurement method is by pararosaniline. The equivalency of PbO_2 to the pararosaniline method for SO_2 determination has not been stated, consequently no statement of compliance with SO_2 standards can be made.

It appears that Esso has provided you air quality information in good faith and may not be aware of accepted air quality measurement and reporting procedures.

For purposes of discussion only assume PbO_2 is equivalent to the standard reference method (pararosaniline). In fact it is not equivalent Esso data is available only for 10 months at 4 stations (1,2,3 and 5), 7 months at 1 (4a), 6 months at 1 (6a), and 3 months at 2 (4b and 6b). (Incidentally, under <u>no</u> conditions should a numbering system

transfer established numbered sites to another location). It is possible to estimate a yearly average for stations 1,2,3 and 5, but not for 4 and 6. The method used to convert the original gravimetric data to ppm is not given. Assuming it was correctly done, the values in mg/m^3 for the 10 month report periods are 0.010; 0.019; 0.016; and 0.008. All of these values are a factor of 10^{-1} below the not to be exceeded 0.10 mg/m^3 1 year average value. The values suggest they may represent a single air quality population, except possibly the utilities aggregate. An analysis of 1981 and 1982 data may reveal location differences. They certainly are not obvious by inspection. The absence of information on the variability of PbO_2 analyses for unexposed candles as checks against laboratory and exposure procedures makes evaluation of even the PbO_2 data difficult and the results suspect.

In any event, while the 10 month averages may be instructive as estimates of annual values, they cannot be used to measure compliance with the 24 hour standard. Compliance with 1 year averages does not in itself assure compliance with the 24 hour average especially in the case of PbO_2 papers which themselves "average out" fluctuations in SO_2. Estimates of compliance with the ONEB 24 hour ambient air quality can only be made by analysis of 24 hour measurements using accepted procedures.

There is no weather or modelling information from which an independent judgement can be made relative to the statement that current stations # 4 and # 6 are located in the area of maximum concentration at ground level.

The "4.2 Ambient Air Quality Control and Data" section of the EIS was reviewed and there are several points that you may wish to consider in your evaluation of their submittal for modification of the present refinery.

1. Item 4.2 reports SO_2 to be the only pollutant emitted. No consideration is given to the emission of nitrogen oxides (NO_x) and no account offered of the prospect of their combustion sources complying with ONEB ambient air quality standard for nitrogen dioxide (NO_2). For instance

are they to use low NO_x furnaces in the modified plants? The statement is made that SO_2 levels will be controlled by monitoring with PbO_2 candles but no explanation of the effectiveness of this control process is made.

2. There isnno account in 4.2 (b) of the combustion products resulting from the flare system nor of their ultimate dispersion and deposit.

3. The incinerator in 4.2 (c) is used to burn fumes which may contain nitrogenous and sulfurous compounds and yet no description is made of the waste gas stream and no emission estimates are given.

4. The data in Table 1 mentioned in 4.2 (d) report existing levels of SO_2 to be 0.20 mg/m^3 at 24 hour average. Is there data to support this figure? The same 4.2 (d) says"...We expect minor increases in SO_2 ppm in the ambient air..."but that is not uniformally represented in Table 1. The values used are not in conformity with data in the letter. The qualitative statement is unsatisfactory and a quantitative accounting should be made. A "Standard Limit" is given in Table 1 for NO_x. There is no ONEB ambient air quality standard for NO_x. No information is given for "Existing" NO_x levels, yet the Industrial Hygiene Survey reports 0.2 ppm NO_2. Is the NO_2 vented, if so what is the fate of contaminants in the exhaust strean?

The air quality portion of this EIS is not substantive, poorly presented, and generally unsatisfactory. If this EIS is at all representative of the quality of reports you receive on air quality it becomes important for the submitting organization to adopt an acceptable protocol, have a set of guidelines on terms of reference, follow established precedent in pollutants to be considered, units and measurement methods to be employed, and some ordered reporting system which may include receptors at risk and areas of expected impact.

It may be possible to offer you assistance in this general area with the prospect of your receiving substantive reports covering essential subject matter.

John T. Middleton

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APPENDIX 6

Motor Vehicle Air Pollution - Bangkok

John Middleton/ONEB/18 March 1983

TO : Deputy Secretary General

Subject : Motor Vehicle Air Pollution; Control Options.

Introduction

Motor vehicles are important sources of air pollution in Metropolitan Bangkok. Motor vehicle emissions are responsible for elevated level of carbon monoxide (CO) and particulate lead (Pb) in roadways, streets, traffic intersections, and parking areas. In addition to CO and Pb, motor vehicles may be important emission sources for hydrocarbons (HC) and nitrogen oxides (NO_x) which react in the atmosphere to produce ozone (O_3) and nitrogen dioxide (NO_2). Motor vehicles also emit some suspended particulate matter (SPM) in addition to Pb and some sulfur dioxide (SO_2) from the sulfur in benzine and diesel fuel.

Motor Vehicle Pollution Sources

CO, Pb, HC, and NO_x are emitted from benzine engine exhaust. HC is also emitted from benzine engine crankcase, carburettor, and the fuel supply system. SPM and SO_2 are emitted from fuel combustion in benzine engines. With the exception of Pb and SO_2, the same pollutants from the same sources are emitted by LPG engines. Diesel engines usually emit less pollution per liter of fuel than benzine engines except for SPM and SO_2. The total amount of emissions from benzine, diesel, or LPG engines, however, is not only a function of the number of motor vehicles, but of their size, age, and operating condition, driving cycle, and distance travelled.

Air Quality Control Strategy

The ONEB has adopted ambient air quality standards for clean air protective of the public health and environment. The control strategy

requires that emission sources be controlled to the extent necessary to comply with the air quality standards established for CO, Pb, NO_2 O_3, SO_2, and SPM. The amount of control needed depends on the current measured air quality and the predicted additional emission sources to be established within specified years, such as those published by the National Economic and Social Development Plans. Priorities for control actions are based on current air quality and their health effects and special knowledge on expected air quality trends. The levels of CO and Pb in Bangkok are very much like those of large cities in Asia, Europe and America. Control of emissions from new and in-use benzine and diesel vehicles, restrictions on lead antiknock compound in benzine, used in some other countries with serious motor vehicle problems provides an accepted and practical way of restoring clean air in Bangkok.

Motor Vehicle Emissions

The estimation of current and future Bangkok motor vehicle emissions requires a considerable amount of additional information. Statistics are needed on the current and projected number of buses, cars, motorcycles, taxis, and trucks, as well as their size and kind of fuel used. Information on the average driving cycle modifies the emissions by considering age of the motor vehicles, speed and distance travelled, percentage of cold or hot engine operation, and some other environmental and operating factors. CO, HC, and NO_x estimations can be made from such a data base and using emission factors and correction constants for speed, hot and cold operations, and corrections for vehicle age as a function of km driven.

A search for motor vehicle statistics useful for estimating motor vehicle emissions yielded mixed results on numbers of vehicles, some data on age and fuel types, and little or nothing on vehicle operations including driving cycles and distances travelled by vehicle age. Unlike the ONEB data for idle CO and HC measured from random cars and motorcycles which shows no difference in CO emissions by age, idle rpm, or engine capacity, emissions of CO, HC, and NO_x are known to vary

during an average driving cycle which consists of many modes including idle and transient states and to be significantly influenced by vehicle, age, distance travelled, speed and percentage hot and cold operation.

The total number of vehicles in Thailand in 1980 was reported as 1,520,566 of which about 37 % were in Bangkok. Another government estimated showed Bangkok in 1980 to have 628,691 vehicles, or about 41 % of the country total. The annual increase in numbers of motor vehicles in Bangkok from 1980 to 1981 may be either 14 % or 22 % The 5 year increase from 1975 to 1980 may be either 34 % or 42 % depending upon the data used. The number of motor vehicles in Bangkok in 1979 and 1980 from one government source are shown below:

Bangkok

	1979	1980
Bus	12,884	301
Car	270,167	279,092
Motorcycle	136,266	172,008
Taxi	14,681	14,736
Truck	85,245	56,653
Other	27,006	28,745
Total	546,249	571,535

A comparison of these Bangkok motor vehicle statistics for 1979 and 1980 makes the 1980 data suspect because the bus figures are about 40 times lower than 1979, and the truck figures are low by about 1.5 times.

A 1980 WHO/UNEP report presents 1979 motor vehicle statistics for all provinces in Thailand and gives vehicle classes, age structure, and fuel use. A summary of the RTG and WHO/UNEP 1979 data follows:

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	Bangkok (RTG)		Thailand (WHO/UNEP)	
	Number	Percent	Number	Percent
Bus	12,884	2.4	35,000	2.4
Car	270,167	49.5	373,000	25.0
Motorcycle	136,266	24.9	702,000	48.0
Taxi	14,681	2.7	-*	-
Truck	85,245	15.6	352,000**	24.0
Other	27,006	4.9	8,000	0.5
Total	546,249	100	1,470,000	100

* No data given

** Includes trailers

The total number of Thailand 1979 motor vehicles is about 17 % smaller than the total given for RTG all provinces in the statistics used for total number of 1979 Bangkok motor vehicles. The WHO/UNEP data report 74 % of the vehicles use benzine and 26 % diesel fuel. There are no data for LPG. Motor vehicles are classified as 72 % private and 28 % commercial, the latter divided into vehicles weighing less than 3.5 tonnes (20 %) and those 3.5 tonnes or more (8 %). The Thailand motor vehicles are separated into 3 age groups : 27 % are reported to be less than 5 years old, 29 % are between 5 and 10 years, and 44 % are 10 years and older. These vehicle age date suggest the median age to be 9 years.

An estimate of 1979 Bangkok motor vehicle emissions was made using RTG statistics for 10 motor vehicle categories. The estimates use US EPA emission factors for pre-controlled internal combustion engine sources (i.e., without air pollution control systems). The emission estimates do not take into account the variation in emissions due to mixed ages of vehicles in the Bangkok motor vehicle population. A number of other errors in the estimates may be attributed to average speed of vehicles, the number of hot and cold engine operations, air temperature, and fuel quality. These several features influence the quantity of emissions. For example, the emission factors used consider the average

speed to be 31.6 km/hr. However, if the average speed is decreased from 31.6 to 8 km/hr the CO emissions will increase by a factor of 2.7. HC, for example, would increase by a factor of 2.5, and NO_x by 1.05 A reduction in average vehicle speed from 31.6 to 16 km/hr increases CO emissions by a factor of 1.57, HC by 1.45, and NO_x by 1.03 There are no Bangkok statistics of km travelled per day for any of the 10 vehicle categories considered. The km values used are valued staff estimates. The vehicle age mix in Bangkok is different than that used for US EPA emission factor estimates. For instance, US vehicle populations under 5 years represent about 39 % of the total, while in Bangkok the population under 5 years is estimated to be 27 %. In the US about 49 % are 5 to 10 years old while in Bangkok 29 % are 5 to 10 years old. In the US 12 % about are over 10 years while in Bangkok 44 % are over 10 years old. Since vehicle emissions are a function of age and distance travelled, the age of the population and the distance travelled by age group influences total vehicular emissions.

Available motor vehicle statistics are inadequate for the preparation of a detailed emission inventory of present and projected populations. They are adequate, however, for estimating emissions for quantitative comparison among the 10 vehicle categories and evaluation of motor vehicle emission control options.

Estimated Motor Vehicle Emissions - Bangkok 1979

Bus - heavy duty vehicle (HDV), diesel

n = 12,884 km = 45

Pollutant	Emission Factor	Tonnes/km	Tonnes/day
CO	13.2	0.17	24
HC	2.5	0.03	4
NO_x	13.4	0.17	24
SO_2	1.7	0.02	3
SPM	0.81	0.01	1

Car - light duty vehicle (LDV), benzine

n = 243,151 km = 50

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Pollutant		Emission Factor	Tonnes/km	Tonnes/day
CO		55.9	13.6	680
HC	exhaust	5.35	1.3	65
	crankcase	2.50	0.6	30
	evaporation	1.57	0.4	19
		9.42	2.3	114
NO_x		2.13	0.5	26

Car - LDV, LPG

n = 27,016 km = 50

Pollutant	Emission Factor	Tonnes/km	Tonnes/day
CO	6.8	0.18	9
HC	1.1	0.03	1
NO_x	2.0	0.05	3

Motorcycle - 2 - stroke

n = 95,386 km = 100

Pollutant		Emission Factor	Tonnes/km	Tonnes/day
CO		17	1.6	162
HC	exhaust	9.9	0.9	94
	crankcase	0	0	0
	evaporation	0.36	0.03	3
		10.26	0.93	97
NO_x		2.13	0.5	26

Motorcycle - 4 - stroke

n ==40,880 km = 100

Pollutant		Emission Factor	Tonnes/km	Tonnes/day
CO		20	0.8	82
HC	exhaust	1.8	0.07	7
	crankcase	0.37	0.01	1
	evaporation	0.22	0.01	1
		2.39	0.10	9
NO_x		0.15	0.01	1

Taxi - benzine

n = 734 km = 500

Pollutant	Emission Factor	Tonnes/km	Tonnes/day
CO	55.9	0.04	20

(6)

HC	9.42	0.01	3
NO_x	2.14	0.00	1

Taxi - LPG

n = 13,947 km = 500

Pollutant	Emission Factor	Tonnes/km	Tonnes/day
CO	6.8	0.1	47
HC	1.1	0.01	8
NO_x	2.0	0.03	14

Trucks - LDV, benzine, not more than 3.5 tonnes

n = 27,534 km = 100

Pollutant		Emission Factor	Tonnes/km	Tonnes/day
CO		77.6	2.14	214
HC	exhaust	10.6		
	crankcase	2.9		
	evaporation	2.2		
		15.7	0.43	43
NO_x		2.6	0.07	7

Trucks - LDV, diesel, not more than 3.5 tonnes

n = 44,924 km = 100

Pollutant	Emission Factor	Tonnes/km	Tonnes/day
CO	1.1	0.05	5
HC	0.29	0.01	1
NO_x	0.99	0.04	4
SO_2	0.34	0.01	1
SPM	0.45	0.02	2

Trucks - HDV, diesel, 3.5 tonnes and more

n = 12,787 km = 45

Pollutant	Emission Factor	Tonnes/km	Tonnes/day
CO	17.8	0.23	10
HC	2.9	0.04	2
NO_x	13.0	0.17	8

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Pollutant	Emission Factor	Tonnes/km	Tonnes/day
SO_2	1.7	0.02	1
SPM	0.81	0.01	0

Total emissions in tonnes/day for 10 motor vehicle categories

	CO	HC	NO_x	SO_2	SPM
Bus - diesel	24	4	24	3	1
Car - benzine	680	114	26		
Car - LPG	9	1	3		
Motorcycle - 2 stroke	162	98	1		
Motorcycle - 4 stroke	82	10	1		
Taxi - benzine	20	3	1		
Taxi - LPG	47	8	14		
Truck - LDV benzine	214	43	7		
Truck - LDV diesel	5	1	4	1	2
Truck - HDV diesel	10	2	8	1	0
Total	1253	284	89	5	3

Motor Vehicle Emission Control Strategy

Control of motor vehicle-created air pollution usually requires consideration of controls for new and in-use vehicles and regulation of fuel quality. ONEB has established a benzine motor vehicle emission standard for CO at engine idle of no more than 6.0 % determined from the average of 2 successive readings by NDIR. A black smoke standard for diesel exhaust has been set at 40 Bosch units and measured in a prescribed way.

Random samples of Bangkok benzine cars have shown about one-half of them to exceed 6 CO %. ONEB has also shown that idle CO % from those vehicles is apparently independent of age, engine capacity, and variations in idle rpm. Experience suggests that idle CO % from benzine vehicles usually increases with vehicle age. It is possible that uniformity in CO % measurements with age is a function of engine maintonance Future CO % emission measurements should attempt to clarify age, engine condition, km, etc., effects. Differences in CO % due to age, engine, and driving cycle variables may be easily detected by measuring emissions when the vehicle is exercised on a chassis dynamometer. These same differences may not be detected by the simplified idle, measurement system.

About 70 % of Thai vehicles are 5 years or older compared with about 60 % in the USA. In Thailand about 30 % of all vehicles are 5 to 10 years old and about 40 % are over 10 years. In the USA about 50 % are 5 to 10 years and about 10 % are over 10 years old. This means that about 30 % of Thai vehicle are less than 5 years while about 40 % of USA vehicles are under 5 years old. While the age of USA vehicles used here is compromised by associating age with annual distance travelled (1 year old cars travel about as far as 6 year old ones, but 4 year old cars travel twice the distance as 10 year old ones). The data suggest that CO control from new vehicles for 5 successive years in Thailand would have a smaller impact on CO air quality than the same level of control in the USA. In turn, this suggests CO control of in-use cars in Thailand may be the best first control step if followed with CO controls on new vehicles. The Thai CO control program should be scheduled for immediate short-term improvement in air quality supported by reduced emissions from controls on new vehicles for the long-term as replacement vehicles for the aging population and compensation for projected increases in the motor vehicle population. An equally important reason for starting CO controls on new vehicles is the introduction of engine and carburettor systems which provide better controlled air, fuel, and ignition systems which remain within manufacturers specifications longer and are less likely to be thrown out of adjustment by tampering and unskilled mechanics. A further reason for introducing controls on new cars is the establishment by the manufacturer of a specified CO design for later compliance by in-use vehicles.

The introduction of CO controls on new motor vehicles provides an opportunity to also control HC and NO_x emissions and regulate benzine road octane number and reduce Pb.

CO Control for In-Use Vehicles

The CO motor vehicle emission estimates for Bangkok, using 1979 data and staff estimates for vehicle uses are summarized below :

Category	Tonnes/day*	Percent
Bus - diesel	24	2
Car - benzine	680	54
Car - LPG	9	1
Motorcycle - 2 stroke	162	13
Motorcycle - 4 stroke	82	6
Taxi - benzine	20	2
Taxi - LPG	47	4
Truck- LDV benzine	214	17
Truck- LDV diesel	5	0
Truck- HDV diesel	10	1
Total	1253	

* Rounded off to the nearest whole number.

The CO vehicle emission sources by fuel type show :

Fuel	CO tonnes/day	Percent
Benzine	1158	92
Diesel	39	3
LPG	56	5
Total	1253	

These estimates suggest the greatest reduction in CO emissions will come from controls for benzine-fuelled cars, motor cycles and light duty trucks. Actual reductions in CO exhaust emissions, however, depend not only on identifying the percent of vehicles which exceed ONEB's 6 CO % emission standard, but on the conditions established for achieving expected reductions. For example, if the annual measured failure rate of

all cars is 50 %, the expected annual % vehicle exhaust emission reduction would be about 10 %. If the failure rate were 30 %, the expected emission reduction would be 8 %, and if failure were only 10 %, the emission reduction expected would be only 3 %. More frequent inspection and maintenance is expected to provide langer average emission reductions.

Conditions established to achieve expected reductions strongly influence the expected reduction. In addition to regular periodic inspection and CO exhaust emission measurement by authorized methods, arrangements must be made to insure that failed vehicles receive the maintenance necessary to achieve compliance with the inspection standard.

A system of sanctions, or compliance requirements, must be established to verify failed vehicles received the necessary repairs. A sanction program might include certification with vehicle retest, certification that the repair facilities are performing properly, have the necessary equipment, and use trained mechanics. There should also be provisions to make certain that repaired vehicles are not intentionally readjusted or modified subsequent to compliance with the CO emission standard such that they no longer comply with that standard. Intentional readjustment and tampering may require special enforcement conditions, such as spot checks of idle adjustment or official inspection seal.

CO control for in-use vehicles can be achieved by inspection and identification of vehicles violating the idle emission standard and an engine maintenance and repair service capable of returning the engine to its proper operating condition, supposedly with CO emission well below 6 CO %."Motor vehicle emission control can only be effective if there are means available for keeping motor vehicles and their engines in optimum operating condition (A. Cichowski, ILO, WHO/UNEP)." That same report gives a brief 1979 summary of maintenance and repair of vehicles in Thailand. In part, it states:

<u>Maintenance and Repair of Vehicles</u>

<u>Personnel</u>

- well established garages, workshops and service stations usually have qualified mechanics
- government and private vocational schools offer training in vehicle maintenance and repair

Equipment

- there are about 1800 service stations and 2000 independent garages but few of them are well equiped
- private and public fleet transport operators have their own workshops equipped for routine maintenance and repair

Spare Parts

- easily available in town centres throughout country, except in the case of unpopular vehicle models
- a large number of used engines and used parts are imported as vehicle owners prefer to have their old engines replaced because the cost is low

Inspection of Vehicles in Use

All vehicles in service are inspected yearly for safety and road worthiness, including exhaust emissions and noise.

- the Police Department is responsible for inspection of motorcycles, taxis and private cars (less than seven persons)
- the Land Transport Department is responsible for inspection of private cars (more than seven persons), busses, coaches and all other commercial vehicles
- inspection stations are situated in Bangkok and all provinces throughout country; there are approved inspection stations set up by the private sector to reduce the work load of the government

Fuel type and engine operating conditions are known to influence CO emissions. US EPA CO emission factors for LDV using benzine is about 56 g/km and using LPG is about 7 g/km. Although emissions from LPG vehicles may be expected to be 8 times lower than

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those from benzine, engine operating conditions may offset the difference. Unpublished data from Korea show the effect of operating conditions by measuring CO % at idle for a set of benzine and LPG LDV before and after engine tune up.

CO % Range	Percent Vehicles in CO % range			
	Benzine		LPG	
	Before	After	Before	After
0 - 3	26.7	100	28.6	100
3 - 4.5	26.7	0	21.4	0
4.5 - 10	46.0	0	50.0	0

Before tune up (repair) the benzine vehicle idle exhaust CO % ranged from 0.6 to over 10 with a mean of 4.5. After tune up the range was 1.5 to 2.5 with a mean of 1.9, The LPG vehicle idle exhaust CO % ranged from 0.1 to 7.2 with a mean of 3.8. After tune up the range was 1.4 to 2.1 with a mean of 1.6.

Vehicle emissions were also measured using a constant volume sampler (CVS) and operating the vehicles on a chassis dynamometer simulating a 10 mode (Japanese) driving cycle. Under those conditions the mean benzine derived CO g/km before tune up was 26.4 and afterwards was 15.7. The LPG derived CO g/km was 8.0 before tune up and 3.6 afterwards. There was a 40 % reduction in benzine CO emissions, and a 55 % reduction in LPG CO emissions due to tune up. Reductions in HC and NO_x also resulted from tune up. The km/l fuel consumption improved by 2.1 % in benzine cars; no measurements were made of LPG km/l changes. It should be noted in these tests that NO_x from LPG exhaust, both before and after tune up, was about 1.5 times higher than from benzine exhaust.

The effectiveness of a tune up in reducing CO % depends on mechanic skills and his use of specified replacement items. The tune up discussed earlier consisted of 10 inspection and replacement or repair items. In each case the adjustments and repairs were made according to vehicle manufacturer specifications. The 10 items are:

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Ignition timing and dwell
Distributor components
Spark plugs
Spark plug wires
PVC system
Air cleaner
Idle speed
Idle air-fuel mixture
Choke
Vacuum tubing

Mechanic skills significantly affect the emission reductions achieved in tune up and engine repair. With a 30 % stringency work requirement a skilled mechanic but without training in vehicle emission control can reduce exhaust emissions by 25 %; with a 40 % work stringency requirement emissions can be reduced by 28 %. A skilled mechanic with training in vehicle emission control can reduce exhaust emissions by 40 % under less stringent conditions and 43 % under more stringent ones.

Black Smoke Control

No discussion of this important subject is given here. A useful reference is in the WHO/UNEP 1980 Workshop report by Dr. W. Kreisel, "Toxicological Assessment of Diesel Emissions and their Technical Control", see especially "III Control of Diesel Exhaust Emissions", pages 17-23.

Discussion and Conclusions

Ambient levels of Bangkok CO for some days in 1975 and 1977 approached those judged to produce unsafe carboxyhaemoglobin levels in people living and working in center city traffic situations. Some CO levels have been measured at 4 locations in Bangkok in 1981-2 and data analyses and evaluation is in progress. Pb levels reported from Bangkok street locations for 1975-6 show values resembling those of rush hour traffic of 14-25 ug/m^3 found in some american and european cities. The Bangkok 1981 levels (not street locations) ranged from 1 to 4 ug/m^3.

The number of motor vehicles registered in Bangkok and the expected annual increase suggests controls for Pb in benzine be proposed and that a compliance program for CO control from in-use vehicles be started.

There is no Thai requirement that motor vehicles be designed and manufactured to any reduced emission requirement. The only expected reductions in vehicle emissions from compliance with ONEB's 6 CO % will come from adjustment of engines to the vehicle manufacturer's original specifications. Since none of the engines offered for sale were required to meet a particular CO design level there is no assurance that after tune up that all vehicles will be 6 CO % or lower. The average age of Bangkok cars today is about 9 years, or likely a 1973 model year. The CO % measured in ONEB's 1980 study for 5-10 year vehicles shows 72 % of them to be 7.9 CO % or lower with a mean of 4.6 CO %. Vehicles 8 CO % and above represent 28 % of the sample. The experimental design does not allow determination of the mean CO % for the entire 5-10 year population. There were about the same percentage of vehicles at or below 7.9 CO % in all other age categories and with about the same population mean, namely 4.6 CO %, There are no Thai data from which a projected CO % emission reduction resulting from engine tune up can be estimated.

ONEB should consider establishing motor vehicle emission standards for new vehicles for purposes of systematically decreasing pollution levels with each new vehicle generation. New vehicle emissions should also be considered from the point of view of having an established Co emission level to which in-use vehicles could be returned through compliance regulations. Further, since new vehicles designed and built to specific emission standards are usually equipped with fuel induction and ignition systems which are factory calibrated and fixed, such vehicles are less likely to go out of adjustment and defy tampering and maladjustment. Emission controls on new vehicles demands compliance by manufacturers and does not solely depend on vehicle owner compliance.

Emission controls for new vehicles may be an appropriate subject for ASEAN Committee on Science and Technology (COST) consideration. Development of regional motor vehicle emission standards has the advantage of establishing a market for clean vehicles making manufacturers market compliance uniform and at minimum cost.

The success of a CO compliance program requires identification and labelling of vehicles that are in compliance and those in violation. There also must be a certification that emissions from offending vehicles have been reduced to at least 6 CO % within a specified time limit. This implies that there are effective action programs to return vehicle engines to normal CO levels (presumably 6 CO % or lower), a way to retest specific vehicles, to confirm their compliance, and a visual designation system declaring the vehicle to be in compliance.

A CO compliance program normally would consider only benzine LDV vehicles. However, the Korean LPG tests cast considerable doubt on the often held view that LPG vehicles are "clean" or "low pollution" cars. The Bangkok LPG emission situation must be described, particularly since the taxi fleet may travel about 7 million km a day, or about one-half that of the 17 times larger benzine LDV population.

Consideration should be given to determining the actual emission compliance success rate for vehicles failing ONEB's 6 CO % standard. Since about one-half of all tested Bangkok vehicles fail ONEB's 6 CO % standard, it becomes important to know what percent reduction in CO emissions is to be expected so that ONEB can develop an alternative plan for vehicles that cannot be brought into compliance. Compliance testing should also consider the merits of vehicle engine tune up or repair based on returning the engine to manufacturer's specification with and without CO repair shop measurements. A successful compliance program designed to meet manufacturers' engine specifications is most likely to meet vehicle owners performance expectations as well as ONEB's CO regulations.

Two basic premises in the ONEB's CO action program are : 1) cooperation of informed and environment-conscious vehicle owners; and 2)

access to reasonablecost vehicle engine repair facilities competent to put engines in good operating condition and meet ONEB's CO emission requirement.

The emission estimates suggest CO needs to be controlled. They also suggest that HC may need to be controlled for purposes of minimizing Bangkok expected ozone levels. Unfortunately, the quantitative validity of all motor vehicle emission estimates are in doubt due to incomplete and inaccurate motor vehicle statistics. ONEB should determine what motor vehicle data are needed (numbers, categories, ages, driving cycles, etc.) for air quality management strategies and request their collection and tabulation by responsible agencies. The estimates given here are quantitatively comparable but are not absolute, principally because of incomplete information on age, distance travelled by vehicle category, and no description of driving cycles. The proposed CO control action plan is solely for vehicles at idle. What percent of the driving cycle is at idle and what impact correction of CO at idle will have on ambient air quality remains unknown.

The ONEB data show about one-half of all LDVs exceed 6 CO % There is no data to show what the CO % will be after vehicle engine tune up or repair. The expected CO % after tune up should be about the vehicle manufacturer's design standard if the tune up is scheduled to return engines to manufacturer's specifications. CO design standard information apparently has not been collected, summarized, or evaluated.

The desireability of reducing black smoke is not discussed.

There is a sound basis for reducing Pb in benzine. No action plan is proposed here for benzine Pb control.

Control Options

The control options given here consider the information available, the vehicle emission data required, the need to identify competent engine tune up facilities, determine the effect of tune up on CO emissions, and formulation and implementation of a pilot action

program for CO emission control. The control options consist of at least 5 levels of activity:

I. Information

1. Obtain manufacturers engine inspection and maintenance manuals and manufacturers specification and procedures for engine tune up.

2. Obtain manufacturers statement for expected engine exhaust CO at idle based on design and operations specifications. This information should be obtained for new vehicles for models sold in Thailand over at least 10 model years. (Remember, the median vehicle age in Thailand is probably 9 years).

3. Obtain list of Bangkok engine tune up or repair service facilities approved by manufacturers.

4. Enquire from other sources regarding tune up or repair services capable of performing work according to manufacturers specifications. (Automobile Club, Petroleum Companies, etc.)

5. Ask manufacturers to list any RTG motor vehicle service facilities which meet their requirements for tune up to specifications.

6. Determine how many of the approved service facilities have CO monitoring devices.

7. List the motor vehicle manufacturers that provide mechanic training courses, and evaluate the training given for its expected impact on reducing engine CO emissions.

II. Vehicle Emission Tests

1. Measure a random sample of Bangkok LPG taxis for exhaust CO %. Ascertain make, model, age, and total km for each vehicle tested. Ask driver to estimate daily km for one work shift. Ask driver how many shifts he works in one week.

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2. Plan and execute a test cycle in which : 1) a benzine LDV exhaust CO % is measured; 2) that same vehicle engine is tuned to manufacturers specifications; and 3) that same tuned vehicle engine exhaust CO % is measured. The tune up service should neither consider nor measure CO as a condition for compliance with engine specifications.

3. Plan and execute a test cycle similar to "2" above and using an equivalent motor vehicle population (same number of vehicles and same range of vehicle makes, models, and age) and tune the vehicles according to mechanics "normal" procedure, with or without CO measurement.

III. CO Pilot Control Program

1. Organize and conduct a 6 CO % control program using a fleet of government owned and serviced LDVs. First priority should be given to a government department or agency of government with a recognized public service record and an officially expressed interest in protection of the environment (i.e., EGAT)

2. establish a second identical program with a city government agency in which there is an established public service record but not necessarily with a dedicated concern for protection of the environment, and in which the services and LDVs are essentially confined to Bangkok and Bangkok driving patterns.

3. A third identical program should make use of a government LDV fleet which operates in Metropolitan Bangkok and environs allowing km accumulation from daily local trips and some daily, longer, higher speed (freeway) trips. If possible, this program should use officials who deal in matters of business and with public trust, and who meet people in the business sector, (i.e, Customs, Tax, or Licensing organizations).

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4. A fourth program should involve the private car owner who uses a LDV primarily for transportation to and from work and family needs and pleasures. Their LDVs would be repaired by the owners or at their chosen repair shop. This fleet would best be selected from families with some motivated commitment, such as those with children in some secondary school club or organization (i.e. Boy Scouts, etc.)

5. Organization of the 4 programs would be similar, namely all LDV, all benzine fuel, all consisting of mixed ages, and all with operating odometers. The number of vehicles in a fleet may vary but should be 100 or more. With the exception of 4 th program, the vehicle engine maintenance, tune up, or repair facility must be operated by the fleet agency or be operating under contract with the fleet agency. Fleet vehicle records should be available to show number of trips made and daily distance travelled. CO % measurements should be taken at start of pilot control program, after each vehicle determined to be in violation has been tuned or repaired according to 1) either "normal" practise or 2) to manufacturers specifications. CO % may also be measured at some routhine vehicle servicing time, such as oil change, etc. If the checked vehicle is out of compliance, it should be tuned and CO % rechecked. Operations detail to be worked out with ONEB and agency.

6. The private LDV program will necessarily have to be developed to meet local conditions and needs. Preference should be given to a plan evolved jointly by ONEB and the young peoples organization (Boy Scouts may be well suited as they are well known, well disciplined, and well respected, and may influence their parents). The organization should organize and operate the program in an open and public way. Competition between units may be usefully exploited, such as developing accepted pressure to have their own family vehicles placed in compliance. With good policy planning and proper administrative sanctions, programing it should beneficially influence environmentally recalicitrant government agencies and further ONEB goals.

IV. Enforcement

1. Sanctions and administrative procedures including visual labelling of "failed" and "passed" vehicles, designation of authorized repair facilities and mechanics, and other operations activities must be identified, properly described, and compromise solutions reached, and action schedules settled before a city-wide CO % control program can be implemented.

2. The designated city-wide CO % control implementation plan should be tested in a medium sized city before undertaking full scale action in Bangkok. Choice of a test city must consider interest and cooperation of city government, the economic importance of the region, and the impact of the program on the public health and tourism.

3. Analysis and evaluation of the city-wide CO % control program should encourage future implementation in Bangkok.

V. Bangkok CO Control Program Options

1. The results of testing Bangkok LPG taxis will indicate need to consider CO control for taxis. If there is a demonstrated need the control action plan should be based on owners or taxi association compliance, not on individual drivers. Sanctions may be passed to the owner by the driver, but ultimate compliance should rest with owners or owner associations.

2. Motorcycles and LDV benzine trucks each represent a significant and about equal source of exhaust CO roughly equivalent to 2/3 of the CO emitted by LDV benzine cars. For adminstrative reasons consideration should be given to controlling CO from these sources separately by scheduling compliance in one year for motorcycles, the second year for trucks, and the third year for cars.

A deliberate, staged schedule, officially announced has the benefit of forewarning manufacturers and sales agencies of the government plan and to encourage them to provide equipment and services to meet the compliance requirements.

APPENDIX 7

Impact of LPG on Motor Vehicle Pollution - Bangkok

John T. Middleton/ONEB/3 June 1983

To: Secretary General

Subject: Light Duty Vehicle (LDV) Useage of Gasoline and LPG - Comparative Impacts on Air Quality.

Air quality in metropolitan Bangkok continues to worsen with increasing numbers of motor vehicles and increasing vehicle kilometers travelled (VKT). A report on "Motor Vehicle Air Pollution : Control Options" was filed on 18 March 1983. That report gives emission estimates for 10 vehicle categories and 3 fuel types. Carbon monoxide (CO) emissions are estimated at 1253 tonnes per day (t/d) of which 1158 t/d, or 92 %, is emitted from gasoline LDV. LPG vehicles emit about 56 t/d of CO, or 5 % of the Bangkok total. LPG vehicles emit less CO than gasoline vehicles because there are fewer LPG vehicles and emissions are lower because less CO is produced in engines burning LPG than in engines burning gasoline.

There are no emission data for Bangkok LDVs using either gasoline or LPG. Estimates of emissions for Bangkok gasoline and LPG LDV can be made using USEPA emission factors for average US LDVs. The average Bangkok LDV is about 9 years old, or a 1973 or 1974 model year, and has no emission controls. Emission data for US uncontrolled gasoline LDVs are available for 1967 and earlier. All later models have some emission controls. Emission factors for some LPG vehicles are available for 1968-1970. A summary of comparative emissions is presented below:

Light Duty Vehicle Emissions in grams per vehicle kilometer, g/km

	CO		HC		NO_x	
	gasoline	LPG	gasoline	LPG	gasoline	LPG
Uncontrolled 1967	55.9	-	5.4	-	2.1	-
Controlled 1968-69	39.7	6.8	3.5	1.1	2.9	2.0
Controlled 1970	33.0	2.1	3.0	0.4	2.7	1.7

Carbon monoxide emissions for 1968-69 gasoline LDVs were reduced by about 30 % from those of 1967. The use of LPG in controlled 1968-69 LDV reduced CO emissions by about 80 % compared with the same age gasoline vehicles. Emissions for 1970 LDV with LPG are about 95 % lower than those using gasoline. Reductions in hydrocarbon emissions also result from use of LPG instead of gasoline. The emission factor differences for NO_x in the limited USEPA tests are lower for LPG fuelled vehicles.

These data show a significant reduction in CO and HC emissions due to use of LPG as a replacement fuel for gasoline.

This dramatic reduction in emission factors, however, must be evaluated with actual emissions from in-use LDVs. Some unpublished emission information for a limited number of in-use 1978-1981 LDVs with simple emission controls shows LPG emissions in g/km are lower than gasoline emissions. The test data given below also show the importance of maintaining engines in proper tune and in compliance with vehicle manufacturer engine performance specifications:

LDV emissions in g/km for in-use 1978-1981 vehicles

Engine condition	CO gasoline	CO LPG	HC gasoline	HC LPG	NO_x gasoline	NO_x LPG
Before tune-up	26.4	8.0	3.0	2.3	1.8	2.8
After tune-up	15.7	3.6	2.4	1.9	1.7	2.4

Gasoline vehicle exhaust for the same LDV was measured for CO % at idle and ranged from 0.6 to over 10.0 with a mean of 4.5 After tune up the range was 1.5 to 2.9 with a mean of 1.9. The LPG vehicle idle exhaust CO % ranged from 0.1 to 7.2 with a mean of 3.8. After tune up it ranged from 1.4 to 2.1 with a mean of 1.6.

The data given above also show LPG vehicles emit less HC than gasoline vehicles. However, in-use LPG vehicles emit more NO_x than do gasoline LDVs and considerably more than the USEPA test vehicles.

The higher than USEPA emissions may be due to differences in age of engines, their design, or trade-off in specifications to achieve lower CO and HC.

The regular and long-term use of LPG in Japanese taxis suggests there may be more extensive information on vehicle emissions available from the Japan Environment Agency. It may be worthwhile investigating their experience with LPG.

LPG has typically been used in LDV as a replacement fuel for gasoline for purposes of reducing emissions from in-use vehicles. LPG is not used as the fuel of choice for new motor vehicles. Motor vehicle manufacturers do not normally produce LPG-fuelled LDVs. Use of LPG in vehicles usually results from government actions taken to reduce LPG fuel costs either by direct subsidy or taxes.

LPG vehicle emissions may produce an unpleasant and noxious odor due to aldehydes resulting from incomplete fuel combustion associated with poor engine maintenance.

The considerable reduction in LDV emissions from use of LPG is largely due to the normally simple composition of LPG. Emissions may vary as the composition of LPG varies, with emissions increasing and contributing to photochemically reactive nonmethane HC, and consequently more ozone, with increasing amounts of C_4 compounds.

This brief summary does not consider safety, costs or marketing of LPG for LDV.

Summary

Substituting LPG for gasoline in LDV will substantically reduce CO and HC emissions but at the expense of increased NO_x and perhaps some aldehydes. A reduction in HC coupled with an increase in NO_x is likely to increase the rate of ozone formation due to a more favorable ratio of HC/NO_x and increased photochemical reactivity.

The magnitude of CO + HC emission reduction is significantly influenced by engine operating conditions and maintenance. Use of LPG in poorly maintained vehicles not only minimizes the potential benefit but may also produce an unpleasant and irritating aldehyde odor in the exhaust.

LPG has never been considered as a fuel of choice by motor vehicle manufacturers.

LPG use in LDV fleets such as government agencies, business and commercial enterprises, and taxis is a good control option for CO and HC if concurrent actions are taken to reduce CO, HC, and NO_x emissions from all future new LDVs.

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APPENDIX 8

Procedures for Emission Inventory Preparation

The below referenced documents are located in the DEQS library :
US EPA, Office of Air Quality Planning and Standards,
Research Triangle Park, NC. 27711, (EPA - 450/4-81-026a-e) September 1981.

Procedures for Emission Inventory Preparation

Volume I	:	Emission Inventory Fundamentals.
Volume II	:	Point Sources
Volume III	:	Area Sources
Volume IV	:	Mobile Sources
Volume V	:	Bibliography

APPENDIX 9

Compilation of Air Pollutant Emission Factors

The below referenced documents are located in the DEQS library :
Compilation of Air Pollutant Emission Factors, Third Edition, US EPA,
Office of Air and Waste Management,
Office of Air Quality Planning and Standards,
AP - 42, Parts A and B (Including Supplements 1 - 13)
Research Triangle Park, NC. 27711, August 1982.

APPENDIX 10

Stationary Source Testing Methods

Source testing methods approved by USEPA for new stationary sources are found in the following referenced document location in the DEQS library :

Office of the Federal Register, National Achieves and Records Service, Codes of Federal Regulations (CFR) 40, US-GPO Washington D.C. 1981

Title 40 Environmental Protection Agency, Part 60 - Standards of Performance for New Stationary Sources, Appendix A. Reference Methods, pp 298 - 486.

APPENDIX 11

Analysis and Evaluation of Bangkok Air Quality Monitoring - Lead

John Middleton/ONEB/15 April 1983

To : Deputy Secretary-General

Subject : Validity of Pb Analyses from SPM Samples Collected at 9 Locations in Bangkok, July - September, 1981.

Introduction

A special study was conducted at 9 different locations in Bangkok from July to September, 1981 to assess particulate Pb levels in selected streets with recognized motor vehicle traffic. The locations studied were :

1	ยานนาวา	Yanawa "A"
2	สะพานพุทธ	Saphan Phut
3	วงเวียนใหญ่	Wong-Wien Yai
4	ยานนาวา	Yanawa B"
5	เยาวราช	Jawaraj
6	สามย่าน	Sam Yan
7	โอเดียน	Odeon
8	ประตูน้ำ	Pratunum
9	คลองเตย	Klong-toey

The Pb levels were determined from SPM samples collected by hivol samplers located at street level and varying distances from the road centerline. Specific site detail is on record and available. SPM samples were collected and weighed according to ONEB approved methods. Pb analyses were performed by the DEQS laboratory according to a procedure specified by Perkin-Elmer, "Analysis of Metallic Air Pollutants", March 1971.

Statistical Considerations of the Original Data

The original data for SPM and paired Pb analyses were obtained, arranged in a number of ways, and several statistical analyses were

performed. The data were considered as separate data sets by location for specific dates for SPM and Pb. These same data sets were also combined (put together) to form a single data set for SPM and one for Pb.

The data can be presented in a variety of ways. Arrays I and II show all the original data arranged by date and location. The array easily shows the sample size, the date of sampling, and the discontinuous sampling periods. There are a total of 65 samples each of SPM and Pb. They are distributed over the period 20 July through 28 September, 1981. The 65 samples were collected on 4 days of the week as follows :

Monday	3
Tuesday	21
Wednesday	0
Thursday	21
Friday	0
Saturday	20
Sunday	0
	65

There are 3 data sets which are known to be incomplete or inaccurate. Location 3 for 22 July is missing SPM; location 5 for 5 August is missing Pb; and location 8 for 28 September originally reported the Pb value as 2.66, but this was changed to 2.05 on 12 April for reason of legibility. The data analyses given consider the first number (2.66) and not the second (2.05).

The small number of samples for each location and the typical interrupted sampling period for Tuesday, Thursday, and Saturday (one exception is one time on Monday for locations 5, 6, and 7), limits the usefulness and interpretation of the data collected. Each location data set was arranged to show the range of values and to select the median value. These data sets were used to determine various statistics which describe the information collected and permit comparisons of the 9

locations. Data for all locations were combined for purposes of describing the total locations population. The combined data are presented in a decile format together with derived statistics in Tables 1 and 2.

The combined data for SPM and Pb show the numerical values required to describe the actual air pollution situation. For example, the arithmetic mean for SPM shows that all locations are represented by 0.5021 mg/m^3; 0.5021 is an estimate of the average for all locations for the period 20 July to 26 September 1981. The standard deviation is 0.2039 mg/m^3, a fairly large value, which reports considerable variation in values for the sampling period. The arithmetic mean is said to be an estimate for the locations and the period. It is not a true value because samples were taken only on 22 of 71 days or about 1/3 of the days during the period, and not for all locations.

The information presented in Tables 1 and 2 also shows how the values are distributed about the median or data mid-point. If the number of observations were larger the median, 50 th decile, and arithmetic mean would likely be the same. The Pb 50 th decile is 1.79 $\mu g/m^3$, the median is 1.94, and the arithmetic mean is 2.62, which states this population distribution is irregular with more high than low values, or some few quite high values. It is usual for such populations to have arithmetic mean larger than the median and for the geometric mean to be smaller than the arithmetic mean. The cumulative frequency distribution of SPM data is presented as class mid-points and as deciles in Fig. 1. The curve is irregular suggesting that there are fewer mid-value "normal" samples than might be expected. However, when the combined data are plotted on semi-log paper, as shown in Fig. 2, they appear to be log normally distributed and may represent a typical air quality sample population.

A summary of statistical information for SPM and Pb for each of the 9 locations is given in Tables 3 and 4. The number of samples for each location is small and apparent differences among locations may be meaningless. Geometric means and deviations were calculated for locations 5, 6, and 7 since those stations had at least 10 samples, although that

sample size is at least one-half as large as minimally preferred. The difference between values for several locations may be real, but sample size limits statistical testing of the significance of differences observed

The difference between means for SPM and Pb for locations 5 and 7 differ by more than 2. The data were analysed to determine if, fact, the difference in means was statistically significant. The statistical test shows that despite the small sample size the analysis of variance states location 5 and 7 to represent a common sample and that the difference in means for both SPM and Pb are statistically different at the 5 % confidence level. The difference in SPM is not statistically significant at the 1 % confidence level while the difference for Pb is. This suggests differences in sampling parameters are influencing SPM and Pb values, such as variations in meteorological conditions (macro and micro), source emission rates, etc. Fig. 3 illustrates the similarity in cumulative frequencies for SPM for locations 5 and 7 and the differences in location values, with location 6 assuming a somewhat intermediate value curve. While the difference between 5 and 7 can be shown to be significantly different by statistics, the actual difference may have no significance in the 9 street location study.

Association of Pb with SPM samples

Table 5 presents a comparison of arithmetic means for SPM and Pb for each of the 9 locations and the % Pb in the SPM sample. Table 6 lists the maximum SPM value for each location and the date on which it occurred. Samples were collected for most of the same days for locations 1-4 and normal expectancy would suggest the maxima for each pollutant should occur on the same date. The maxima are on the same date in 2 of 4 locations. The maxima dates for locations 5-9 all occur at different dates. Table 7 shows the maximum Pb values to occur on the same date in 3 out of 4 times in locations 1-4, and on the same date 2 out of 3 times in locations 5-7, and at different dates for locations 8-9. A comparison of Pb maxima dates with SPM maxima dates shows the dates to be the same for locations 1,2 and 8. It appears that there are a number of exposure variables influencing SPM and Pb sample values.

Least Squares and Regression of SPM and Pb

The least squares and linear regression was calculated from the arithmetic means for SPM and Pb for each of the 9 street locations. No calculation was made of the least squares and linear regression for the 63 paired values. The regression calculation requires that one variable be independent (x) and the other (y) be a random value from a population of values (y) corresponding to a given independent value (x). The assumption was made that SPM is an independent value and that Pb was a random corresponding value. The linear regression is Pb = (5.9829)(SPM)-(0.481). Plot of this "line of best" fit is shown as a solid line in Fig. 4. The same figure shows the plot of the 63 paired values from all 9 locations. The line represents the linear association of Pb analysed from a single representative section of the SPM glass fiber filter. The assumption that the SPM sample is an independent variable is open to question and may be in error for there is neither data to corroborate the validity of the weight of the SPM sample, nor data to define the exposure conditions during the collection period. The (x) solid line plot represents the regression line which best fits the 9 points used and does not necessarily describe the association between the 2 variables.

Confidence limits of the regression estimate were not calculated because of the scattered plot of the 63 paired SPM with Pb data sets.

The line of best fit seems to pass through the arithmetic mean for SPM and Pb, suggesting the calculated values represent the 9 location averaged data. The regression line falls short of the paired arithmetic means when data collected at the 9 locations are pooled and treated as a single population of all 63 pairs.

Another graphic presentation of the data is shown by the broken line which is drawn through the paired geometric mean and paired 84 th percentile for SPM and Pb. This line represents the association of SPM and Pb for 84 percent of the total data sets presented linearly rather than within a lognormal frequency population curve. The dispersion of the 3 sets of means about the calculated line of best fit (solid line) is also shown in Fig.4.

Pb Analyses of Replicated SPM Samples

The integrity of the Pb values assigned to the collected SPM sample depends upon sample and analysis variables. There is one data set of 9 samples representing 1 sample from each of the 9 different locations in which an original Pb analysis is compared with a later replicate Pb analysis taken from the original SPM sample. Identical laboratory analytical procedures were reportedly used in each case. The Pb values for the 9 locations for original and replicate SPM samples are given in Table 8 together with the differences between original and replicate. An analysis of variance of these Pb data shows that the original and replicate arithmetic means represent a single population. The t test for paired data shows the Pb values of the replicates are significantly different from the original Pb values at the 5 % confidence level. Since the 18 samples represent 1 population, it is very likely that the 19 % difference between original and replicate determinations is due to DEQS laboratory procedures.

Conclusions

The original SPM and Pb data collected at 9 street locations in Bangkok from 20 July - 28 September 1981 have been summarized and several statistical analyses have been made. The information collected has limited value due to sample size and sample collection dates. The statistical analysis performed provide estimates of mean levels of SPM and associated Pb for the study period.

The analyses performed suggest some location differences in SPM and Pb values, but no consistent association of Pb levels with SPM

sample weights. The Pb values range from 0.68 ug/m^3 at location 1, Yanawa "A" on 3 August, to 6.55 ug/m^3 at location 3, Wong-Wien Yai on 22 July, 1981. These data values may not accurately state the concentration present. Statistical analysis of a single companion set of Pb replicate samples shows the replicate sample values to be significantly lower than the original values by 19 %.

The Pb values derived from the SPM samples represent a small percent of the total SPM weight. The accuracy of the amount of Pb reported is in doubt.

The AIT Pb values reported for 1975 - 1976 are typically much higher than ONEB 1981 values. The AIT sample collection method is very different from that used by ONEB and does not allow comparison of data.

There is reason to believe that ONEB Pb data reasonably estimate specific day, local site, and seasonal Pb levels. Accurate and valid particulate Pb air quality information requires improvements in laboratory procedures, analyses, and data quality assurance.

Recommendations

There are 3 priority categories of recommendations.

1. Lead laboratory procedures, analyses, and quality assurance.

   a. Stop all further routine analyses of Pb in SPM samples.
   b. Organize and carry out a specially designed set of analyses for Pb determinations from a select group of samples from the 9 street location study and a select group from the 1981 Bangkok SPM monitoring program. Use the current laboratory procedures, analyses, and measurement methods for determining Pb levels in the selected sample groups.
   c. Request a Bangkok professional laboratory familiar with routine analyses of metallic air pollutants using

Perkin-Elmer procedures and measurement equipment to determine the Pb content of a select set of SPM samples. The select set should consist of the remaining portions of the SPM samples listed in Table 8 divided into replicated pairs by location.

d. Establish a schedule to adopt the US EPA Pb analysis procedure and abandon the current DEQS Pb analysis procedure. Itemize the equipment and materials required for the US EPA method and promptly and systematically acquire them.

e. Make the necessary arrangements to participate in an interlaboratory comparison for Pb sample analyses.

f. Establish a new particulate Pb study for purposes of determining Pb levels at selected street locations and to evaluate the health hazard of Pb to populations at risk.

2. Design and conduct of field studies

a. State the purpose (goal) of the proposed study

b. Outline the program proposed to meet the purpose with stated equipment, personnel, and support requirements.

c. Design the study to conform with statistical requirements for proper data analysis. Generally, limit the number of items to be studied, make certain the number of observations is not limited (larger rather than smaller), and that the frequency of observations considers daily, seasonal, emission source, and other significant variables.

d. Collect, tabulate, and perform appropriate statistical summaries of studies in progress and make running account statements of work plan conditions, achievements, and need for operation changes.

3. Analysing and interpreting air monitoring data.

a. Establish a regular, acceptable, and understandable

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statistical treatment of ONEB air quality data. The data summaries should be presented in a format which enables the reader to judge the acceptability of the monitoring information and to be able to compare the information with that of other air quality monitoring organizations.

b. The objectives in "3a" can be easily met by complying with generally accepted quality assurance programs, use of the WHO data reporting format, and by following the WHO data analysis and interpretation procedures.

c. The air quality and motor vehicle emission data collected in Bangkok, Chiang Mai, Hat Yai, and other locations should be reported in a standard format enabling inter-city comparisons and assessment of statistical significant similarities and differences. The value of short-term surveys lies in their validity as a measure of current local conditions and as a measure of air quality trends with changes in economic and social development.

Table 1. Statisstical Analyses of Hivol Suspended Particulate Matter (SPM) Samples Collected at 9 Bangkok Locations Representing Various Motor Vehicle Traffic Densities. July - September 1981

Deciles	SPM Concentration mg/m^3	Various statistics for the SPM data set for Bangkok, Jul.-Sept. 1981 9 Stations.	
10	0.2893	No. of observations	65
20	0.3228	Range min	0.2284
		max	1.0630
30	0.3529	Median	0.4402
40	0.3891	Arithmetric mean	0.5021
50	0.4380	Standard deviation	0.2039
60	0.5258	Geometric mean	0.4644
70	0.6314	Standard deviation	1.4754
80	0.7000	84th Percentile	0.6852
84	0.7260	(84th Percentile from array	0.7260)
90	0.7685		
95	0.9177		
98	0.9833		
100	1.1000		

94

Table 2. Statistical Analyses of Lead (Pb) Content of SPM Samples Collected from 9 Bangkok Locations as given in Table 1.

Deciles	Pb Concentration ug/m^3	Various statistics for the Pb data set for Bangkok, Jul,-Sept, 1981		9 stations
10	1.12	No. of Observations		65
20	1.33	Range	Minimum	0.68
			Maximum	6.55
30	1.49	Median		1.94
40	1.63	Arithmetic Mean		2.62
50	1.77	Standard Deviation		1.55
60	2.50	Geometric Mean		2.24
70	3.10	Standard deviation		1.75
80	4.07	84 th percentile		3.92
84	4.36	(84th Percentile from array		4.36)
90	4.90			
95	5.27			
98	6.34			
100	6.6			

Table 3. Summary of Statistical Information for SPM Hivol Samples, Bangkok, July - September, 1981

Location of Collected Samples

	1	2	3	4	5	6	7	8	9
	JUL	JUL	JUL	JUL	AUG	AUG	AUG	SEP	SEP
Date	20-31	20-29	24-31	20-31	5-28	5-28	5-28	16-28	16-28
	3 AUG	3 AUG	3 AUG	3 AUG					
Days	SA 2	SA 1	SA 2	SA 2	SA 4	SA 4	SA 3	SA 1	SA 1
	TU 3	TU 3	TU 2	TU 3	M 1	M 1	M 1	TU 2	TU 2
					TU 2	TU 2	TU 2		
Sampled	TH 2	TH 2	TH 1	TH 2	TH 4	TH 4	TH 4	TH 1	TH 1
No. of Observations	7	6	5	7	11	11	10	4	4
Range mg/m^3 Min	0.3104	0.5483	0.7085	0.3004	0.5546	0.2559	0.2284	0.3245	0.3637
Range mg/m^3 Max	0.9383	0.7940	0.9585	0.4151	1.0630	0.4690	0.5025	0.4424	0.6466
Median	0.4071	0.6769	0.7581	0.3694	0.6615	0.3895	0.2811	0.3682	0.5127
Arithmetic mean	0.4880	0.6767	0.8190	0.3605	0.7069	0.3831	0.3010	0.3756	0.5089
Standard mean	0.2238	0.0802	0.1166	0.0426	0.1373	0.0735	0.0765	0.0494	0.1270
Geometric mean					0.6964	0.3762	0.2941		
Standard deviation					1.3381	1.2266	1.2406		
84 th Percentile					0.9310	0.4615	0.3649		

Table 4. Summary of Statistical Information for Pb from SPM Hivol Samples, Bangkok, July - September 1981

Location of Collected Samples

	1	2	3	4	5	6	7	8	9
	JUL	JUL	JUL	JUL	AUG	AUG	AUG	SEP	SEP
Date	20-31	20-29	22-31	20-31	7-28	5-28	5-28	16-28	16-28
	3 AUG	3 AUG	3 AUG	3 AUG					
Days	SA 2	SA 2	SA 2	SA 2	SA 4	SA 4	SA 3	SA 1	SA 1
	TU 3	TU 3	TU 2	TU 3	M 1	M 1	M 1	TU 2	TU 2
					TU 2	TU 2	TU 2		
Sampled	TH 2	TH 2	TH 2	TH 2	TH 3	TH 4	TH 4	TH 1	TH 1
No. of Observations	7	6	6	7	10	11	10	4	4
Range ug/m^3 min	0.68	1.70	3.66	0.82	2.92	1.39	1.17	1.63	1.00
max	1.75	5.87	6.55	1.33	5.96	3.91	3.43	2.66	1.81
Median	1.41	3.08	6.03	1.27	4.27	2.20	1.77	2.26	1.29
Aritmetic mean	1.32	3.47	5.50	1.23	4.20	2.16	1.91	2.20	1.35
Standard deviation	0.41	1.48	1.15	0.25	0.90	0.69	0.62	0.54	0.35
Geometric mean					4.11	2.07	1.84		
Standard deviation					1.24	1.33	1.33		
84 th percentile					5.10	2.75	2.45		

Table 5. Comparison of Pb with SPM, Bangkok, July-September 1981

Location	No. of Observations	Arithmetic Mean		
		mg/m^3 SPM	ug/m^3 Pb	% Pb
1	7	0.4880	1.32	0.27
2	6	0.6767	3.47	0.51
3	5	0.8190	5.50	0.67
4	7	0.3605	1.23	0.34
5	11	0.7069	4.20	0.59
6	11	0.3831	2.16	0.56
7	10	0.3010	1.91	0.63
8	4	0.3758	2.20	0.58
9	4	0.5089	1.35	0.26
Total	9	0.5133	2.59	0.50
Total	65	0.5021	2.62	0.52

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Table 6. Distribution of Maximum SPM Values by Location, Bangkok, July - September, 1981

Location	SPM mg/m^3	Date	
1	0.9383	22-Jul	
2	0.7940	22-Jul	
3	0.9585	27-Jul	Data missing for 22 July
4	0.4151	29-Jul	
Location			
5	0.7813	17-Aug	
6	0.4690	26-Aug	
7	0.5025	10-Aug	
Location			
8	0.4424	16-Sep	
9	0.6406	28-Sep	

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Table 7. Distribution of Maxima for Pb and SPM Values by Location, Bangkok, July - September, 1981

Location	Pb ug/m^3	Date of maximum Pb	Date of maximum SPM
1	1.75	22 Jul	22 Jul
2	5.87	22 Jul	22 Jul
3	6.55	22 Jul	27 Jul No data for 22 Jul
4	1.64	29 Jul	29 Jul
Location			
5	5.96	23 Aug	17 Aug
6	3.91	23 Aug	26 Aug
7	3.43	26 Aug	10 Aug
Location			
8	2.66	16 Sep	16 Sep
9	1.81	21 Sep	28 Sep

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Table 8. Comparative Analyses of Replicated Pb Samples, Bangkok July-September 1981

Pb content in ug/m^3 from a single SPM sample collected at 9 locations analyzed at 2 different dates.

Location	Date Sampled	Original	Replicate	Difference Original-Replicate
1	31 Jul	0.99	1.22	-0.23
2	22 Jul	5.87	4.89	+0.98
3	29 Jul	6.29	4.20	+2.09
4	29 Jul	1.64	1.00	+0.64
5	17 Aug	4.77	3.66	+1.11
6	23 Aug	3.91	3.05	+0.86
7	26 Aug	3.43	2.66	+0.77
8	28 Sep	2.05	2.16	-0.11
9	21 Sep	1.81	2.06	-0.25
			Total	+5.86
Arithmetic mean		3.42	2.77	
Standard deviation		1.93	1.31	

Difference (Sum of individual differences of original less replicate) +5.86*

* The differences between original and replicate sample analyses are statistically different at the 5 % confidence level.

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Figure 1. SPM Cumulative frequency curve for combined locations

o = Cumulative frequency from class mid point distribution

x = Cumulative frequency from decile distribution

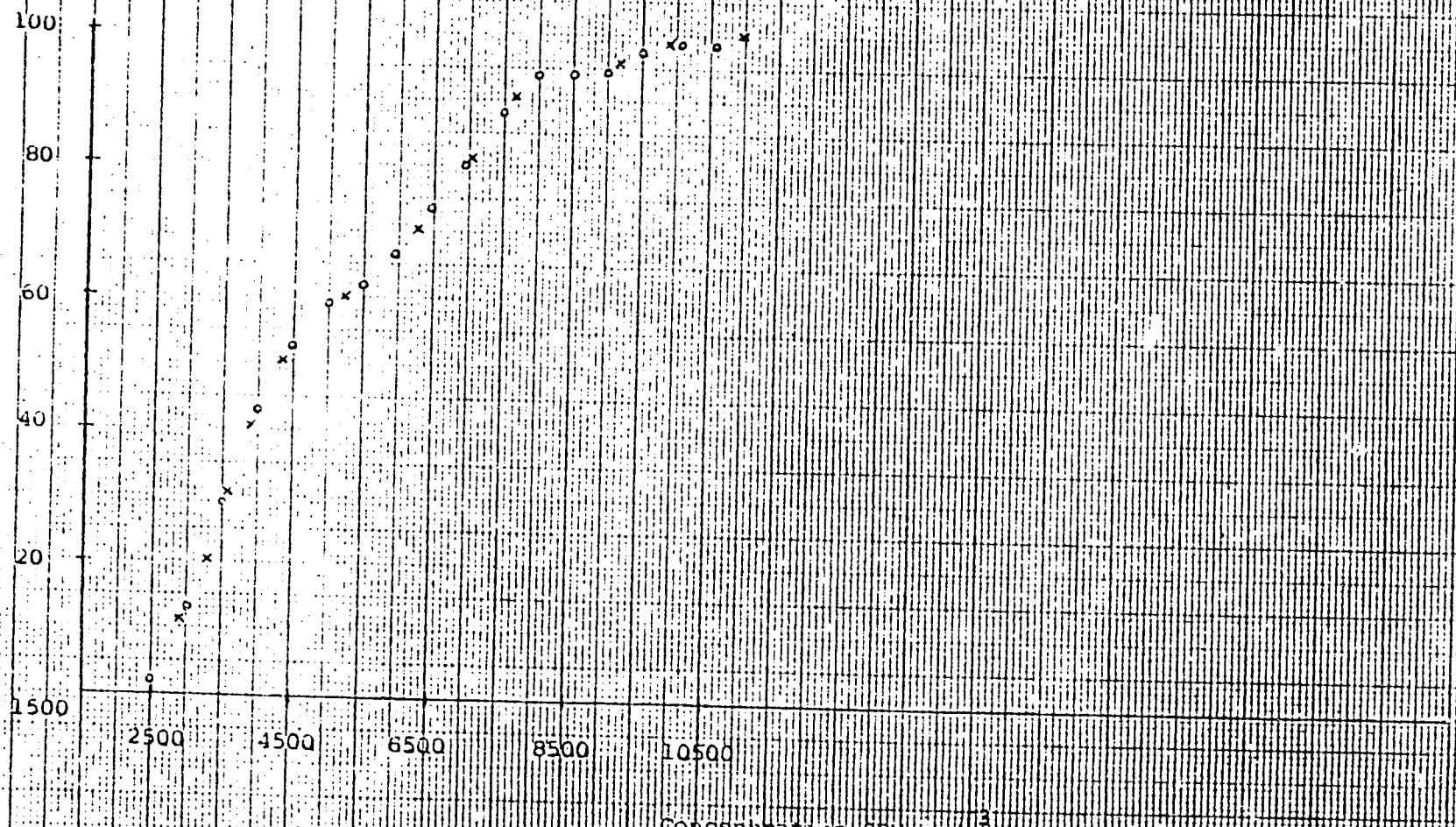


Figure 2. Cumulative frequency distributions for combined locations for SPM and Pb. Bangkok, July - September, 1981

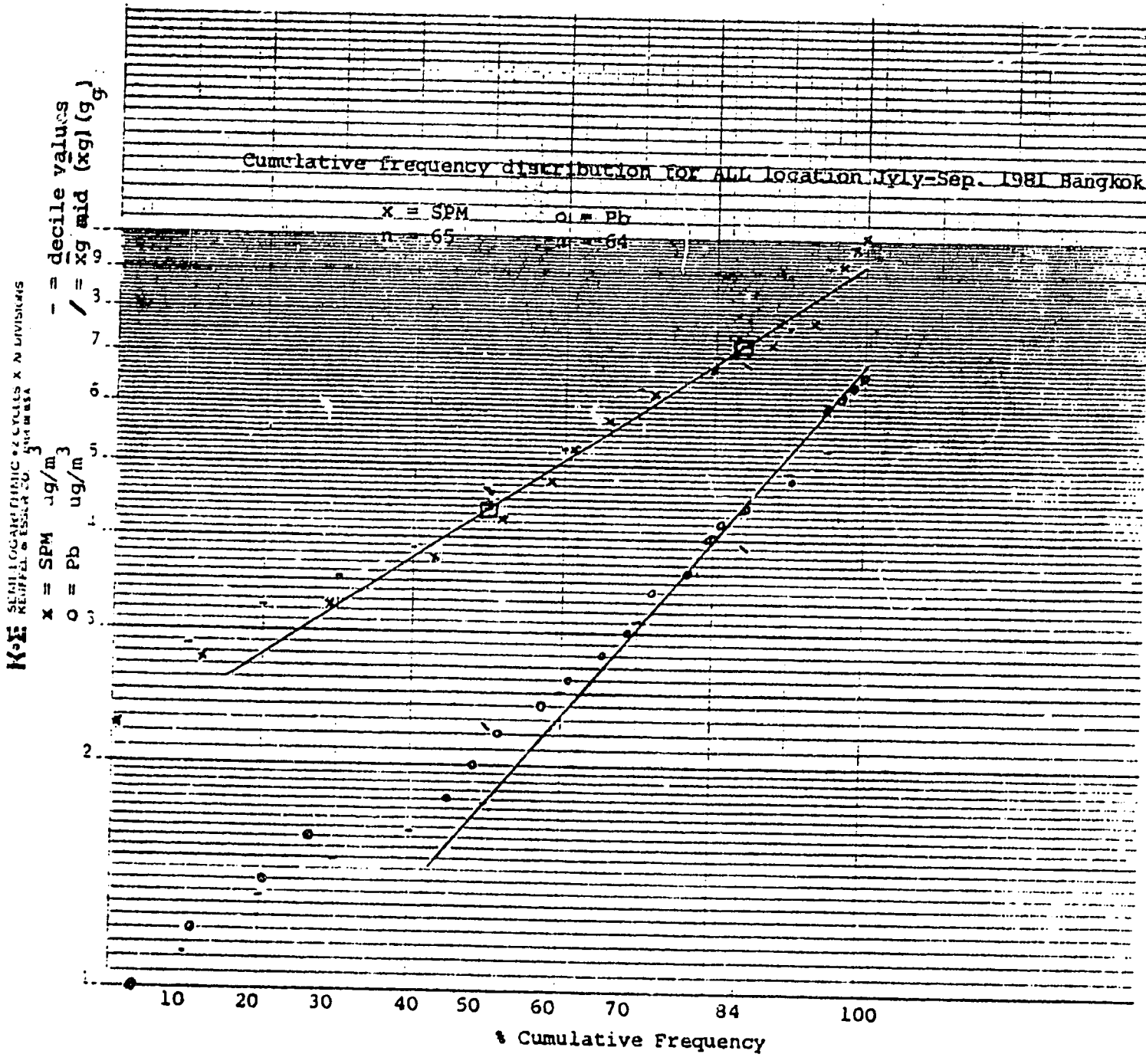
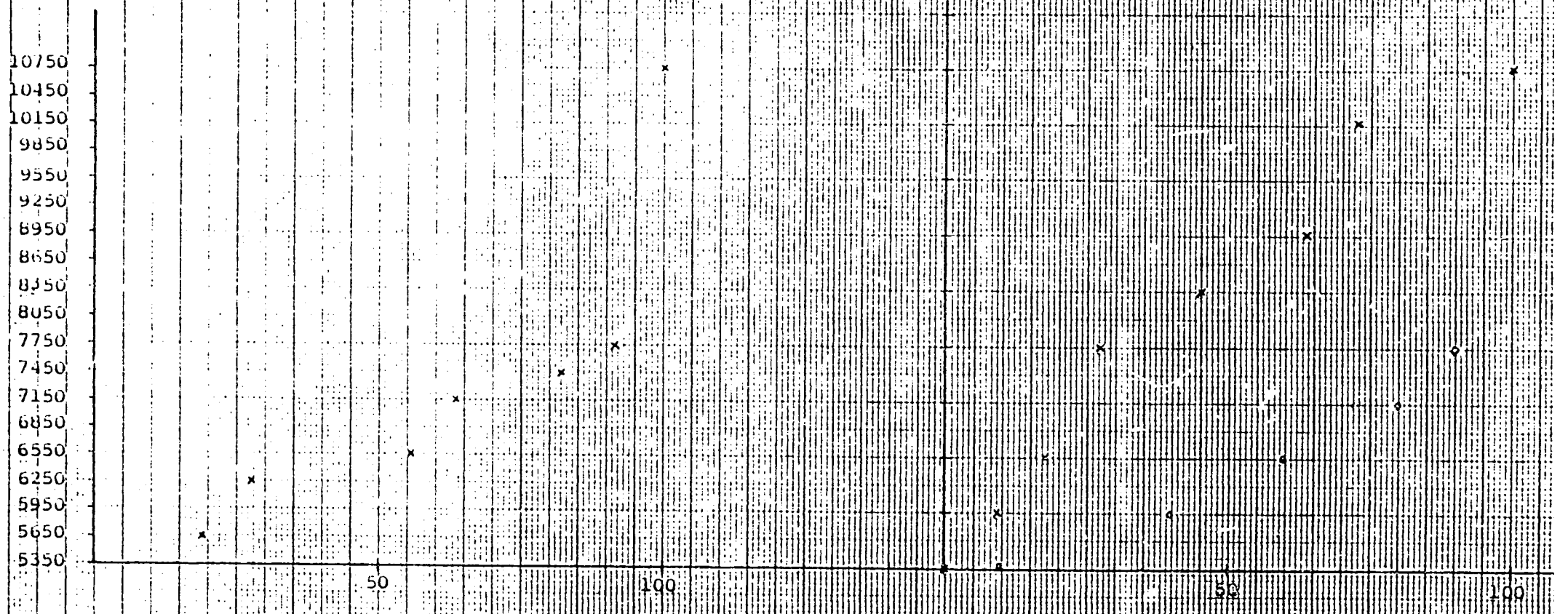


Figure 3 SPM Cumulative frequency curve Location 5,6 and 7 Bangkok July-September 1981



Cumulative Frequency Location 5

x = wt ug/m^3

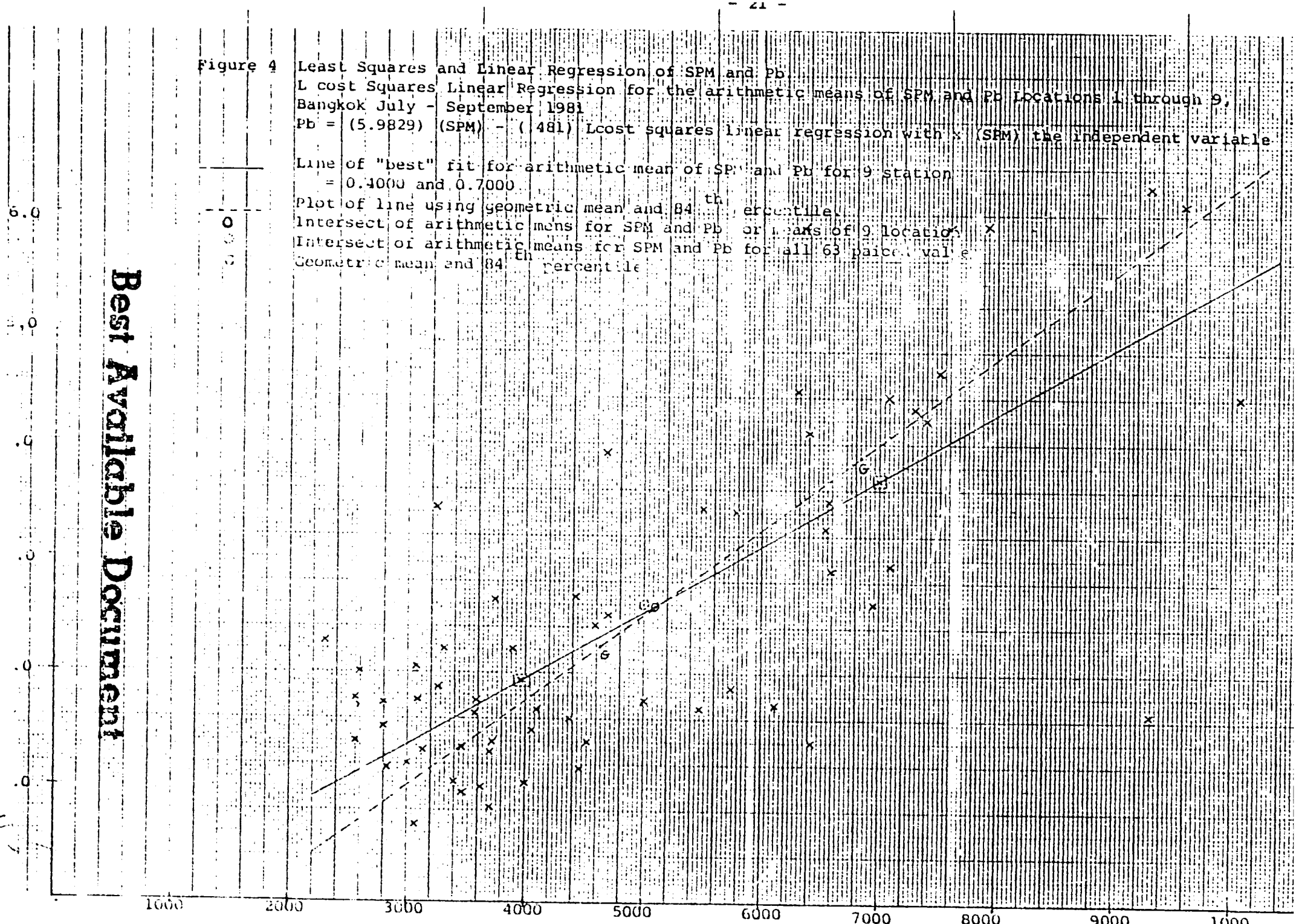
Cumulative Frequency

x = wt Location 6 ug/m^3

o = wt Location 7 ug/m^3

Figure 4 Least Squares and Linear Regression of SPM and Pb
L cost Squares Linear Regression for the arithmetic means of SPM and Pb Locations 1 through 9, Bangkok July - September 1981
Pb = (5.9829) (SPM) - (481) Lcost squares linear regression with x (SPM) the independent variable

Line of "best" fit for arithmetic mean of SPM and Pb for 9 station = 0.4000 and 0.7000
Plot of line using geometric mean and 84th percentile
Intersect of arithmetic mens for SPM and Pb for means of 9 locations
Intersect of arithmetic means for SPM and Pb for all 63 paired values
Geometric mean and 84th percentile



Best Available Document

ARRAY I Daily SPM. at varions station in Bangkok, Thailand, 1982 (mg/m^3)

Day	July				August							September	
	Yanawa	Saphan phut	Wong-Wien Yai	Phayakrai	Yanawa	Saphan p'hut	Wong-Wien Yai	Phayakrai	Jawaraj	Sam Yan	Odeon	Pratunum	Klong-toey
1	6	5	5	6	1	1	1	1	5	11	10	4	4
2													
3					0.3104	0.5485	0.7336	0.3722					
4													
5													
6									TH.0.6615	0.3622	0.2595		
7													
8									SA.0.6401	0.3920			
9													
10													
11									TU.0.5546	0.3292	0.5025		
12													
13									TH.0.5790	0.2809	0.2557		
14													
15									SA.0.6601	0.4380	0.3075		
16													
17												TH.0.4424	TH.0.3637
18									TU.0.7813	0.3895	0.2821		
19													
20	0.6177	0.7073		0.3157					TH.0.6300	0.4615	0.3075		
21													
22	0.9383	0.7940		0.3004					SA.0.7355	0.2559	0.2802	TU.0.3597	0.5773

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Day	July				August							September	
	Yanawa	Saphan phut	Wong-Wien Yai	Phayakrai	Yanawa	Saphan phut	Wong-Wien Yai	Phayakrai	Jawaraj	Sam Yan	Odeon	Pratunum	Klong-toey
23									Mo.6365	0.4677	0.2284		
24	0.3416	0.6600	0.7581	0.3466									
25												0.3245	0.4482
26									TH.0.7105	0.4690	0.3253		
27	0.4565	0.6568	0.9585	0.3694									
28									SA.0.7540	0.3678	0.2615	0.3768	0.6466
29	0.4071	0.6938	0.9311	0.4151									

ARRAY II Daily Lead at various station in Bangkok, Thailand, 1982

Day	July				August							September	
	Yanawa	Saphan phut	Wong-Wien Yai	Phayakrai	Yanawa	Saphan phut	Wong-Wien Yai	Phayakrai	Jawaraj	Samyan	Odeon	Pratunum	Klong-toey
1	1	2	3	4	SUN 1	2	3	4	5	6	7	WED	9
2													
3					TU.0.68	1.70	4.22	0.82					
4													
5					TH								
6										TH.1.74	1.39	SUN	
7													
8					SAT				SA.4.10	2.20			
9					SUN								
10													
11									TU.3.44	2.20	1.78		
12													
13									TH.3.39	1.49	1.78		
14													
15					SAT				SA.3.55	1.63	1.76		
16					SUN								
17													
18									TU.4.77	2.23	1.17	TH.2.66	1.00
19													
20	TU.1.74	4.46		1.33					TH.4.45	2.42	2.05	SAT SUN	
21					SAT				SA.4.79	2.03	1.77	TU.1.63	1.31

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Day	July				August							September	
	Yanawa	Saphan phut	Wong-Wien Yai	Phayakrai	Yanawa	Saphan Phut	Wong-Wien Yai	Phayakrai	Jawaraj	Sam Yan	Odeon	Pratunum	Klong-toey
22	TH.1.75	5.87	6.55	1.21	SUN								
23								—	MO.5.96	3.91	2.33		
SAT24	1.08	2.93	5.92	1.27									
SUN25												SAT1.86	1.18
26									TH.2.92	2.52	3.43	SUN	
27	TU.1.41	3.24	6.14	1.28									
28					SAT				SA.4.62	1.39	1.68		1.41
29	TH.1.56	2.60	6.29	1.64	SUN								
30													
SAT31	0.99		3.86	1.04									

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APPENDIX 12

Analysis and Evaluation of Bangkok Air Quality Monitoring - Suspended Particulate Matter

John Middleton/ONEB/23 April 1983

TO : Deputy Secretary General

Subject : Analysis and Evaluation of Bangkok Air Quality Monitoring Data.

OBJECTIVES

Regularized air quality monitoring has produced about 1000 paired data sets for SPM and Pb from 4 Bangkok location for 1980, 1981 and 1982. The SPM was measured by ONEB approved methods and Pb was determined by DEQS analytical procedures. The objectives of this data review were to determine the adequacy of the data and account for the reported discrepancy between number of exceedances determined for the 24-hour periods and the annual mean values.

FINDINGS

The DEQS summaries present the data for each pollutant by location and time month and year by minima, geometric means, and maxima. Line graphs are provided to illustrate the findings. The report shows location and seasonal differences and discusses some of the observed differences. The report does not give any statistical analysis of the data, does not offer any interpretation of findings, and does not discuss the frequency of exceedances of ONEB 24-hour and annual ambient air quality standards.

In order to determine the adequacy of the data for making air quality interpretations the original data collections were presented by calendar dates. The sheer size of the data available limited the analysis to SPM only, for only 1 location, Chulalongkorn University, and 1 year only; 1981 with the largest number of observations. Pb is not

considered. The raw SPM data are arrayed in Table 1. The 131 observations are presented by calendar day, 1 January through 31 December 1981, in Figure 1. No data are given for consecutive days, consequently the individual entries remain as isolated values and not connected. Table 2 shows the samples were drawn as follows : Monday 1, Tuesday 45, Wednesday 2, Thursday 38, Friday 0, Saturday 44, and Sunday 1. Table 2 also shows the distribution of SPM concentration by deciles calculated from data array given in Table 1. Figure 2 presents the statistical analyses and data summary for class interval and data array estimates. The mean values are necessarily considered estimates since they are derived from incomplete and irregular sampling frequencies.

A plot of the deciles derived from the data array given in Table 1 is shown in Figure 3 using lognormal paper. The population appears to be lognormally distributed. The upper skewed distribution is due to the few unusually high values reported. More samples and more samples in other years at the same location are needed to interpret the significance of the 1981 high values. The distribution of estimated SPM values for a complete year cannot be constructed from the information available. Further study of the correctness of the estimates is under investigation for purposes of attempting a yearly sample estimate from 131 out of 365 days intended to account for present sampling date discontinuities.

The Chulalongkorn SPM data show 2 exceedances of the 24-hour mean, once on 20 January and once on 29 December, 1981. There were 110 exceedances of the annual mean. Table 2 shows that more than 80 % of the observations exceed 0.1040 mg/m^3; the annual standard is exceeded 64 % of the time. Until such time as a way is found to reasonably estimate a yearly data population; no prediction can be made about the number of expected exceedances per years for either the 24 - hour level or the annual geometric mean.

CONCLUSIONS

The 3 year, 4 location, air quality monitoring data for SPM and Pb provide basis for estimating daily values and their compliance with ONEB ambient air quality standards.

The Chulalongkorn University SPM data cannot now be used to predict either 24-hour or annual values for the calendar year because the number of observations is biased for Tuesday, Thursday, and Saturday sampling periods and is not representative of the days in a calendar year. Search for a statistical solution for the discontinuous sampling system is continuing.

The 2 Tables and 3 Figures suggest ways of presenting and analysing collected air quality data. Comparisons of locations and years may be made using the kind of information summarized in Table 2, and performing frequency distribution analyses for individual years by locations using the format of Fiure 3. Details and evaluation of trends should be developed and presented according to a sample interpretation given on pp 45-52, "Analysing and Interpreting Air Monitoring Data", WHO Offset Publication No. 51, 1980.

The DEQS report should be written to make certain the values are real for the days sampled and only estimates for the calendar year. The actual exceedances for ONEB SPM air quality standards of 2 times for 24-hour and 110 times for annual are real. NO estimate of the number of exceedances expected in a calendar year can be given until an acceptable solution is found for correctly stating the probabilities of the collected data representing a calendar year.

Present and future air quality monitoring data must be collected for a prescribed sampling period that faithfully represents the days of the week and the three seasons and at the same time collects the largest number of samples possible considering facilities and personnel.

Priority for data collection should be given for locations representing important populations at risk and for continuity in sampling site locations.

Table 1. SPM Chulalongkorn 1981 = "A"

0660-		1104-				1607-	
0731-		1110-				1643-	
0768-		1134-				1652-	
0797-		1135-				1656-	
0789-		1144-				1659-	
0801-		1161-				1673-	
0806-		1162-				1728-	
0826-		1174-				1732-	
- 0828-	7.6 %	1193-				1734-	
0830-		10- 1195-	32.1 %		68.7 %	10-1736-	
0839-		1214-				1745-	
0872-		1217-				1752-	
0886-		1217-				1796-	
0902-		1220-				1833-	
0911-		1222-				1845-	
0929-		1227-				1853-	
0931-		1232-				1860-	
0972-		1262-				1889-	
- 0989-	15.3 %	1269-				1902-	
0993-		10- 1301-	39.7 %		76.3 %	10-1912-	
1017-		1328-				1919-	
1017-		1336-				1942-	
1019-		1346-				1943-	
1035-		1348-				1954-	
1042-		1358-				1955-	
1049-		1363-				2030-	
1055-		1364-				2063-	
1064-		1378-				2068-	
- 1090-		1382-				2091-	
1093-		10- 1397-	47.3 %		84.0 %	10-2114-	
- 1099-	24.4 %	1404-				2115-	
		1409-				2117-	
		65- 1415-				2118-	
		Median 66- 1416-	50.4 %			2153-	
		1422-				2162-	
		1437-				2169-	
		1438-				2206-	
		1442-				2236-	
		1447-				2257-	
		10- 1463-	54.9 %		91.6 %	10-2294-	
		1527-				2336-	
		1537-				2372-	
		1550-				2478-	
		1551-				2500-	
		1559-				2565-	
		1575-				2578-	
		1595-				2593-	
		48- 1589-	61.1 %			2655-	
						2708-	
						10-3300-	
					100 %	51-3886-	

24-h std = 0.33
Ann std = 0.10

n = 131

20 April 83 **Arithmetic mean**
n = 131
$\bar{x}$ = 0.15326 = 0.1533
σ_n = 0.05579 = 0.056
σ_{n-1} = 0.0560
Σ_x = 20.0772
Σ_x^2 = 3.48488

22 April 83 **Geom. mean** $\bar{x}$
n = 131

Transformed
$\bar{x}g$ = 0.1438 90
σ_n = 1.4232 40
σ_{n-1} = 1.4251

Annual Geometric mean
0.1439 mg/m³

Geometric Std. deviation

1.4232 = Sn for the entire population is used.

2 exceedances of 24-h $\bar{x}$
110 exceedances of annual $\bar{x}$

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Table 2. Statistical Summary of SPM, Chulalongkorn University, 1981

Decile	Concentration mg/m^3
10	0.0878
20	0.1046
30	0.1169
40	0.1305
50	0.1420
60	0.1567
70	0.1778
80	0.2009
84	0.2114
90	0.2456
95	0.2938
98	0.3507
100	0.3886

Statistical Summary	
No. of Observations	151
Days of Observations	Monday 1
	Tuesday 45
	Wednesday 2
	Thursday 38
	Friday 0
	Saturday 44
	Sunday 1
Range	0.0600-0.3886
Median	0.1416
Arithmetic mean	0.1533
Standard deviation	0.0558
Geometric mean	0.1439
Standard deviation	1.4232
84 th Percentile	0.2048

Decile concentrations are derived from the data array.

The stated 84th percentile is the product of MgSDg.

The geometric mean calculated from class mid-points from 0.2495 to 0.42495 by 0.0500 class interval is 0.1434 (Refer to Fig. 2)

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Figure 1.

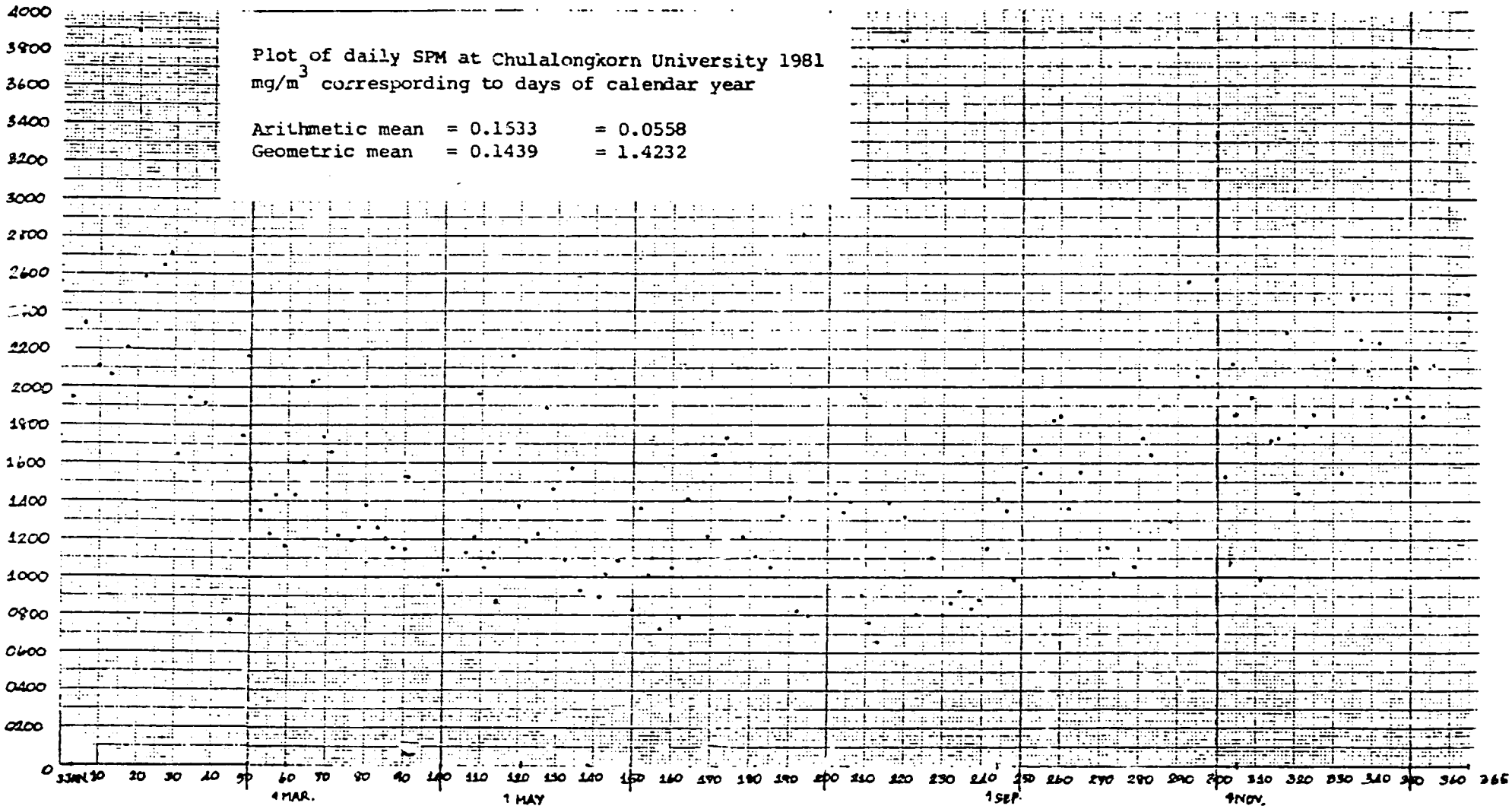

Plot of daily SPM at Chulalongkorn University 1981
mg/m3 corresponding to days of calendar year
Arithmetic mean = 0.1533 = 0.0558
Geometric mean = 0.1439 = 1.4232
4000
3800
3600
3400
3200
3000
2800
2600
2200
2000
1800
1600
1400
1200
1000
0800
0600
0400
0200
0
1 JAN
4 MAR.
1 MAY
1 SEP.
4 NOV.

FIGURE 2 SPM CHULALONGKORN 1981

HISTOGRAM = NO. DAYS AT CLASS INTERVAL
POLYGON = SAME
= CUMULATIVE BY CLASS INTERVAL
= Decile Concentrations from array of 131 observations

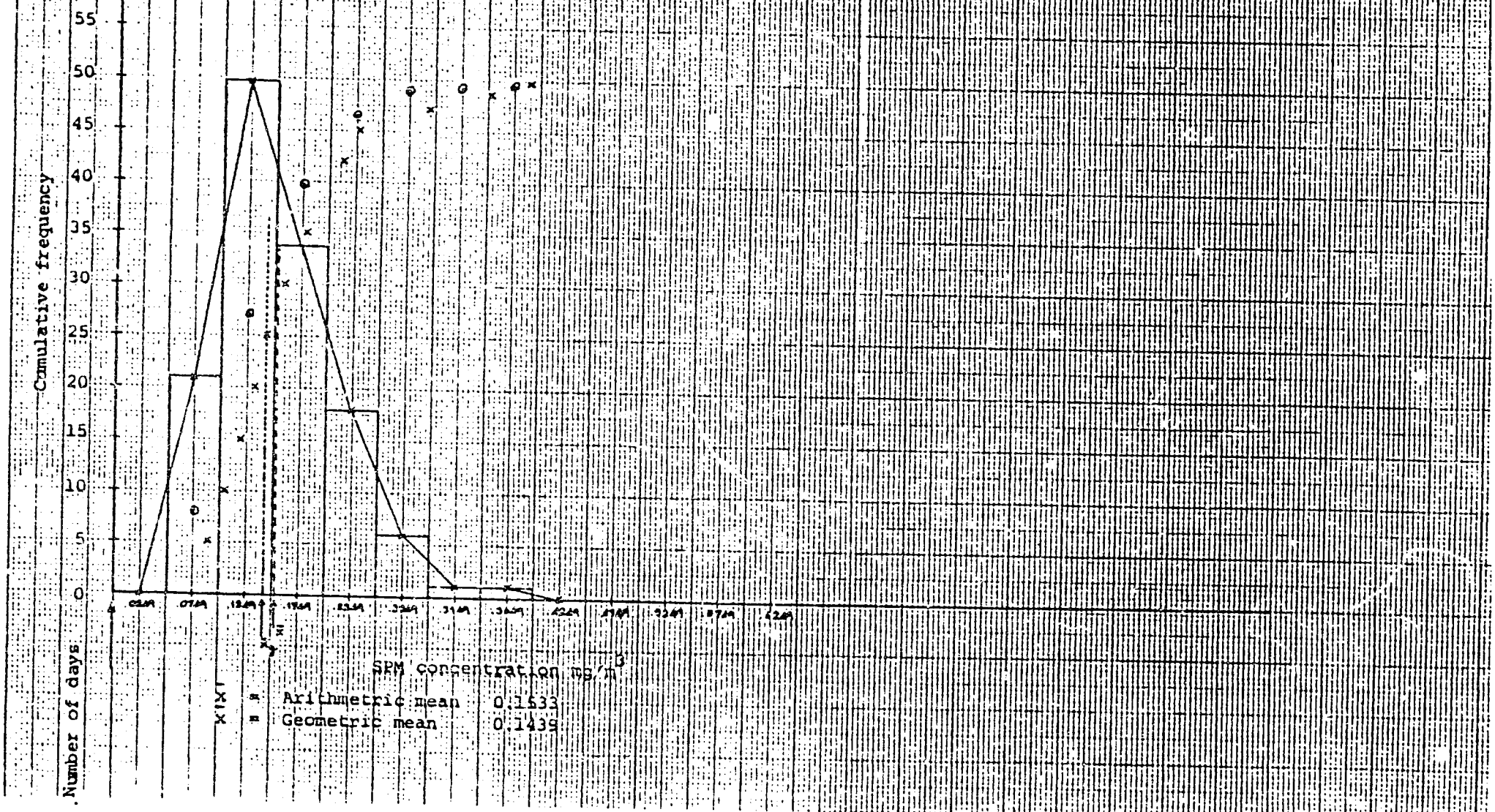
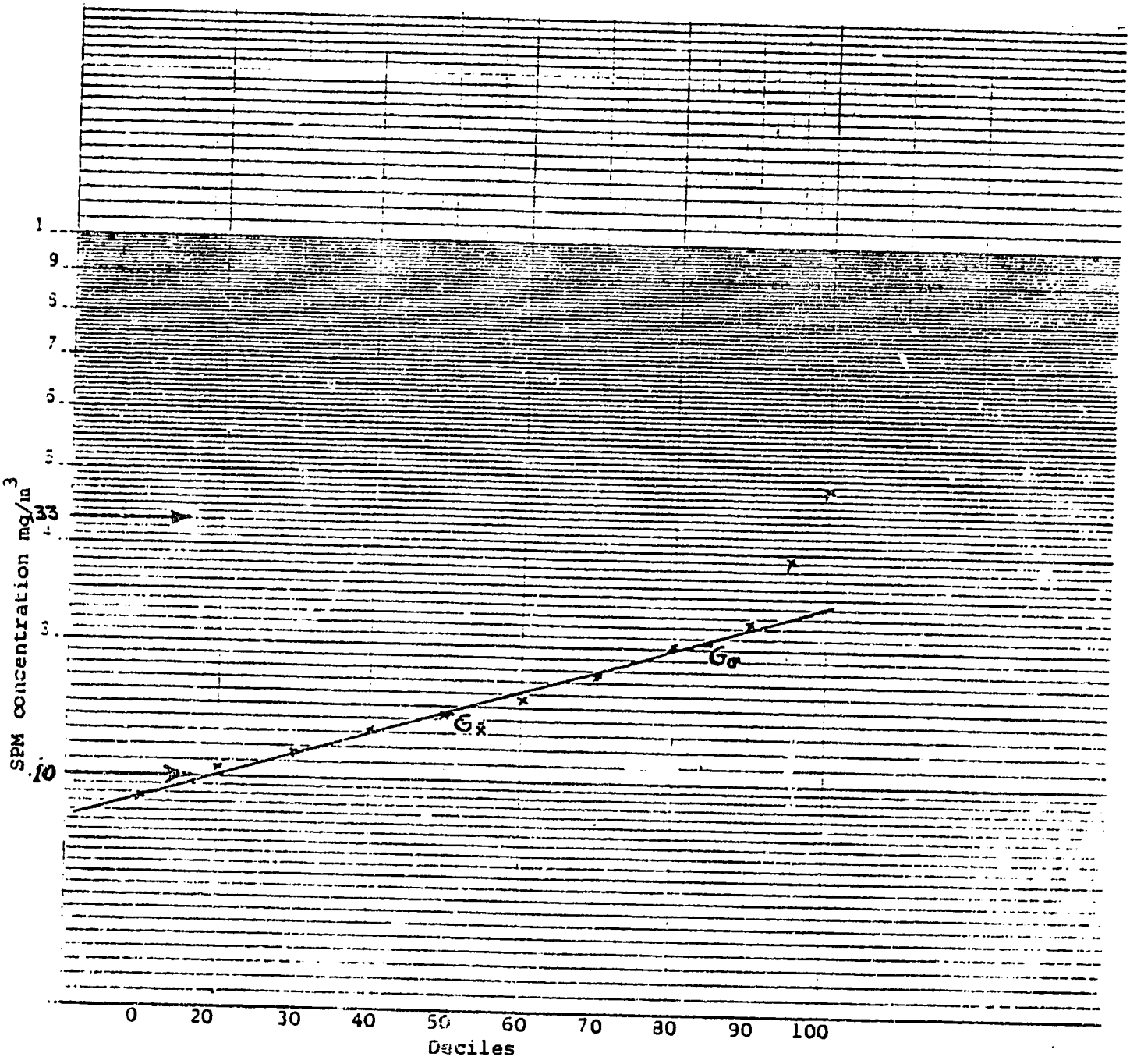


Figure 3 Decile plot of Chulalongkorn SPM (1981) values with geometric mean and 84 th percentile population curve

Geometric mean = 0.1439 mg/m^3

84 th percentile= 0.2048 mg/m^3



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APPENDIX 13

USEPA Analysis of Bangkok SPM Data, 21 June 1983

Assistance for John Middleton Regard ing SPM Data in Bangkok, Thailand

Estimate of the annual geometric mean

The geometric mean for a set of data is defined as

$$Mg = \left[\prod_{i=1}^{n} x_i \right]^{1/n}$$

Where x_i are the individual observations x.....,xn, and n is the number of observations. This calculation can be facilitated with the use of logarithms and is independent of the underlying distribution. In order to properly estimate the annual geometric mean (as well as other statistics) the sample of observations should be representative of the entire year. Every day does not need to be sampled, but, in general, each season or calendar quarter should be represented, as well as each day of the week. These periods require equivalent representation since they may correspond to different pollutant levels; disproportionate representation could yield biased statistics.

The problem of sample representativeness is usually handled by an appropriate sampling schedule combined with a minimum data completeness criteria. EPA currently recommends one sample every six days as a minimum sampling schedule for TSP. this systematic schedule ensures equal representation of each day of the week as well as seasons of the year. For the calculation of summary statistics (such as the geometric mean) from EPA's data bank, we currently require a minimum of five observations per calendar quarter with the additional requirement that if one month doesn't have any observations, the other months must have at least two. Statistics are usually not reported for sites which do not meet this criteria.

In situations in which the data may not be representative of the entire year, statistics may be calculated with the use of weighting factors. For example, the annual geometric mean may be based on the geometric means of the observations within each calendar quarter. This approach is being considered for EPA's revised particulate matter standard. This would allow for a different number of samples in each quarter, as long as the minimum number were still satisfied.

These general considerations, unfortunately, do not completely solve the problem for the SPM data from Chulalongkorn University. As you point out, these data were derived from a schedule on which samples were essentially taken only on Tuesdays, Thursdays, and Saturdays. Using the EPA criteria, these data would meet the minimum required completeness. However, depending on the actual weekly emission patterns, the annual geometric mean resulting from these data could be biased. For example, if the SPM on Sundays is significantly lower than the SPM on other days the geometric mean calculated from the sample would be higher than the true geometric mean. Knowledge or assumptions about the weekly emission pattern can allow us to improve the estimate of this geometric mean. The following are some examples: If we assume that Tuesdays, Thursdays and Saturdays are representative of the remaining days, on the average, then the sample annual geometric mean would be representative of the true annual geometric mean. On the other hand, if Saturdays are representative of Sundays, while Tuesdays and Thursdays are representative of Mondays, Wednesdays or Fridays, then an appropriate weighted average should be used.

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Comparability of 0.10 mg/m^3 annual SPM standard with 0.33 mg/m^3 24-hour SPM standard

The comparability of an annual SPM standard with a 24-hour SPM standard depend on the interpretation of attainment of the respective standards as well as the variability among the SPM measurements. I will assume that the 24-hour SPM standard is comparable to the current EPA 24-hour TSP standard which only allows one 24-hour TSP exceedance per year. The effective stringency of this standard depends on the number of samples; the chance to detect exceedances of the standard level increases as the number of sampling days increases. This is not the case with the annual standard where the annual geometric mean is somewhat independent of sample size.

The other factor which affects the relative stringency of these standards is the variability among SPM measurements. This variability can be expressed in terms of characteristics such as peak-to-mean ratios or standard geometric deviations, which may vary from site-to-site, or year-to-year.

One way to compare the annual and 24-hour standards is in terms of a measure of typical variability. For the Chulalongkorn University SPM, the 3-year geometric standard deviation, calculated from your data, is 1.86. Using this value, a geometric mean of 0.10/mg/m^3 and the assumption that the distribution can be represented by a lognormal, then the expected second highest concentration among 131 samples would be 0.38 mg/m^3, with 3 to 4 exceedances expected per year. Thus on the basis of this variability and sample size, the 24-hour would be expected to be exceeded even when the annual standard was attained. Looking at the actual data, the 24-hour standard was not exceeded in 1980; it was exceeded once in 1981 (the December 29 value of 0.33 would not count as an exceedance), and it was exceeded 11 times in 1982. This corresponds to the estimated average exceedance rate of 4 times per year.

The annual standard was only exceeded in 1981 with an annual geometric mean of 0.12 mg/m^3. This value was calculated as a simple

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unweighted geometric mean. The mean for 1980, a partial year, was 0.08 mg/m^3 and the mean for 1982 was 0.09 mg/m^3. On the basis of these results, the 24-hour standard appears to be more stringent than the annual standard, at this site. If the variability (e.g. geometric standard deviation) is smaller at other sites, then the annual standard may become more stringent.

APPENDIX 14

Guideline on Air Quality Models

A publication on file in DEQS library :

Guideline on Air Quality Models, OAQPS-Guideline Series, USEPA, Office of Air Quality Planning and Standards Research Triangle Park, NC 27711, EPA - 450/2-78-027, OAQPS No. 1.2 - 080, April 1978.

APPENDIX 15

Air Quality Models

A publication on file in DEQS library

Summaries and Proposed Recommendations Concerning Air Quality Models Submitted to Environmental Protection Agency, USEPA, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, October, 1980.

APPENDIX 16

Stationary Source Control Technologies and Systems

Pertinent sections listed below are contained in the following publication on file in DEQS library.

Best Available Control Technology - Lowest Achievable Emission Rate BACT/LEAR Clearinghouse, USEPA, Control Progresses Development Division, Office of Air Quality Planning and Standards, Research Triangle Park, NC 27711, May 1982.

Appendix B. Control Technology Determination by Type of Source - Summary of Emissions Limitations, pp. B 1 - 122

Appendix C. Control Technology Determinations for External Combustion Sources, pp. C 1 - 38.

Appendix G. A Compilation of Control Technology Determinations, pp. C 1 - 660.

APPENDIX 17

Source Monitoring Systems for Enforcement of Emission Standards

These systems are described in the following publication on file in the DEQS library :

Continuous Air Pollution Source Monitoring Systems, Handbook, USEPA, Technology Transfer Cincinnati, OH 45268. EPA 625/6 - 79 - 005, June 1979.

APPENDIX 18

Air Pollution Control in Thailand

A Publication on file in the DEQS library.
Air Pollution Control in Thailand, Final Report to the National Environment Board, Prepard by John T. Middleton, 18 July 1979.

APPENDIX 19

Air Pollution Course Materials, 1 February 1983 memorandum

John Middleton/ONEB/1 February 1983

To : Deputy Secretary General

Subject : Air Pollution Course Materials

Through the courtesy of USEPA and the especial interest of Mr. Ronnie E. Townsend, Chief, Manpower and Technical Information Branch, ONEB was given an extensive set of Air Pollution Teaching and training materials. There are 3 course categories:

Correspondence
Self Instruction
Lecture and Laboratory

The materials in EQSD cover 22 course subjects and may be used within the Division for special study, but may also be useful to teachers offering courses at undergraduate and graduate level. I shall look into using the training materials for Division staff and discuss the possibilities of extending their use to AIT and selected universities.

Any suggestions you care to offer for their use will be appreciated.

AIR POLLUTION COURSE MATERIALS

Environmental Quality Standards Division, Received from U.S. Environmental Protection Agency, Air Pollution Training Institute, November 1982

Correspondence Courses

416 Inspection Procedures for Organic Solvent Metal Cleaning (Degreasing) Operations

Guidebook

Inspection Source Test Manual

434 Introduction to Ambient Air Monitoring

Guidebook

Student Manual - Atmospheric Sampling (Same Manual as used in Course 435)

436 Site Selection for Monitoring of SO_2 and TSP in Ambient Air Guidebook

Optimum Site Exposure Criteria for SO_2 Monitoring

Selecting Sites for Monitoring Total Suspended Particulates

437 Site Selection for the Monitoring of CO and Photochemical Pollutants in Ambient Air

Guidebook

Selecting Sites for CO Monitoring

Site Selection for the Monitoring of Photochemical Air Pollutants'

Self Instruction Courses

412 Baghouse Plan Review

Student Guidebook

Display Slides - 35 mm, 1-75

Casette - "Baghouse Operation and Maintenance".

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417 Controlling VOC Emissions from Leaking Process Equipment Student Guidebook

422 Air Pollution Control Orientation Course Instructions for Use Units - 1-9, including casettes for 1-2 and 5-9

448 Diagnosing Vegetation Injury Caused by Air Pollution
Boxed material - 1

473 Introduction to Environmental Statistics
Boxed meterial - 2

Student Manual
Student Workbook

Lecture and Laboratory Courses

411 Air Pollution Meteorology
Instructor's guide
Student Manual
Student Workbook
Workbook of Atmospheric Dispersion Estimates
Plume Rise

413 Control of Particulate Emissions
Instructor's guide
Student Workbook

415 Control of Gaseous Emissions
Instructor's guide
Student Manual
Student Workbook

420 Air Pollution Microscopy
Instructor's guide
Laboratory Manual
Asbestos - Containing Materials in School Buildings

423 Dispersion of Air Pollution - Theory and Model Application

Instructor's guide

Student Workbook

Selected Readings Packet

426 Statistical Evaluation Methods for Air Pollution Data

Instructor's guide

Handouts

Table of Contents for 2 sSelected References

427 Combustion Evaluation

Instructor's guide

Student Manual

Student Workbook

435 Atmospheric Sampling

Instructor's guide

Student Manual

Student Laboratory and Exercise Manual

444 Air Pollution Field Enforcement

Instructor's guide

Student Manual

Student Workbook

450 Source Sampling for Particulate Pollutants

Instructor's guide

Student Manual

Student Workbook

452 Principles and Practice of Air Pollution Control

Instructor's guide

Student Workbook

Meteorological Factors Affecting Atmospheric Pollutants Cost Effectiveness of Air Pollution Control Strategies

464 Analytical Methods for Air Quality Standards

Instructor's guide

Student Manual

Laboratory Exercise Manual

Guidelines for Development of a Quality Assurance Program Transfer Standards for Calibrations of Air Monitoring Analyzers for O_3

Technical Assistance Decument for the Calibration of Ambient O_3 Monitors

482 Sources and Control of Volatile Organic Air Pollutants

Instructor's guide

Student Workbook

Regulatory Documents

Control Techniques for Volatile Organic Emissions from Stationary Sources

Summary of Group 1 Control Technique Guideline Documents for Control of Volatile Organic Emissions from Existing Stationary Sources

1 December 1982

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APPENDICES

Appendix 1. Eastern Seaboard (ESB) overview relative to the preparation of an air quality management plan for the Map Ta Phut development planning area. 17 December 1982 memorandum.

Appendix 2. DEQS Emission Inventory Questionnaire

Appendix 3. RTG Air Quality Standards

Appendix 4. RTG Measurement Methods for Air Quality Standards

Appendix 5. Comments on Adequacy of Data for Air Quality Assessment. December 1982 memorandum.

Appendix 6. Motor Vehicle Air Pollution - Bangkok. 18 March 1983 memorandum.

Appendix 7. Impact of LPG on Motor Vehicle Air Pollution - Bangkok. 3 June [illegible] 3 [illegible] memorandum.

Appendix 8. Procedures for Emission Inventory Preparation

Appendix 9. Compilation of Air Pollutant Emission Factors.

Appendix 10. Stationary Source Testing Methods.

Appendix 11. Analysis and Evaluation of Bangkok Air Quality Monitoring-Lead. 15 April 1983 memorandum.

Appendix 12. Analysis and Evaluation of Bangkok Air Quality Monitoring-Suspended Particulate Matter. 23 April 1983 memorandum.

Appendix 13. USEPA Analysis of Bangkok SPM Data, 21 June 1983

Appendix 14. Guideline on Air Quality Models

Appendix 15. Air Quality Models

Appendix 16. Stationary Source Control Technologies and Systems

Appendix 17. Source Monitoring Systems for Enforcement of Emission Standards

Appendix 18. Air Pollution Control in Thailand

Appendix 19. Air Pollution Course Materials, 1 February 1983 memorandum