

**ASEAN/UNEP STUDY TOUR & TECHNICAL WORKSHOP ON  
WATER QUALITY MONITORING AND MANAGEMENT**

**14 - 19 December 1981, Singapore**

**Report**

## CONTENTS

Section	Page	
1	Conclusions and Recommendations	1
2	Background, Objectives and Programme of the Workshop	3
3	Summary of the Workshop Content	5
3.1	Opening Address	5
3.2	Election of Chairman	6
3.3	Summary of Papers and Discussions	6
3.4	Summary of Field Visits	16
3.5	Summary of Group Study	17
4	Annexes	21
(1)	List of Participants and Observers	
(2)	Workshop Programme	
(3)	List of Group Study	
(4)	Opening Address	
(5)	Philosophy of Pollution Control and Water Quality Monitoring and Management	
(6)	Several Aspects of Water Quality Management in Indonesia	
(7)	Development of Water Resources and Water Pollution Control in Singapore	
(8)	A Review of the Analytical Methods Used in Singapore for Water Pollutants	

- (9) Analytical Quality Control and Assessment of Limits for Analytical Data
- (10) Selection of Monitoring Stations and Frequency of Sampling
- (11) Brief Description of Wastewater Treatment Plants visited during the Field Visits
- (12) Application Form for Permission to Discharge Trade Effluent into a Public Sewer/Watercourse/Controlled Watercourse
- (13) Guidelines for the Submission of Trade Effluent Reports



The major conclusion of the Workshop was that water quality management system and practices were unique for each ASEAN country due to the differences in physical environment social, economic and ecological conditions. However, the philosophy and concept behind the system and practices are common and they must be clearly and fully understood before the system and practices can be designed. Recognizing this fact, the participants from other ASEAN countries focussed their attention on the philosophy and concept of water quality management and practices employed in Singapore, rather than on the operational details. They concluded that the Workshop considerably helped improve their conceptual understanding and knowledge of water quality management and that it contributed significantly to their work in water quality management.

It was unanimously agreed that technical co-operation in the area of water quality management among the ASEAN countries should be promoted and strengthened. In this context, the participants recommended the following co-operation programmes listed according to their preferences;

- 1) Short training courses of 1-2 month duration in three major areas;
  - a) Water quality planning and management;
  - b) Wastewater treatment technologies; and
  - c) Water Pollution study.
- 2) Information exchange system for water quality management;
- 3) Experts exchange;
- 4) Joint research and study of some common regional problems of high priority;
- 5) Study tour programmes; and
- 6) Seminars and workshops.



The recommendations were deliberately broad to provide flexibility for designing a detailed implementation programme as and when the need arises.

BACKGROUND, OBJECTIVES AND PROGRAMME  
OF THE WORKSHOP

This ASEAN/UNEP Study Tour & Technical Workshop on Water Quality Monitoring & Management is one of the priority projects under the ASEAN Environment Programme endorsed by the ASEAN Experts Group at its Fourth Meeting and adopted at the ASEAN Ministers of the Environment Meeting in April 81.

The Study Tour & Technical Workshop was attended by participants from Indonesia, Malaysia, the Philippines, Thailand and Singapore. A Consultant and an Observer from the Regional Office for Asia and the Pacific of the United Nations Environment Programme (UNEP) were also present by invitation. The list of delegates and observers appears as Annex 1.

The programme for this Workshop (see Annex 2) was therefore designed with the aim of achieving the following objectives:-

- (1) To enable the participants to gain an overview of Singapore's state of progress and achievement in water quality management with emphasis on the management of domestic sewage and industrial effluents;
- (2) To expose the participants to practices in water quality management with emphasis on technical aspects of effluent and water quality monitoring and laboratory analyses with reference to Singapore's experience; and
- (3) To explore further opportunities for sharing experiences in water quality management among the ASEAN countries.



In taking note of the wide range of backgrounds, experiences and interests of the participants, the first part of the Workshop was aimed at providing the participants with basic concepts relating to the following issues;

- (1) The complex inter-relationship among production, environmental resources and environmental quality;
- (2) The integration of engineering, ecological and socio-economic dimensions in pollution control; and
- (3) The functional structure of a system for managing sewage and industrial effluents.

Subsequent papers were centred on the technical aspects of analytical methods and analytical quality control for the determination of water pollutants and on the design of a water quality monitoring programme. It was hoped that participants would use this Workshop as a forum to share their experiences in water quality management taking Singapore's experience as a case study.

In addition to the lectures and discussions, field visits were arranged for the participants to see pollution control practices for different types of wastewaters as well as to provide an insight into the technological, economic and management aspects of each treatment system.

To enable the participants to pursue their areas of interest in greater depth, they were divided into two groups (see Annex 3); one group on the planning, management and engineering aspects of water quality management, and another group on the monitoring and laboratory aspects. One morning session was allocated to the two groups for this purpose.

3.1 Opening Address

The opening address was given by Dr R S Bhathal, Director of the Singapore Science Centre, who welcomed the participants and opened the Study Tour and Workshop. As highlighted by Dr Bhathal, the Workshop aimed;

- (a) to promote technical collaboration among the ASEAN countries based on Singapore's experience in managing domestic sewage and industrial effluents; and
- (b) to develop expertise in the ASEAN region to generate complete, accurate, representative and comparable data on water quality for better management.

He pointed out that the problems of water quality and water pollution were critical not only in the ASEAN countries but also in many other countries of the world.

With rising energy costs, he suggested that it might be extremely beneficial for the industrial sector to start thinking more seriously about recycling water in their manufacturing operations wherever possible. This would not only save water for the factory but would also reduce the volume of wastewater discharged and thus simplify subsequent treatment.

He further added that the society had to bear the very high costs for waste disposal. A solution would be to recycle the wastes which could be profitable in most cases.

He stressed that the application and viability of recycling should not just be decided on operational management criteria. The decisive factor should be what was socio-economically viable and, in the long-term, most sensible.



In conclusion, he hoped that the deliberations and discussions in the Workshop would help solve some of the problems associated with the monitoring and management of water quality.

The full text of his address is given in Annex 4.

### 3.2 Election of Chairman

Mr Tan Teng Huat, leader of the Singapore delegation, was unanimously elected as the Chairman.

### 3.3 Summary of Papers and Discussions

#### (1) Philosophy of Pollution Control

Dr Sermpol Ratasuk, Consultant to UNEP, began by pointing out the difference between the terms Water Quality Management (WQM) and Water Pollution Control (WPC). WQM looks at water usage at regional or national level. As such, it encompasses a wider field than WPC, which deals only with sources of wastewater. The concept of WQM is to optimise social, economic and ecological costs for a certain level of water quality. To achieve this, one will have to be clear as to what to manage, who to manage and what it is for.

In any production process, wastes are inevitably released. WQM aims to strike a balance between the use of water as a waste sink and for other tangible or intangible purposes. Pollution is the result of the imbalance in the use of the environment.

As in all other resource management, there are certain goals that WQM has to achieve. Adoption of a policy provides the guidelines for setting goals from which objectives are defined. In defining objectives, one would have to take the socio-economic aspects into consideration.

Policy need not be static and should be reviewed from time to time. Once the objectives are defined, the attainment of these objectives requires: operating pollution control facilities, controlling effluent discharge, monitoring of environmental quality, and research and development. Research and Development, in Dr Ratasuk's view, is essential as standards and technologies adopted by ASEAN, based on conditions in other countries, may not be suitable for our type of situation.

In the discussions which followed the presentation of the paper (Annex 5), a question was raised as to whether it was possible for the Government in carrying out pollution control to also provide the necessary pollution control facilities, and for industries to pay for the cost. Dr Ratasuk replied that this would depend on whether the economic structure allowed for it. Consideration also has to be given on how the cost could be passed onto the industries without the consumer being exploited.

On whether polluters or consumers should pay for the cost of pollution control, Dr Ratasuk was of the view that it should depend on the type of goods produced. For goods that benefitted the poor, an appropriate system of cost-sharing between the industries and the government should be devised otherwise the cost would be passed onto the consumers.

Another approach would be for the controlling agency to provide financial assistance to small industries to set up treatment facilities. However, this could involve using public funds to subsidise inefficient industries. Without the right incentive, efforts at reducing wastes may not achieve their objectives.



(2) The Management of Domestic Sewage & Industrial Effluent

In his presentation, Dr Ratasuk mentioned that the management of industrial effluents is not simply the straightforward application of technology. Socio-economic factors may have to be taken into consideration. Small industries with limited production capacity, space and inefficient production technology will have difficulty in bearing the cost of wastewater treatment. Moreover, these small industries are unlikely to extend their co-operation to the controlling agency in pollution control. At times, strict enforcement of effluent standards may have adverse socio-economic consequences, such as requiring small industries unable to comply with the effluent standards to close down. In such an instance, selective control strategies may have to be adopted. This will be successful only if the total pollution load from key industries is significantly large compared to the total pollution load from the small industries.

Attention was directed to another approach which aims at centralising small industries in industrial estates. These small industries will then be able to take advantage of economy of scale by having their wastewaters treated in a central plant within the estate. Some participants in the Workshop felt that this approach can be adopted for a new industrial estate but was unlikely to succeed if relocation of existing small industries was necessary.

As for the treatment of domestic sewage, Dr Ratasuk pointed out that the provision of an integrated sewerage and sewage treatment system is very costly. One alternative is to install small treatment plants for individual houses. Another would be to have a nightsoil collection system followed by anaerobic digestion. It must be

borne in mind that preventing pollution caused by domestic sewage will help to minimise public health risks.

Industrial effluent standards set by the controlling agency must be related to the quality attainable by present day treatment technology, treatment cost, type of water usage and the type of industries. The controlling agency which sets the effluent standards usually looks at the economic feasibility of attaining it. Industries on the other hand, look at the financial feasibility aspect measured in terms of a positive rate of return on capital investment. Conclusions drawn from both approaches may differ. In such a case, Dr Ratasuk stressed again that one must understand the why, the how and the what for in water quality management.

From time to time, reviews aimed at reducing production losses or minimising wastewater treatment costs are necessary. Increasing energy costs may make treatment processes which require high energy inputs less attractive. One example is anaerobic treatment. The recovery of valuable biogas as a by-product makes anaerobic treatment of high BOD wastewater increasingly more attractive.

(3) Several Aspects of Water Quality Management in Indonesia

Ir. Badruddin of Indonesia presented a paper (Annex 6) describing an on-going study which covered several aspects of water quality management in Indonesia, viz;

- a) water quality monitoring;
- b) water quality management (case study on Citarum River); and
- c) water pollution abatement (case study on Cimahi Area).



Water quality monitoring is conducted to make an inventory of the water resources and to monitor water pollution and sedimentation due to erosion.

Water quality management plans need to be developed for each river basin in order to protect the quality of water resources for multiple beneficial use. A case study of a water quality management plan for one river basin (Citarum River) was therefore made as a model for application to other river basins in Indonesia.

The search for the appropriate technology to be used for pollution abatement in Indonesia led to the development of a pilot plant in an industrial area at Cimahi, West Java. This pilot plant uses physico-chemical processes comprising sedimentation, rapid and slow mixing and multi-layer sedimentation with provision for future addition of a biological process.

In the ensuing discussion, it was felt that in a full-scale treatment plant, chemical dosing should be automated to handle the varying nature of the industrial waste. Disposal of sludge arising from such a plant could be another problem particularly if heavy metals are present in the industrial waste. One method being considered is the disposal of sludge to waste areas created by mining activities. As the treated effluent from such a plant will be used for agriculture, the long term effect of its usage may have to be evaluated.

(4) \* Development of Water Resources & Water Pollution Control in Singapore

Mr Chiang Kok Meng of Singapore presented a paper on how Singapore developed and managed its water resources to meet the increasing demand for water. To increase the water resources, areas outside protected water catchments

have been developed. Pollution control measures and the implementation of cleaning up programmes ensure that water collected from these unprotected catchments are not polluted.

In addition, existing sewerage infrastructure has to be extended to keep pace with the increasing volume of domestic sewage and industrial effluents. Legislations were provided to ensure that pollution control measures can be effected.

The full text of his paper with the Water Pollution Control and Drainage Act 1975 and its attendant regulations appear in Annex 7.

(5) Review of the Analytical Methods Used  
In Singapore for Water Pollutants

As part of water quality management in Singapore, water pollutants in the seawater, drains, canals, streams, rivers and industrial and sewage effluents are analysed. The analytical methods used in Singapore were reviewed by Miss Seah Huay Leng (see Annex 8). These pollutants are the oxygen consuming matters, non-toxic salts, poisons and heavy metals, inorganic salts and unaesthetic wastes. Bacteriological examinations are also conducted. However they were not covered in this review.

The types of parameter selected for analysis of the pollutants depend on the source of the samples and the objectives of the analysis, which can be the evaluation of the water quality or the extent of pollution.

The analytical methods adopted to analyse the pollutants are based on the latest edition of the "American Standard Methods for the Examination of Water and Wastewater". Analysis can be done using either the automatic analyser or wet methods.



During the discussion, it was noted that the methods of analysis used by the other ASEAN countries are also based on the "American Standards for the Examination of Water and Wastewater". Another observation was that most tests are carried out using the wet method. Also, some of the analyses are done in-situ because of the remoteness of the sampling points from established laboratory. Although it would appear that the ASEAN countries adopted similar methods of analysis, it was suggested that a review of these methods be made to reflect conditions in the ASEAN countries.

It was also suggested that some biotic indices could be used to counter-check the physico-chemical characteristics of the water. Some work in this direction are already underway. Examples are: analyses of the algae growth potential of rivers flowing into reservoirs; and studies on the flora in the Straits of Johore and effluent outfalls.

It was suggested that the exchange of technical information on common areas of interest be looked into. This could be at Governmental or professional level, as this would enhance water quality management activities in the region.

It was cautioned that good quality water as measured by physico-chemical characteristics alone may not imply an ideal environment for the promotion of aquatic life as other factors, such as the availability of hatching grounds for fishes, are also necessary.

(6) Analytical Quality Control and Assessment  
of Limits for Analytical Data

Mr Tok Gek Chong of Singapore discussed briefly on the analytical quality control and assessment of limits for analytical data (Annex 9).



He stressed that quality control of analytical data started with sample collection. Data from the laboratory could only be of value if they accurately described the characteristics and concentrations of constituents in the water sample.

He mentioned that to achieve reliable and accurate data, the laboratory should be staffed with trained personnel who could perform the required tests. The physical facilities and equipment should also be adequate.

He concluded his presentation by giving an account on the development of quality control charts. The assessment limits for analytical data would best be determined from the precision and accuracy quality control charts which should form a crucial part of the comprehensive quality control assurance programme.

In the discussion that followed, it was stressed that there was a need to have a training programme to enable new staff to acquire the skills necessary for analytical procedures. The importance of an analyst understanding the meaning of the results obtained and their relationship with other parameters could not be over-emphasised. This would entail conducting a short course covering concepts related to laboratory tests performed in addition to training of laboratory skills. Furthermore, it was observed that laboratory staff were generally not interested in the maintenance of their equipment but only on their analytical results. This over-dependency on others in the maintenance of laboratory equipment was not desirable. Within a laboratory set-up there should be at least someone trained to maintain the equipment and this training could be part and parcel of the laboratory training programme.

A suggestion was also made on the licensing of laboratory analysts. A test system could be used for the purpose of certifying recognised competent analysts. Sample results submitted by licensed laboratory analysts would be accepted by the enforcement authority in good faith. This would indirectly reduce the heavy work load on the enforcement authority and also minimise disputes as well.

It was further pointed out that advanced laboratory equipment should not be purchased merely for their sophistication. The practicability and usefulness of these equipment should be evaluated. The ability of suppliers to provide good, prompt and satisfactory maintenance service for these equipment should also be considered before purchases are made.

(7) Selection of Monitoring Stations  
& Frequency of Sampling

Mr Huang Sabin of Singapore presented a paper (Annex 10) on the Selection of Monitoring Stations and Frequency of Sampling in Singapore. In Singapore, water resources are scarce and precious. Comprehensive measurements of water quality in the island are therefore necessary to enable the development of water resources to be carefully planned.

Water quality monitoring serves to check on the success of the pollution control efforts that the government had put in. It also provides back-up statistics and evidence for legal action to be taken against polluters. In addition, the knowledge and information obtained from water quality monitoring could facilitate the implementation of future pollution control plans.

The choice of the number of monitoring stations and the frequency of sampling in a sampling programme is



constrained by availability of means, manpower, expertise and equipment. Singapore has chosen to work on a large number of sampling points and a moderate sampling frequency in the monitoring of water quality on the island.

There is no hard and fast rule to govern the choice of sampling points. The considerations are largely based on experience and common sense. In the case of rivers/canals sampling points, the considerations are representation of the catchment, accessibility, suitability for flow measurement, stability of section profile, and continuity of monitoring. Sampling points for reservoirs are chosen also to give detectable quality gradient. As for sea sampling points, they are chosen relatively close to the shore in order to monitor land based pollution.

The frequency of sampling is dependent on the desired degree of statistical confidence, the objectives of the sampling programme, and the type of parameters measured. It should be adjusted in accordance with the development in the area in order for the monitoring programme to remain useful and meaningful.

In conclusion, the author stressed the importance of exercising flexibility in the implementation of sampling programmes. It is necessary to review and modify the sampling programmes on a regular basis in view of the ever changing water quality and pollution control objectives.

In the discussion that followed, a comment was made on the practice by Singapore to take samples from rivers only at low tides. There could be a difference in the variation of parameters against the depth between low and high tides. To this, it was agreed that there could be distinctive difference for the case of partially stratified estuaries and big rivers, but the rivers in Singapore are much too small for such cyclic variation to be detected.

As to whether stratification would be formed in estuaries in this region, Dr Ratasuk clarified that, mixing at low flow condition could destroy stratification. However, at high flow condition, there could still be stratification in estuaries.

It was further commented that before the choice of sampling points and the frequency of sampling could be determined, the land use plan and the inventory of waste sources in the area should first be consulted. The frequency of sampling should be chosen to provide sufficient data to enable an accurate and meaningful correlation or trend to be determined.

It was mentioned that chromium was detected in the bottom sediment along certain coasts of Indonesia where cooling water was discharged. In Singapore, however, as sea water used for cooling purposes is not recycled, only traces of chromium and other heavy metals have been detected.

On the question of ground water monitoring in Singapore, it was clarified that only bacteriological tests are carried out. The reason is that ground water is scarce and is not extensively used in Singapore. The island has an extensive system of potable water supply to serve nearly the whole population.

#### 3.4 Summary of Field Visits

Field visits were arranged for participants and observers to see pollution control practices in six factories and a zoo. A visit was also made to a large wastewater treatment plant serving a new town. Brief description of each site visited can be found in Annex 11. Of the eight treatment plants visited, two plants employed physico-chemical processes for removing such pollu-



tants as oils, nickel, copper, chromium, cyanide, etc. The other six plants removed organic pollutants using various aerobic biological processes such as aerated lagoons, activated sludge and bio-filters. At the Bedok Wastewater Treatment Plant, the participants also studied the sludge treatment process in addition to the activated sludge plant.

In addition to visiting the wastewater treatment plants, participants also visited the Department of Scientific Services to see the operation of the GC/MS system and the Electron Captured GC system. The two systems are computerized and can be used for identification and determination of pesticides in water.

### 3.5 Summary of Group Study

The group study occupied the whole morning session on the fourth day of the Workshop. The content of each group study can be summarized as follows:

#### Group I - Planning, Management & Engineering

Mr Chiang Kok Meng briefed the participants on the organisational set-up and function of the Ministry of the Environment.

He also informed them of the various levels of control to ensure that proposed developments do not later create environmental problems. He touched on the Land Use Concept and development control. He also briefed the participants on other forms of control eg. control on allocation of industrial premises, control on the discharge of trade effluents, import of anionic detergent, storage of toxic chemicals, and control/enforcement on the quality of effluents discharged.

Mr Foong Chee Leong outlined the procedure adopted by Singapore in the control and management of industrial effluents from factories. The Trade Effluent Regulations, 1976 is the main legislative instrument. Under the regulations, an industry must obtain a permit from the Sewerage Department for the discharge of trade effluent into a public sewer or a watercourse.

At the start of the exercise, a survey was carried out to obtain an inventory of industries which discharge trade effluent. This included determination of the types and strengths of the effluents. Thereafter the industrialists were required to apply for permission on prescribed forms (Annex 12) to discharge the trade effluents.

Industries whose trade effluents did not comply with the prescribed standards, were required to install a treatment plant. The industries could either rely on their own expertise or engage a consultant to design and install the treatment plant.

The design and construction of a treatment plant was usually undertaken in three stages viz:

- (1) Preliminary design - this involves site investigation, effluent sampling and testing, laboratory studies, evaluation studies and treatment proposal;
- (2) Detailed engineering design after approval has been obtained from the Sewerage Department on the treatment proposal; and
- (3) Construction and commissioning of the treatment plant.

A detailed guideline on these three stages is given in Annex 13.



After the treatment plant had been constructed and commissioned, the factory would be given a period of time to ensure that the treatment plant would function properly. After which, regular monitoring of the treated effluent would be carried out.

In the discussion that followed, the Chairman clarified that it was an offence to construct any form of by-pass structure for discharging untreated trade effluent.

Mr Foong emphasised that any agreement between the factory and its consultant was strictly a matter between themselves. However, the Controlling Authority has the right to require the consultant to make amendments in the treatment proposal. The industry being the discharger, would however, be solely responsible for ensuring that the treated effluent complies with the prescribed standards. This practice is also adopted in the other member countries.

Dr Ratasuk pointed out that it was essential that the Controlling Authority be staffed with qualified and experienced officers. Otherwise, the officers would not be able to carry out a constructive evaluation of the consultant's proposal.

#### Group II - Monitoring & Laboratory

Demonstrations on the use of laboratory equipment, such as the AA, automatic analyser and TOC, were conducted. Participants were also given the opportunity to try using them.

Participants discussed problems associated with instrumentation in water quality analysis. They also raised the need to train personnel on the operation and maintenance of sophisticated laboratory equipment.

Participants shared the view that the procedure for phenol determination in the Standard Methods does not differentiate phenolic compounds from different sources. Mr Tok suggested that the GC Mass Spectograph is a possible alternative method.



ANNEX 1

LIST OF PARTICIPANTS & OBSERVERS

ASEAN/UNEP STUDY TOUR & TECHNICAL WORKSHOP  
ON WATER QUALITY MONITORING & MANAGEMENT  
14 - 19 DECEMBER 1981, SINGAPORE

LIST OF PARTICIPANTS

INDONESIA

- 1        Ir. Badruddin Mahbub  
          Head of Division Water Quality & Environment  
          Institute Hydraulic Engineering
  
- 2        Ir. Sri Hudyastuti  
          Staff  
          Ministry of Environment

MALAYSIA

- 3        Tengku Bakry Shah  
          Environmental Control Officer  
          Ministry of Science, Technology & Environment
  
- 4        Mr Shariff Mustaffa  
          Senior Assistant Environmental Control Officer  
          Ministry of Science, Technology & Environment

PHILIPPINES

- 5        Ms Amy Lecciones  
          Senior Environmental Planner  
          National Environmental Protection Council  
          Ministry of Human Settlements
  
- 6        Mr Edgardo Alpay  
          Acting Chief  
          Water Pollution Control Division  
          National Pollution Control Commission

SINGAPORE

- 7        Mr Tan Teng Huat  
          Assistant Director  
          Environmental Engineering Division  
          Ministry of the Environment
  
- 8        Mr Chiang Kok Meng  
          Chief Engineer (Pollution Control)  
          Sewerage Department  
          Ministry of the Environment



- 9 Mr Tok Gek Chong  
Senior Scientific Officer  
Sewerage Department  
Ministry of the Environment
- 10 Mr Foong Chee Leong  
Executive Engineer (Pollution Control)  
Sewerage Department  
Ministry of the Environment
- 11 Miss Seah Huay Leng  
Scientific Officer  
Sewerage Department  
Ministry of the Environment
- 12 Mr Huang Sabin  
Engineer (Pollution Control)  
Sewerage Department  
Ministry of the Environment

#### THAILAND

- 13 Mr Suwit Uawanichkul  
Chemist  
Office of the National Environment Board
- 14 Mr Adisorn Naphavaranonh  
Environmental Engineer  
Department of Industrial Works  
Ministry of Industry

#### OBSERVERS

- 15 Mr Yeo Siow Jin  
Principal Civil Engineer  
Construction & Maintenance Department  
Port of Singapore Authority
- 16 Mr Tony Chee Kim Hee  
Port Chemist  
Chemistry Department  
Port of Singapore Authority
- 17 Mr Loh Hon Keong @ Lo Fa Kheong  
Engineer  
Public Utilities Board
- 18 Mr Wong Kee Wei  
Engineer  
Public Utilities Board

- 19 Mr Richard Lim Yew Hang  
Manager  
Ulu Pandan Sewage Treatment Works  
Sewerage Department
- 20 Mr Wah Yuen Long  
Manager  
Bedok Wastewater Treatment Works  
Sewerage Department
- 21 Mr Wong Nung Sim  
Engineer (Planning & Design)  
Sewerage Department
- 22 Mr Lee Teng Koh  
Engineer (Building Plan Unit)  
Sewerage Department

UNEP

- 23 Dr Sermpol Ratasuk (Consultant)  
Deputy Director  
Thailand Institute of Science & Technology
- 24 Mr R M Lesaca (Observer)  
Deputy Regional Representative



ANNEX 2

WORKSHOP PROGRAMME

PROGRAMME

ASEAN/UNEP STUDY TOUR AND TECHNICAL WORKSHOP  
ON WATER QUALITY MONITORING AND MANAGEMENT  
14 - 19 DEC '81, SINGAPORE

---

- Venue: Registration & Opening Ceremony - Department of Trade  
Conference Room, Suite 201,  
2nd Floor, World Trade Centre  
Telok Blangah Road  
Singapore 0409
- Worskhop Sessions : - Sewerage Department  
Conference Room H, Suite 901  
9th Floor, World Trade Centre  
Telok Blangah Road  
Singapore 0409

Monday, 14 Dec 81

- 9.00 am : Registration
- 9.15 am : Opening Ceremony
- 9.30 am : Reception
- 10.30 am : Philosophy of Pollution Control
- 12.15 pm : Lunch Break
- 2.00 pm : The Management of Domestic  
Sewage and Industrial Effluent
- Indonesian Information Paper -  
"Several Aspects of Water  
Quality Management in  
Indonesia"
- Singapore Information Paper -  
"Development of Water  
Resources & Water Pollution  
Control in Singapore"

Tuesday, 15 Dec 81

- 9.00 am : Review of Analytical Methods  
for Water Pollutants
- Analytical Quality Control  
and Assessment of Limits for  
Analytical Data



12.00 pm : Lunch Break

1.30 pm : Field Visit

Wednesday, 16 Dec 81

8.15 am : Field Visit

1.00 pm : Lunch Break

3.00 pm : Selection of Monitoring Stations  
and Frequency of Sampling

Thursday, 17 Dec 81

9.00 am : Individual Study Groups

12.00 pm : Lunch Break

1.30 pm : Field Visit

Friday, 18 Dec 81

8.30 am : Field Visit

12.30 pm : Lunch Break

2.00 pm : Laboratory Demonstration

3.30 pm : Workshop Assessment

Saturday, 19 Dec 81

8.30 am : Summary and Closing Ceremony.

ASEAN/UNEP STUDY TOUR & TECHNICAL WORKSHOP  
ON WATER QUALITY MONITORING & MANAGEMENT  
14 - 19 DECEMBER 1981, SINGAPORE

---

PROGRAMME FOR FIELD VISITS

Tuesday, 15 Dec 81

- 1.30 pm : Depart from WTC
- 2.00 pm : M/s Matsushita Refrigeration Ind (S) Pte Ltd  
1 Bedok South Road (1646)
- 3.15 pm : Depart
- 3.30 pm : Bedok Wastewater Treatment Works  
Koh Sek Lim Road (1648)
- 5.00 pm : Depart for WTC/Hotel Asia

Wednesday, 16 Dec 81

- 8.15 am : Depart from Hotel Asia for WTC
- 8.30 am : Depart from WTC
- 9.00 am : M/s Beecham Pharmaceuticals (Pte) Ltd  
Quality Road (2261)
- 10.20 am : Depart
- 10.30 am : M/s Kyowa (S) Pte Ltd  
2-8 Pioneer Lane (2262)
- 11.30 am : Depart
- 11.40 am : M/s Mobil Oil S'pore Pte Ltd  
18 Pioneer Road (2262)
- 1.00 pm : Lunch
- 2.30 pm : Depart for WTC

Thursday, 17 Dec 81

- 1.30 pm : Depart from WTC
- 2.00 pm : M/s Amoy Canning Corpn (S) Pte Ltd  
13 km Upper Bukit Timah Road (2158)



- 3.00 pm : Depart
- 3.10 pm : M/s Yeo Hiap Seng Ltd  
950 Dunearn Road (2158)
- 4.30 pm : Depart from WTC/Hotel Asia

Friday, 18 Dec 81

- 8.15 am : Depart from WTC for Hotel Asia
- 8.30 am : Depart from Hotel Asia
- 9.30 am : Singapore Zoological Gardens  
80 Mandai Lake Road (2272)
- 12.00 pm : Depart
- 12.30 pm : Lunch
- 2.00 pm : Laboratory demonstrations at Department of  
Scientific Services
- 3.15 pm : Depart
- 3.30 pm : Workshop Assessment
- 4.45 pm : Depart for Hotel Asia

ANNEX 3

LIST OF GROUP STUDY



GROUP STUDY

THURSDAY, 17 DEC 81

Group I - Planning, Management & Engineering

Ms Amy Lecciones

Mr Adisorn Naphavaranonth

Ir Sri Hudyastuti

Mr Shariff Mustaffa

Mr Edgardo Alpay

Leaders

Mr Chiang Kok Meng

Mr Tan Teng Huat

Leaders

Mr Foong Chee Leong

Mr Huang Sabin

Group II - Laboratory & Monitoring

Ir Badruddin Mahbub

Tengku Bakry Shah

Mr Suwit Uawanichkul

Leaders

Mr Tok Gek Chong

Miss Seah Huay Leng

Observers - Group I

Mr Yeo Siow Jin

Mr Loh Hon Keong

Mr Wong Kee Wei

Group II

Mr Tony Chee Kim Hee

Rapporteurs - Mr Lee Teng Koh

Mr Wah Yuen Long

ANNEX 4

OPENING ADDRESS



TEXT OF OPENING ADDRESS BY DR R S BHATHAL, DIRECTOR, SINGAPORE SCIENCE CENTRE AT THE OPENING OF THE ASEAN/UNEP STUDY TOUR AND TECHNICAL WORKSHOP ON WATER QUALITY MONITORING AND MANAGEMENT HELD ON 14TH DECEMBER 1981 AT 0915 HRS AT THE DEPARTMENT OF TRADE CONFERENCE ROOM, SUITE 201, 2ND FLOOR, WORLD TRADE CENTRE, SINGAPORE.

---

On behalf of the Government of Singapore, I wish to extend a warm welcome to all the distinguished delegates from the various ASEAN countries. We are indeed very honoured to have been given this opportunity to host the first of the technical workshops and study tours recommended by the ASEAN Experts Group on the Environment at their 4th Meeting held in Singapore from 8-10 April 1981.

The objectives of the Technical Workshop and Study Tour are:

- a) to promote technical collaborations among the ASEAN countries based on Singapore's experience in managing domestic and industrial effluents;
- b) to develop expertise in the ASEAN region to generate complete, accurate, representative and comparable data on water quality for better management.

This Technical Workshop and Study Tour is sponsored by UNEP and organised by Singapore's Ministry of the Environment. I understand that for the study tour, the Ministry of the Environment has arranged for the delegates to be taken on a visit of seven local companies to observe how industrial effluent is treated. The delegates will also be visiting the Bedok Wastewater Treatment Works and the laboratories of the Department of Scientific Services and the Ministry of the Environment.

As you know there are several environmental concerns permeating policy and planning in water pollution. These range from problems of availability and storage to those of adequacy of supply and of appropriate standards for water quality to the ways in which water is used in domestic, industrial and agricultural applications and to the problems of discharge of effluents of various types. Today, the problems of water quality and water pollution are critical not only in the ASEAN countries but also in many other countries of the world. The World Health Organisation estimates that each year as many as 500 million people are affected by debilitating or incapacitating diseases transported by water : such as typhoid, infectious hepatitis and many varieties of gastrointestinal disorder.

The use of waterways as a medium for the dissipation of sewage and human wastes is one of the key problems in water pollution. The direct impact of sewage on fresh-water is compounded by the contribution of industrial process effluents, by-product heat and toxic chemicals, which all serve to cause radical transformations in the biosystems of waterways and the water in them.

Water pollution is often a problem of accumulation of several impacts: industrial wastes and chemicals, sewage, nitrates leaked from fertilizers and hot water from electricity generating stations, are all examples of common types of pollution which in combination have a much more severe effect than individually. Although water has a capacity for cleaning itself to a certain degree, one of the more serious criteria which have to be applied in pollution control is the sheer volume of pollutants entering waterways : the eutrophication of waterways, or their ageing through the impact of the pollution load, is a reflection of the



total load as well as of the type of individual loadings entering the waterway.

Bearing this in mind, Singapore has had to exploit its limited water resources as effectively as possible in order to meet the growing demand for water for domestic, industrial, agricultural and other uses. The philosophy of water pollution control in Singapore has been to tackle the problem at source. In effect the quality of the water supply in Singapore has been protected by the following measures:

- a) controlling activities in the reservoirs (such as boating) and on adjacent lands; and
- b) controlling wastewater discharges into watercourses.

Pollution in drains, streams, rivers and coastal waters is minimised by controlling all wastewater discharges from domestic, industrial and other sources. Trade effluents (i.e. wastewaters originating from any trade, business, manufacture or building construction) must be treated to prescribed standards of quality before it is discharged into the public sewer or watercourse (where sewers are not available).

Over the last decade (1970-79) Singapore has invested \$644 million for the expansion of its sewerage infrastructure. \$167 million was spent in FY 1980 while \$131 million has been budgeted for FY 1981 for further expansion. At present there are 1440 km of sewers, 1639 sewage treatment plants and 6 major treatment works with a total capacity of 780,000 m<sup>3</sup>/day. About 81 percent of the population is served by modern sanitation. This figure compares very favourably with that of some advanced countries like

England (95%), Sweden (84%) and United States (75%).

Singapore's catchment and rural areas are served with R2. R2 is a toilet specially developed by the Sewerage Department of the Ministry of the Environment. About 5,600 households in the catchment and rural areas use the R2. Households were required to install the R2s because they lacked proper sanitation and were not served by a sewerage system. The Sewerage Department hopes to phase out nightsoil buckets by 1984. These are still being used by about 12,000 premises.

The Sewerage Department makes regular inspections of industrial and trade premises to ensure that all necessary measures are taken to minimise the discharge of waterborne pollutants. The Department also encourage factories to recycle water in their manufacturing operations wherever possible. With rising energy costs it may be extremely beneficial for the industrial sector to start thinking more seriously of the concept of recycling. Recycling can make an effective contribution to industrial processes in the following ways :

- a) reduction in energy consumption
- b) reduction in raw material consumption
- c) reduction in waste quantities
- d) improvement in ecological stability

In fact, the use of recycled water will not only save water for the factory but will also reduce the volume of wastewater discharged and thus simplify subsequent treatment. Good house-keeping in a factory can make a significant contribution to economy in the use of water. A detailed study of factory operations may reveal possibilities of reducing water consumption and water pollution by relatively simple modifications to certain procedures.



In those cases where alternatives are available factories should consider making use of these processes and raw materials which will give rise to lesser pollution problems.

In industry, the saving of raw materials through the recycling of production residues and the processing of used products has been practised for a long time. However, wastes are only recovered where this is profitable. Any waste which cannot be recovered profitably is handed over to society for disposal or released into the natural environment.

The very high costs for waste disposal are borne by society. Costs for repairing ecological damage and the "costs" of irreparable ecological damage are likewise borne entirely by society. The "ecological costs" or "social costs" are not usually taken into account in the economic cost-benefit comparison.

The application and viability of recycling should not just be decided on operational management criteria. The decisive factor must be what is socially-economically viable and, in the long term, most sensible.

A cost comparison of "throw-away" with "recycling" should therefore not just take the costs for waste disposal into consideration. The costs of obtaining raw materials (in this case water) and the "social costs" must likewise be included in the calculation.

Recycling also gives rise to costs. However, in most cases, recycling of wastes is a profitable solution.

Pg 6

I hope your deliberations and discussions will help to solve some of the problems associated with the monitoring and management of water quality.

It now gives me great pleasure to declare the ASEAN/UNEP Workshop and Study Tour on Water Quality Monitoring and Management open.



ANNEX 5

PHILOSOPHY OF POLLUTION CONTROL AND WATER  
QUALITY MONITORING AND MANAGEMENT

Philosophy of Pollution Control and Urban Water  
Quality Monitoring and Management

by

Sempol Ratasuk

---

1. Introduction

This paper is prepared specifically for the ASEAN/UNEP Study Tour Cum Technical Workshop on Urban Water Quality Monitoring and Management, to be held in Singapore from December 14-19, 1981. As specified in the Terms of Reference for the consultant, this paper is required to be an overview paper on the Philosophy of Pollution Control and Water Quality Data Management as applicable to the ASEAN region. The consultant has designed this paper to serve as the basis for discussions in the Workshop thus, the paper does not attempt to discuss the technical details of the various components of water quality management.

The consultant cannot, given the broad scope of the paper, exclude pollution control and water quality monitoring from a full urban water quality management. However, the consultant firmly believes that, in working on any subject, one must clarify and understand the philosophy and concept of the subject before one may discuss the technical details.

Therefore, the consultant has in the first place, concentrated upon developing the conceptual basis of environmental management. Then, he proceeds to review the concepts and practices of management of domestic sewage and industrial effluent, and water quality monitoring, drawing on his experience in Thailand; whenever appropriate.



## 2. The Conceptual Framework

### 2.1 The Concept of Pollution

There is one undisputable law that no process in this world, whether it be natural or man-designed, that can achieve 100% conversion efficiency. Therefore, the outputs in terms of mass and/or energy are always less than the inputs. Since mass and energy neither be created nor destroyed, thus any conversion process has wastes, the amount of which depends on the conversion efficiency. The wastes after released from the production process must go somewhere. Eventually, they end up in the physical environmental systems; i.e. air, water, and soil. This described situation is diagrammatically shown in Figure 2.1

Environmental pollution is defined<sup>(1)\*</sup> as  
"the presence, the discharge or the liberation into the waters, air, or soil, of all or whatever form of material or energy, with intensity, in quantity, in concentration or with characteristics which produce conditions in the waters, air, or soil which are:

- (a) improper, toxic or offensive to health,
- (b) inconvenient to the public well-being,
- (c) damaging to fauna and flora, or
- (d) prejudicial to the safety, use and pleasure of public property or to normal community activity."

---

\* Number in parentheses corresponds to the number in the Reference Section.

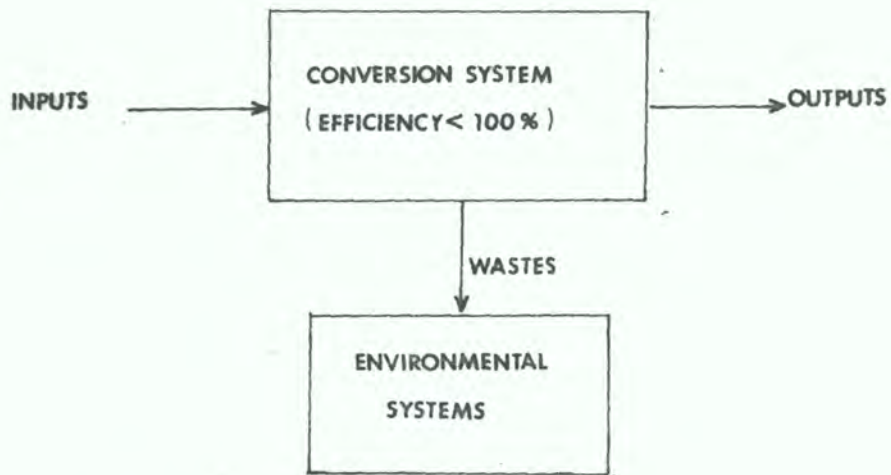


Figure 2.1 Concept of Pollution

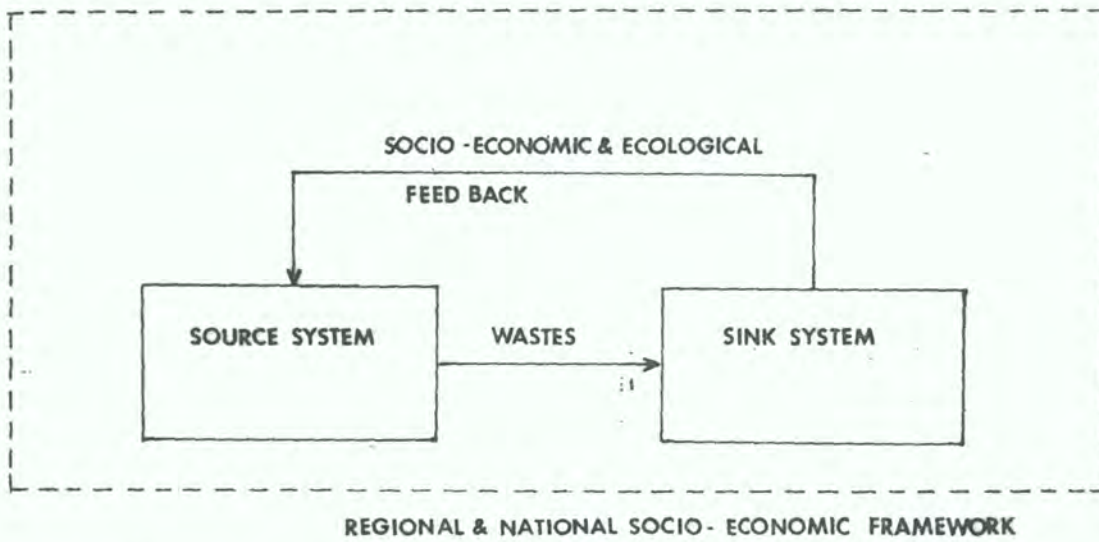


Figure: 2.2 Concept of Environmental Management



The discussion in the first paragraph and the above definition of environmental pollution, indicate that air, water and soil are natural resources which are utilized for various beneficial purposes for man living and at the same time, are also used for waste disposal, that environmental pollution is in fact, the indication of unbalanced use of the environmental resources; and that man also cares for fauna and flora living in the environmental system.

Therefore, pollution control is essentially, an attempt to balance the beneficial use of the environment with its unavoidable use as waste sinks. Since man, flora and fauna are linked through a complicate and intricate web of the biosphere, pollution control does not only aim to achieve social and economic goal, but also aim to achieve ecological goal.

## 2.2 The Concept of Environment Quality Management

Environmental management is essentially resource management. However, environmental management concerns mainly with the quality aspect of the environmental resources. The whole concept is how to achieve the desired social, economic, and ecological goals in the most cost effective way. Reduction of the amount of wastes discharged into the environment means cost increase in one hand, and benefit gain in another hand. In theory, the environmental quality should be maintained at the marginal point at which one additional dollar spent in pollution reduction is equal to one additional dollar gained from further improvement of environmental quality. In practice, this marginal concept cannot be transformed into physical reality because:

(a) many pollutants are involved and each pollutant has different adverse impact on environmental quality and the ecosystem,

(b) uses of environment especially water, are intangible, thus are difficult to determine their monetary benefits; and

(c) pollution control facilities cannot be designed to give precise efficiency.

In real world, environmental management system has to compromise between theoretical optimum condition and practical optimum condition.

Environmental management system has to function within a given operational framework and strives for the established objectives and goals. The operational framework is the environmental policy. It should be made clear that policy provides answers to the WHY and WHAT FOR. Therefore, it has to be based on systematic and scientific analysis of all the relevant aspects. Policy will provide guidelines for setting goals and objectives of the environmental management. What have to be done and how it should be done to achieve the goals and objectives are essentially, the subject of planning.

Planning is anticipatory decisions making which is based upon scientific and logical analysis of the problem. A plan is essentially, a systematic presentation of the decisions or the actions intended to carry out to reach the goals and objectives within a given time frame. Therefore, planning is a component of the environmental management system.

Given that pollution control facilities have been constructed, the environmental management will concern itself with the following tasks; operating pollution control facilities, controlling the effluent discharge, monitoring environmental quality; and research and study for backing up the other management tasks. To carry out these tasks efficiently and effectively will require financial input, planning and management skill, well-equipped laboratories, legal and financial instrument, effective control mechanisms and procedures, expertise, and appropriate organizational structure.

### 2.3 The Concept of Water Quality Management

Water quality management is the management of two coupled



systems within the regional and national socio-economic framework as diagrammatically shown in Figure 2.2. The sink system is natural receiving water bodies which may be a network consisting of a main river or estuary and a system of tributaries streams or canals. For some coastal areas the sink system does include the marine system. The source system normally covers an entire water basin which contains various waste generation sources (urban areas, agricultural areas, and industries). Clearly, urban water quality management (UWQM) is only a component of the whole water quality management system.

The scope of management of the source system involves not only control of the pollutant discharge from various sources but also control of land use. The concept of land use control in water quality management is to prevent and minimize the pollution, to facilitate the control of pollutant discharge, and to increase the economy of scale in pollution reduction through centralized treatment. Industrial estate is one example of land use control.

There is a linkage between regional socio-economic development and water quality management. For a given river basin, the required water quality level will be a constraint of the development. In other words, the water quality requirement is one essential criteria for formulating population policy, human settlement policy, agricultural policy, industrial policy, and land use policy. Therefore, water quality management will have to be integrated with the management of other socio-economic sectors.

As in all other resources management, water quality management will have to have goals and objectives. The goals herein, means what to be achieved at the end of the efforts while the objectives are what must be achieved along the path towards the goals. In water quality management, the goals are social, economic, and ecological benefits to be accrued from a certain level of water quality. The objectives are to maintain water quality at the required level in the most cost-effective way. In practice, the objectives are translated into water

quality standards and effluent standards which are sets of maximum tolerable limits of various quality parameters for the receiving waters and the discharge effluent.

The established goals and objectives for water quality management must be realistic and achievable within a certain time frame. The goals may be set up in stages starting from aesthetic appreciation towards water-contact recreation. These goals require different sets of standards for instance, a minimum dissolved oxygen (DO) of 0.5 mg/l is required for aesthetic appreciation whilst a minimum DO of 5.0 mg/l is required for water contact recreation. To increase the minimum DO level from 0.5 mg/l to 5.0 mg/l means great increase in pollution control cost. Therefore, in establishing the goals, the following questions will have to be answered:

(a) Is that particular water use really needed and by whom ?

(b) Can the goals be achieved within a given time frame and minimized resources ?

In case of UWQM these two questions imply that UWQM is an integral part of urban development. As such, its budget allocation cannot be considered in isolation from other urban development projects particularly from such environmental improvement projects as solid wastes, drainage, air pollution, etc.



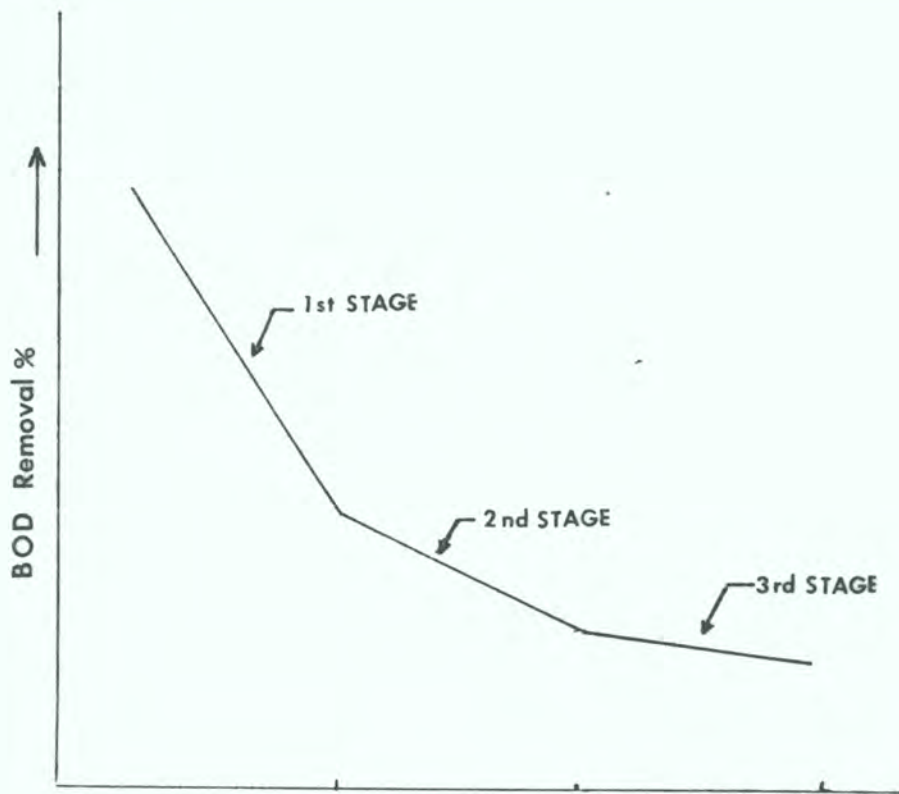


Figure 3.1 Efficiency of a Multi-Stage Biological Process

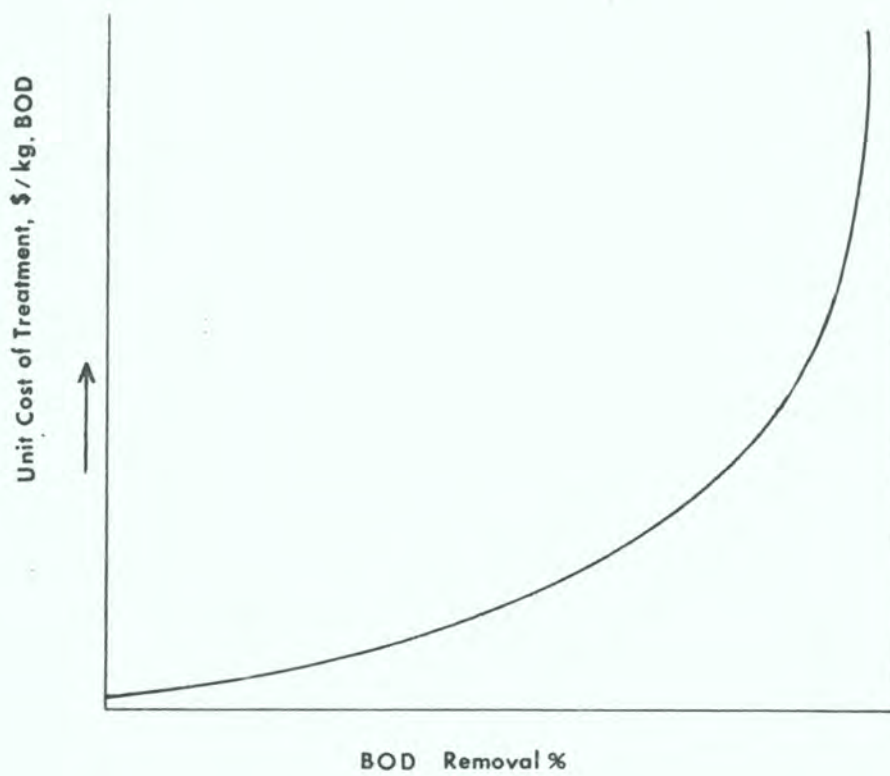


Figure 3.2 Response of Treatment Cost to Treatment Efficiency

production capacity, lack of space, and inefficient production technology make waste treatment too much a burden for most small factories. Strict enforcement of the effluent standards would be the same as ordering them to close down.

A large number of factories (15,000 in the case of Bangkok) make effective control extremely difficult to achieve. Therefore, the effectiveness of the control programme depends to a great extent on cooperation from the industries. The cooperation in the author's experience, is hardly obtained from industries particularly from small industries. The situation is more or less, similar to a cat chasing mouse game in which the control agency plays cat and the factories play mouse.

With limited financial and human resources, the control authority in most cases, has to concentrate its efforts on some large industries. This selective control strategy may be effective if the total pollution load from the key industries is significantly large compared with the total pollution load from small industries.

Another approach to the control of small industries is to provide them with appropriate incentives to move into an industrial estate. Once concentrated in a small area, an economy of scale can be benefited through centralized treatment. However, without using appropriate legal measures, this approach will never work.

The control agency generally, is reluctant to shut down the factories for fear of adverse socio-economic consequences. Especially in a country like Thailand where unemployment and economic slump are serious problems at present, closing factories will certainly not be an appropriate solution.

The discussion thus far, seems to imply that there is no way to solve the pollution problems of small industries. In fact, it is not that hopeless. For small industries producing small volume of organic wastes (BOD), the problem can only be solved with the provision



of community-wide waste collection and treatment systems. In the case of small electroplating shops, it would be feasible to collect the wastes from various shops and treat them in a central treatment plant which will have to be sited within a reasonable hauling distance from groups of factories. A number of central treatment plants will be needed to cover the whole urban area. Valuable heavy metals can be recovered to offset the operating cost. This concept of central treatment and recovery system was primarily explored in Thailand<sup>(3)</sup> and is being pursued by the consultant and his staff with significant financial support from UNEP.

### 3.1.2 Domestic Sewage

Only few urban areas in the ASEAN region have integrated central wastewater collection and treatment system. Normally, human excreta receives only rudimentary treatment in cesspools or septic tanks while sullage is directly discharged into storm drains together with septic tank effluent. Sewers are normally laid along streets and drain into natural receiving waters at many points.

Construction of an integrated sewerage system after the urban area is fully developed is technically difficult and very costly considering the direct construction cost and the indirect cost incurred by disruption of traffic and utilities such as telephone services, during the construction. Normally, the sewerage system costs many times more than the central treatment plant. In the case of Bangkok, Camp, Dresser and McKee<sup>(4)</sup> estimated in 1968 that a separate sewerage system for Bangkok would be US \$ 544 million for serving the area of 370 km<sup>2</sup> and 3,240,000 people. The central treatment plants would add another US \$810 million. This budget was found to be too much a burden for the city administration. Therefore, the plan prepared by Camp, Dresser and McKee has not virtually been implemented.

Due to the high cost of sewerage system as well as the technical difficulty in its construction in fully developed urban area, other control alternatives have been worked out. In Japan



some urban areas have nightsoil collection systems.<sup>(5)</sup> The nightsoil collected every one or two weeks is centrally treated by anaerobic digestion. Another control alternative is to install small waste treatment plants for individual houses. The treatment plant employing the extended-aeration activated-sludge process, is connected to the toilet, thus receiving only excreta. The sullage is still discharged into public sewers. Obviously, both the nightsoil collection system and the individual household waste treatment system will remove only a portion of the pollution load. Studies<sup>(6)</sup> in the United States indicate approximately 50% contribution of the BOD load by sullage as shown in Table 3.1. However, proper treatment and disposal of human excreta, may not be sufficient for solving water pollution problem, but will significantly help minimize health hazard of water pollution.

Another approach that has been explored in the United States is pressure sewer system.<sup>(7)</sup> This system may be less expensive and easier to construct than conventional gravity sewer system but may be more expensive and more difficult to operate.

### 3.2 Effluent Standards

#### 3.2.1 Industrial Effluent

Industrial effluent standards should be set up with due consideration given to the water quality standards, and the practical feasibility of treatment technologies. In practice, there should be different sets of effluent standards, each set applicable to a particular class of water use. Also, for some particular industries, specific standards should be applied.

Figure 3.1 shows a relationship between the efficiency of biological treatment and the number of treatment stages. The first stage will achieve highest efficiency and the efficiency will fall rapidly in the subsequent stages unless the mode of treatment in the subsequent stages is changed, for example, from anaerobic to aerobic



Table 3.1 Average pollutional Loading and wastewater Volume from Domestic Household (4 members) in USA.

Wastewater event	Number per day	Water Volume per use in gallons (a)	Total water use in gallons	BOD in pound per day (b)	percent
Toilet Sullage	16	5	80	0.208	49.2
Bath/Shower	2	25	50	0.078	18.4
Laundry	1	40	40	0.085	20.1
Dishwashing	2	7	14	0.052	12.3
Total			184	0.423	100.0

(a) Liters = 3.8 x gallons

(b) Grams per day = 453 x pounds per day

mode; or from chemical to physico-chemical mode. Therefore, there is a certain practical limit of treatment efficiency. In the consultant's experience, biological treatment can achieve not more than 95% BOD removal only for wastes having COD/BOD ratio greater than 2, and for wastes having COD/BOD ratio less than 2, 98-99% BOD removal is possible. In laboratory practice, the remaining 2-5% BOD can be significantly removed using chemical precipitation and carbon adsorption. However, additional treatment cost is prohibitive as shown in Figure 3.2.

Appendix 1 presents revised effluent standards for Thailand proposed by a USAID expert<sup>(1)</sup> and Appendix 2 presents the effluent standards presently being enforced by the Ministry of Industry. In the consultant's experience it is not economically possible for a number of industries to comply with the existing BOD standard. An example is the case of molasses alcohol distilleries generating stillage having an average BOD of 30,000 mg/l. In this case the required effluent of 60 mg/l BOD means 99.8% BOD reduction. This particular waste has COD/BOD ratio of about 3.2, thus only 96% BOD removal or an effluent of 1,200 mg/l BOD is the most that can be expected. Undoubtedly, no factories would want to invest in constructing a waste treatment plant if they know well that it will never produce the effluent of the required standards.

### 3.2.2 Domestic Sewage

Effluent standards for domestic wastewaters are rather straight forward compared with those for industrial effluents. In the beginning stage of water pollution control effort, the standards may be concentrated mainly on BOD, Suspended Solids, and MPN. At the advanced stage, removal of nitrogen and phosphorus may be required and conversion of ABS detergents to LBS types is also desirable. The conversion may increase the production cost by 15 % and it will certainly be passed on to the consumers.



### 3.3 Technological Opportunities

#### 3.3.1 Industrial Wastes

Industrial wastes indicate production losses, thus the pollution load is a direct measure of production losses. Legal enforcement of pollution control laws creates economic incentive to reduce the production losses, through in-plant improvements, and improvement of production technologies. Regarding waste treatment cost as a component of production cost, the new concept in industrial waste management is to optimize the production cost as diagrammatically shown in Figure 3.3. Reduction of pollution load through process and in-plant improvements, and waste recovery or utilization are two opportunities which must be explored thoroughly before making decision on waste treatment. Waste recovery and utilization in small industries in most cases, is not financially feasible due to the small economy of scale. Nevertheless, financial feasibility of various theoretical opportunities should be thoroughly investigated.

In the treatment of organic industrial wastes in urban area, the activated sludge process has been traditionally, used. This preference is understandable since the activated sludge process is highly efficient under proper operation, and is very compact. In addition, the electricity cost was so high that other alternative biological processes would be more economically attractive.

Since the energy cost keeps on rising, the activated sludge process will be increasingly less economically attractive compared with other low-energy, high-rate processes. Trickling filter using plastic media is becoming increasingly attractive. The consultant designed a bio-filter plant for treating soft-drink waste having 1,200 mg/l BOD. The plant has been in operation since April, 1981 and the results so far, have been satisfactory. At the BOD loading of  $1.6 \text{ kg/m}^3/\text{day}$ , the biofilter achieved 69 % COD reduction or 85 BOD reduction.<sup>(8)</sup> No nuisance odour, flies, and birds have ever been observed. From economic analysis under



Thailand's conditions a two-stage plant consisting of a bio-filter and a small activated sludge plant will be more economical than a single large activated-sludge plant. However, in the case of the soft-drink waste the filter effluent is further treated in aerated lagoons to eliminate sludge disposal problem.

For relatively high BOD wastes say over 5,000 mg/l, the anaerobic contact process or the anaerobic filter process is economically attractive, especially if the biogas is used in the industrial process. In the case of small molasses distilleries, the net gain from replacing oil with biogas will recover the investment within 2.1 years<sup>(9)</sup> as shown in Table 3.2. In the consultant's opinion, anaerobic digestion will be becoming more attractive. The anaerobic filter is the most interesting alternative for treating small volume of relatively high BOD wastes.

### 3.3.2 Domestic Sewage

Sewage treatment plant design begins by determining the hydraulic load and BOD load from per capita water consumption and per capita BOD. While the per capita water consumption can be accurately determined from records of water use, the per capita BOD is more or less a conjecture based on experience in other countries. The first sewage treatment plant for a housing estate in Bangkok was designed based on 50 gm BOD/person/day; and the design of subsequent plants followed suit. The consultant and his staff<sup>(10)</sup> found that the actual BOD generation was less than 20 gm/person/day as shown in Table 3.3. This finding helped explain why all the treatment plants in Bangkok have received only one third of the design load.

The activated-sludge process is most popular in sewage treatment. Due to rising electricity cost, trickling filters using plastic media should receive due consideration as discussed in the previous.



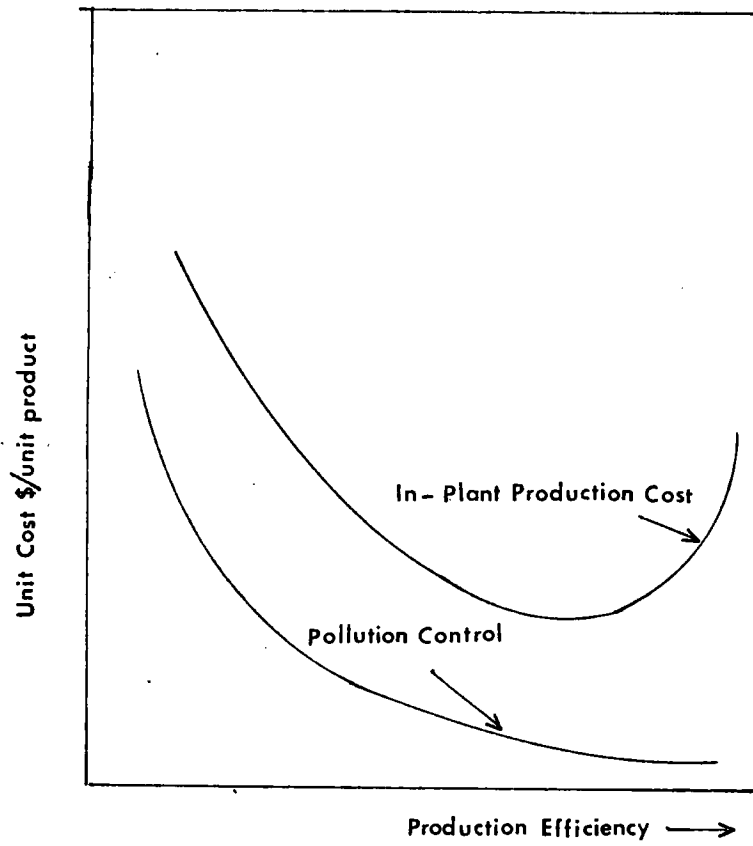


Figure: 3.3 Optimization of Total Production Cost

Table 3.2 Recovery of the investment cost of Anaerobic treatment for mollasses distillery stillage in Thailand

Stillage	=	100	m <sup>3</sup> /d
Construction Cost (Anaerobic Filter)	=	4,400,000	฿
Operating cost	=	420	฿/day
Biogas production	=	3,480	m <sup>3</sup> /d
Heating value of gas	=	3,951	kcal/m <sup>3</sup>
Heating value of fuel oil	=	10,033	kcal/l
Oil equivalent of biogas	=	1,370.4	l/d
Fuel oil cost	=	4.50	฿/l
Biogas cost	=	6,167	฿/d
Net profit	=	5,747	฿/d
	=	2,097,655	฿/yr
Pay - off period	=	2.1	yr

1 us\$ = 23 ฿

Table 3.3 BOD load per cepita per day

Housing Estate	Waste water Volume, l/capita/d	BOD mg/l	BOD load gm/capita/d
Huay Kwang	160	139	22.24
Bang-Bua	152	105	15.96
Bang-na	199	107	21.29
average	170	117	19.89



### 3.4 Effluent Monitoring

Routine monitoring of sewage and industrial effluent is needed for determining if a treatment plant is functioning as designed and if the original design criteria are correct. Data from the effluent monitoring are therefore, "feed-back" on the management of the pollution control programmes operated by the factory and the control agency.

#### 3.4.1 Industrial Effluent

Due to a great number of industries it will not be possible for the control agency to monitor effluents of all the factories. Therefore, the routine effluent monitoring programme must be conducted by the industries. The effluent dischargers must be legally required to submit to the control agency, periodic reports presenting the monitoring data. This requirement will have to be established as a condition in the permit procedure. The control agency will have to design the monitoring programme for each type of industry considering its potential pollution load.

A typical monitoring programme may have to spell out the following requirements;

- (1) The required sampling points covering raw wastes, effluent from various unit processes, and final effluent (in some cases, the sampling may have to cover the receiving waters, benthal deposits, etc.);
- (2) Frequency of sampling, analyses, and observations;
- (3) Sampling and analysis procedures;
- (4) Records to be maintained; and
- (5) Reports required for submission to the control agency.

#### 3.4.2 Sewage Effluent

Monitoring of sewage effluent should be subject to the same rules as those of the sewage effluent. However, since in most cases, sewage treatment plants are owned and operated by municipalities or water pollution control authorities, the control is not as difficult as in the case of industrial effluent.



#### 4. Water Quality Monitoring

##### 4.1 The Conceptual Framework

Water quality monitoring is an integral component of the water quality management system, and is feed back mechanism for the management. A water quality monitoring programme will produce water quality data which will be used for the following objectives;

- (a) To evaluate the achievement of the water quality management;
- (b) To assist the effluent discharge control in identifying major sources of pollution;
- (c) To assess the pollution condition;
- (d) To establish an information base for water quality development planning and ecological study.

These objectives clearly indicate the importance of water quality monitoring in the water quality management. Unsystematic water quality monitoring will yield useless data, thus wasting efforts and resources.

Water quality monitoring is in fact, a process consisting of integrated tasks as follows;

SAMPLING → ANALYSIS → DATA INTERPRETATION → REPORTING

The end product or the output is a report which is issued periodically as deemed necessary in the water quality management programme. Since the monitoring report is an essential basis for making decisions, the report must be founded upon reliable, accurate, and meaningful data. Therefore, there must be a quality control system for the whole process of water quality monitoring. This means

the sampling programme must be properly designed to obtain truly representative samples, the samples must be well preserved before analysis, there must be an analytical quality control system, and finally, the data must be properly interpreted to yield meaningful results.

It should be noted that water quality monitoring may not involve only collection of water samples but it also involves collection of bottom deposits samples for analyses of pesticides, heavy metals, and benthic organisms.

#### 4.2 Sampling Programme

The objective of a sampling programme is to collect truly representative samples which when being analysed will yield the results reflecting actual pollution condition in the receiving waters on the sampling day. Clearly, a proper sampling programme is a key to the success of water quality monitoring. Therefore, serious attention should be paid to the design of sampling programme.

In designing a sampling programme, the application of data must be clearly defined and translated into a work plan. The plan will have to clearly describe the following items;

- (a) Sampling stations and points;
- (b) Sampling techniques and equipment;
- (c) Frequency of sampling;
- (d) Methods of sample preservation; and
- (e) Analysis programme for the samples.

Decisions on the above items will need to consider the following information;



- (a) Maps of the water quality management area showing pollution sources, outfall positions, land-use pattern, drainage pattern, the receiving waters, and the tributary streams;
- (b) Climatic pattern;
- (c) Flow pattern of the receiving waters;
- (d) Physical characteristics of the receiving waters; and
- (e) Tidal influence if the receiving waters is estuary.

#### 4.2.1 Sampling Stations and Points

In selecting the sampling stations, it is first, necessary to select the upstream boundary station and the downstream boundary station as shown in Figure 4.1. The upstream boundary station is needed for establishing the base-line water quality data which will depend upon the pollution load from sources upstream in relation to their distance from the upstream boundary station. The downstream boundary station is needed for completing the picture of pollution effects from sources within the management area.

In case of a non-tidal river, the upstream boundary station is normally located at the upstream limit of the management area. In case of a tidal river, the upstream boundary station should be at the extreme tidal limit which may extend much beyond the management area. The downstream boundary station is normally at the river mouth or at the end of the recovery zone of the dissolved oxygen sag curve, which ever is appropriate.

The number of additional sampling stations will depend on the distance between the upstream and downstream boundary stations. The stations do not necessarily have to be equally spaced but their siting should meet the following criteria;

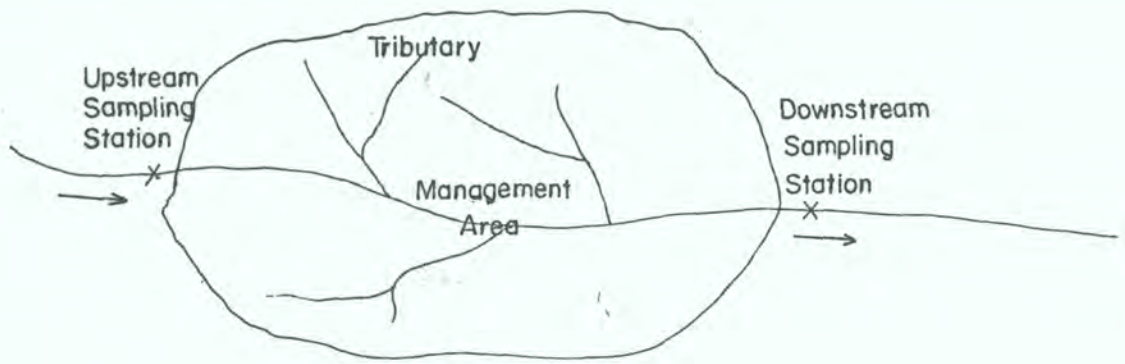


Figure. 4.1 Upstream and downstream boundary sampling station.

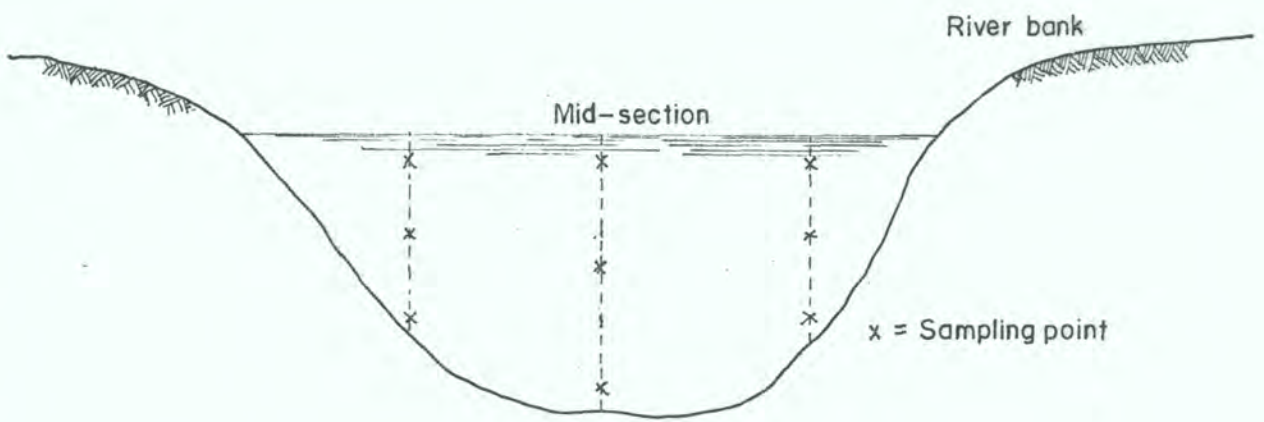


Figure. 4.2 Sampling point across river x-section



(a) The number of sampling stations and their spacing should be sufficient for delineating reliable longitudinal profiles of water quality parameters.

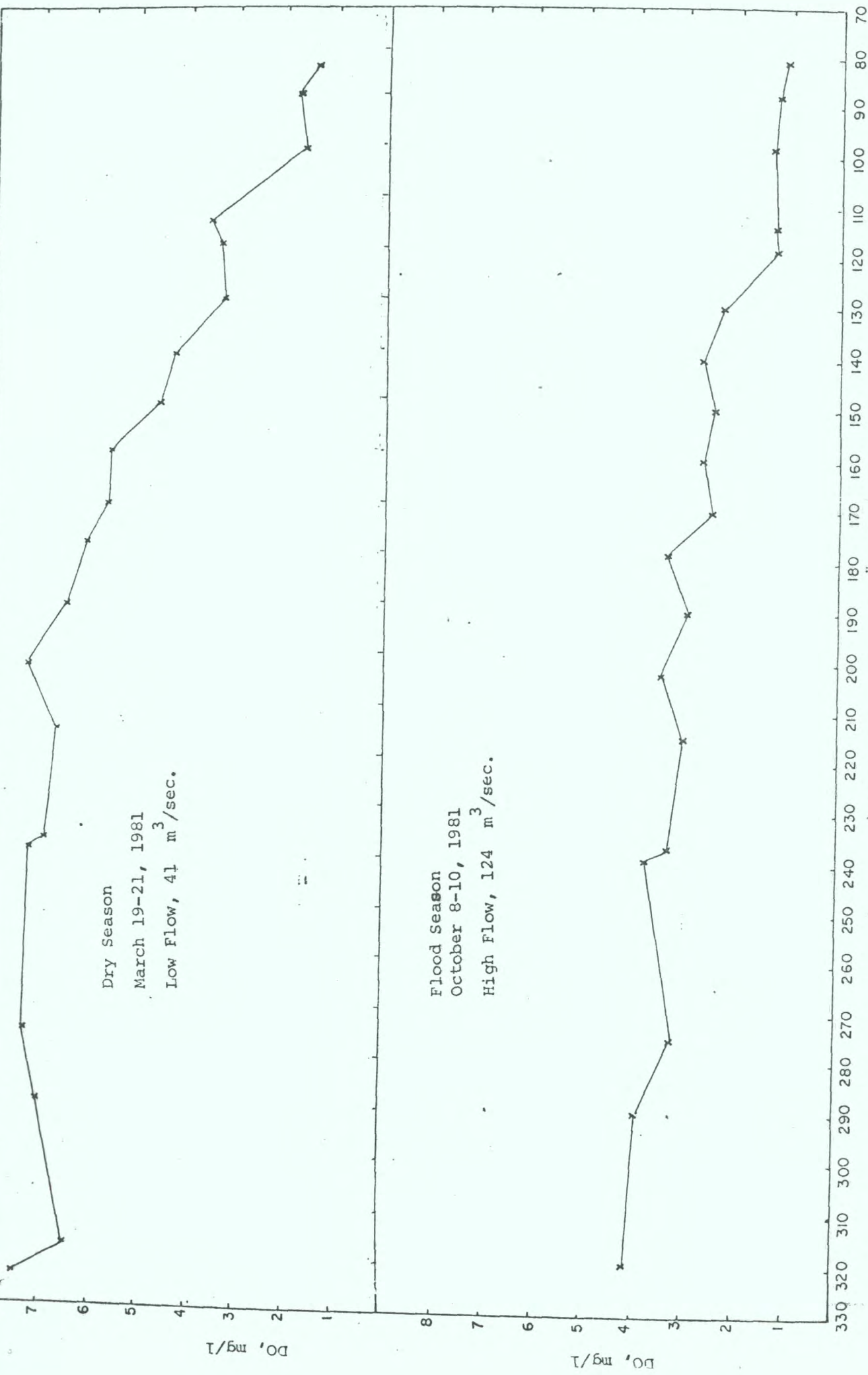
(b) The stations should avoid the uncomplete mixed zone, downstream or upstream of major outfalls and tributary streams, and avoid aeration created by in-stream structures.

(c) The stations should cover the pollution effects of major pollution sources.

At a given sampling station, the sampling points must be determined. This requires a preliminary survey in which grab samples are collected at various points across the section as shown in Figure 4.2, to determine the degree of lateral and vertical mixing. If there is no significant lateral gradient of the water quality parameter samples may be collected at mid-section. Normally, 3 samples will be collected, from approximately 0.5 metre below surface, mid-depth and 0.3 metre above bottom. The grab samples are normally mixed forming one composite sample for analyses. However, in-situ measurement of pH, temperature, and dissolved oxygen (DO) must be made for the 3 samples.

#### 4.2.2 Frequency of Sampling

There are two time-scales of sampling frequency. The first scale is the frequency of sampling days in a week or a month. The second scale is the frequency of sampling in the sampling day. Normally, the sampling days should be more concentrated during the critical period which is usually during low flows. However, this is not always true. In most urban areas, water quality especially, DO, is seriously affected by urban runoff. In the case of the Tachin River in Thailand,<sup>(11)</sup> DO is low during high flows due to water drained from paddy field through many tributary canals as shown in Figure 4.3. Therefore, general rules cannot be laid down for selecting the period of sampling and the number of sampling days will have to be determined for each



Kilometers upstream from river mouth

Figure 4.3 Longitudinal DO profile of Tachin River during Low Flow and High Flow



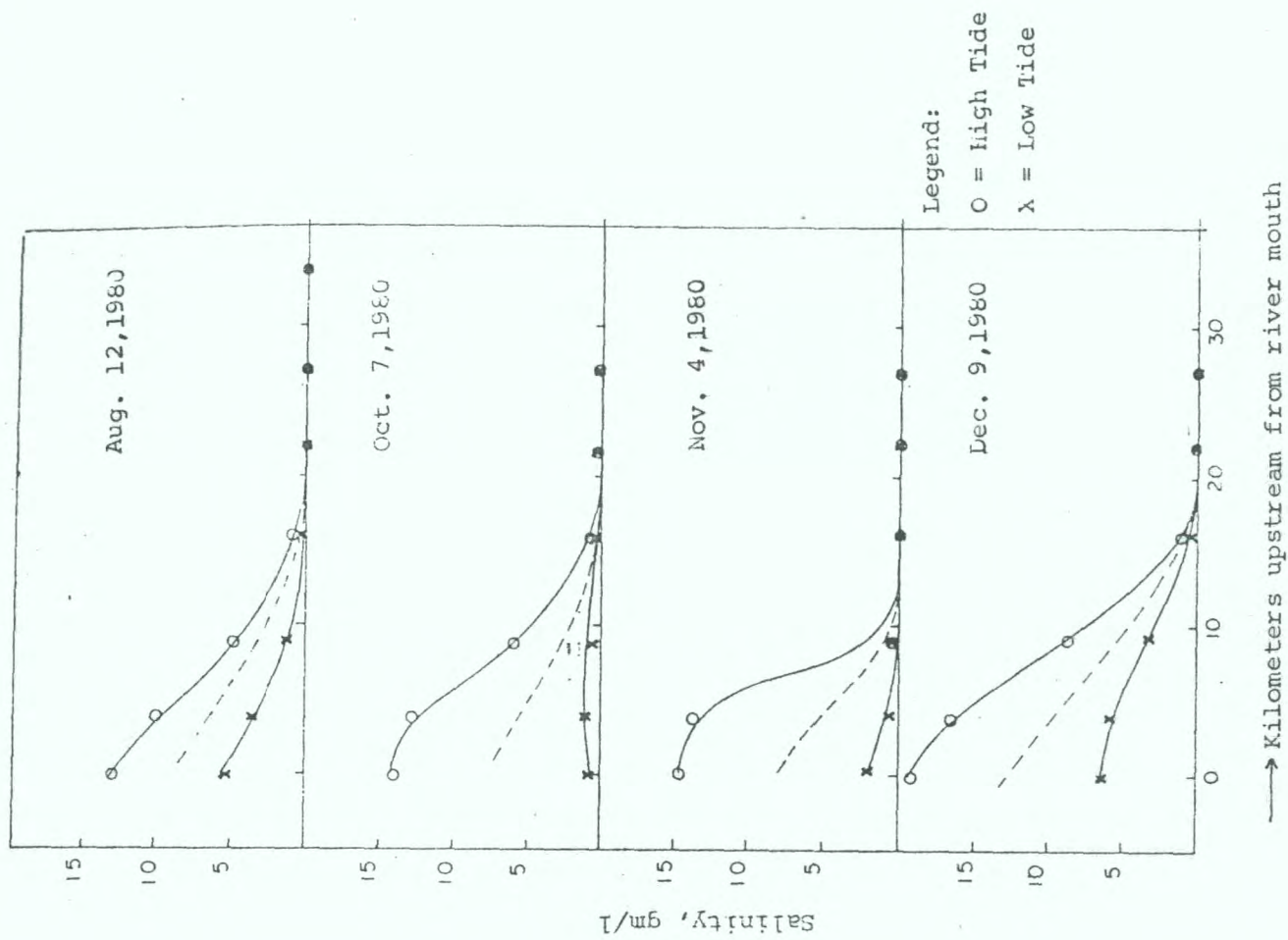
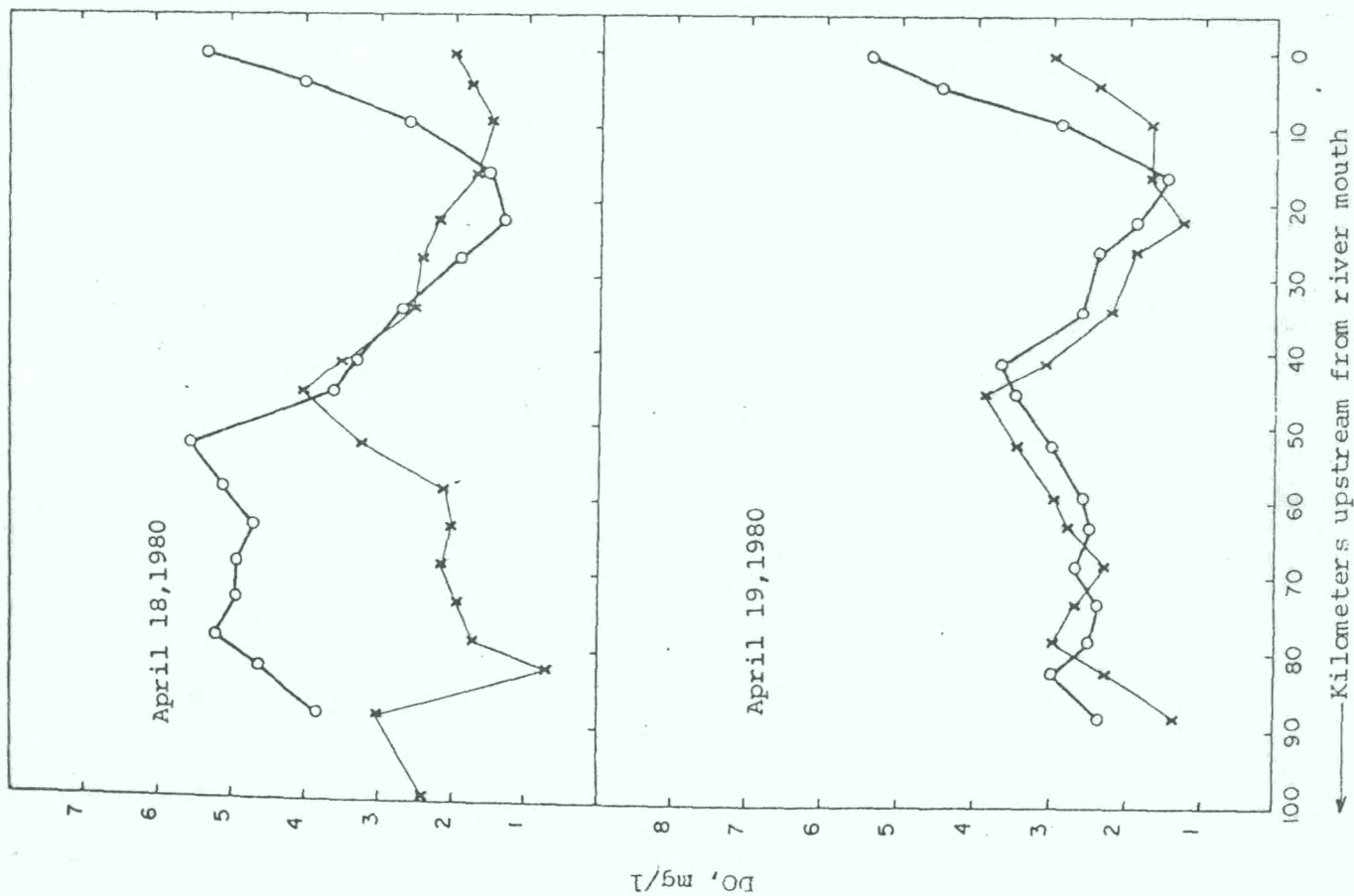


Figure 4.4 Water Quality Variations in Estuary of Tachin River

individual case. Selection of the sampling days will also depend on other factors. One of the most important factors is the variation of daily hydrograph. The sampling day should be when the flow is steady. Therefore, the daily flow data will have to be routinely collected for determining the steady flow period. Another factor is the variation of waste discharge. The sampling days will have to be coordinated with the waste discharge practice so that the pollution effect will be determined.

On the sampling day, the duration and frequency of sampling depends on the time variation of water quality as influenced by time variation of flow tidal condition waste discharge, and photosynthetic oxygenation rate. Normally, the sampling duration should cover 24 hours. In the case of a tidal river or estuary, water quality will vary from high water to low water as shown in Figure 4.4. In this case, collection of samples at high water and low water will delineate the two extreme limits of water quality variation. The average of the two extreme values will be approximately equal to the tidal average - the average of individual samples collected at every one hour interval over a full tidal cycle. The consultant's experience confirmed the validity of this tidal-slack sampling method.<sup>(12)</sup> However, if data on tidal variation of water quality are required, samples will have to be taken at one or two-hour interval.

For a non tidal river, if steady condition exists i.e. the river flow is steady and the waste discharge is steady, only grab samples<sup>(13,14)</sup> collected once in the sampling day will be adequate. However, if there is a variation of waste discharge or there is a pronounced effects of algal photosynthesis, samples must be taken at frequent intervals (one each hour or two) over a 24 hr. period.

If resources are not sufficient for the intensive sampling programme, the number of sampling stations should be reduced. A few stations with sufficient number of samples to define results in terms of statistical significance are much more reliable than many stations with only a few meaningless samples at each.<sup>(15)</sup>



#### 4.2.3 Sampling Techniques and Equipment

If it is possible, the downstream and the upstream boundary stations should have automatic continuous monitoring system. However, the automatic monitoring system can measure only DO, pH, temperature, and conductivity. Therefore, other quality parameters such as BOD, Total Nitrogen, etc. will have to be determined from laboratory analysis of representative composite samples.

Water quality sampling is normally done manually using a sampler called Ruttner Water Sampler. The sampler must be sunken to the required depth as quick as possible to ensure that the water at that particular depth is actually collected. Care must be taken to see that the sampler is filled up before hauling it back to the surface.

#### 4.2.4 Methods of Sample Preservation

Collected water samples must be preserved to retard biological changes or chemical changes before laboratory analysis, and to reduce volatility of some pollutants. This can be achieved using the following methods, pH control, chemical addition, refrigeration, and freezing. The EPA Manual of Methods for Chemical Analysis of Water and Wastes<sup>(16)</sup> recommends choice of preservatives for various constituents. Some information are shown in Table 4.1 - 4.2.

#### 4.2.5 Analysis Programme

On the sampling day, it is also necessary to collect flow data, tidal condition, effluent monitoring data and climatological data especially rainfall. Solar intensity and surface condition of the receiving waters may have to be recorded or observed in some cases. It may be necessary to collect all of these data few-days before the sampling day at various locations in the management area, and at some locations outside and upstream of the management area. These data are necessary for understanding the change in water quality and waste assimilative capacity of the receiving waters.

Table 4.1 General Guidelines for Sample Preservation

<u>Preservative</u>	<u>Action</u>	<u>Applicable to:</u>
HgCl <sub>2</sub>	Bacterial Inhibitor	Nitrogen forms, Phosphorus forms
Acid (HNO <sub>3</sub> )	Metals solvent, prevents precipitation	Metals
Acid (H <sub>2</sub> SO <sub>4</sub> )	Bacterial Inhibitor	Organic samples (COD, oil & grease organic carbon)
	Salt formation with organic bases	Ammonia, amines
Alkali (NaOH)	Salt formation with volatile compounds	Cyanides, organic acids
Refrigeration	Bacterial Inhibitor	Acidity-alkalinity, organic materials, BOD, color, odor, organic P, organic N, carbon, etc., biological organism (coliform, etc.)



Table 4.2 Recommendation for Sampling and Preservation of Samples According to Measurement (1)

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time (6)
Acidity	100	P, G <sup>(2)</sup>	Cool, 4°C	24 Hrs.
Alkalinity	100	P, G	Cool, 4°C	24 Hrs.
Arsenic	100	P, G	HNO <sub>3</sub> to pH < 2	6 Mos.
BOD	1,000	P, G	Cool, 4°C	6 Hrs. <sup>(3)</sup>
Bromide	100	P, G	Cool, 4°C	24 Hrs.
COD	50	P, G	H <sub>2</sub> SO <sub>4</sub> to pH 2	7 Days
Chloride	50	P, G	None Req.	7 Days
Chlorine Req.	50	P, G	Cool, 4°C	24 Hrs.
Color	50	P, G	Cool, 4°C	24 Hrs.
Cyanides	500	P, G	Cool, 4°C NaOH to pH < 12	24 Hrs.
Dissolved Oxygen				
Probe	300	G only	Det. on site	No Holding
Winkler	300	G only	Fix on site	No Holding
Fluoride	300	P, G	Cool, 4°C	7 Days
Hardness	100	P, G	Cool, 4°C	7 Days
Iodide	100	P, G	Cool, 4°C	24 Hrs.
MBAS	250	P, G	Cool, 4°C	24 Hrs.
Metals				
Dissolved	200	P, G	Filter on site HNO <sub>3</sub> to pH < 2	6 Mos.

Table 4.2 (Continued)

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time (6)
Suspended			Filter on site	6 Mos.
Total	100		HNO <sub>3</sub> to pH < 2	6 Mos.
Mercury				
Dissolved	100	P, G	Filter HNO <sub>3</sub> to pH < 2	38 Days (Glass) 13 Days (Hard Plastic)
Total	100	P, G	HNO <sub>3</sub> to pH < 2	38 Days (Glass) 13 Days (Hard Plastic)
Nitrogen				
Ammonia	400	P, G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH < 2	24 Hrs. <sup>(4)</sup>
Kjeldahl	500	P, G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH < 2	24 Hrs. <sup>(4)</sup>
Nitrate	100	P, G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH < 2	24 Hrs. <sup>(4)</sup>
Nitrite	50	P, G	Cool, 4°C	24 Hrs. <sup>(4)</sup>



Table 4.2 (Continued)

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time (6)
Oil & Grease	1,000	G only	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH < 2	24 Hrs.
Organic Carbon	25	P, G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH < 2	24 Hrs.
pH	25	P, G	Cool, 4°C Det. on site	6 Hrs. (3)
Phenolics	500	G only*	Cool, 4°C H <sub>3</sub> PO <sub>4</sub> to pH < 4 1.0 g CuSO <sub>4</sub> /l	24 Hrs.
Phosphorus				
Ortho-phosphate, Dissolved	50	P, G	Filter on site Cool, 4°C	24 Hrs. (4)
Hydrolyzable	50	P, G	Cool, 4°C H <sub>2</sub> SO <sub>4</sub> to pH < 2	24 Hrs. (4)
Total	50	P, G	Cool, 4°C	24 Hrs. (4)
Total, Dissolved	50	P, G	Filter on site Cool, 4°C	24 Hrs. (4)
Residue				
Filterable	100	P, G	Cool, 4°C	7 Days
Non-Filterable	100	P, G	Cool, 4°C	7 Days

Table 4.2 (Continued)

Measurement	Vol. Req. (ml)	Container	Preservative	Holding Time (6)
Total	100	P, G	Cool, 4°C	7 Days
Volatile	100	P, G	Cool, 4°C	7 Days
Settleable Matter	1,000	P, G	None Req.	24 Hrs.
Selenium	50	P, G	HNO <sub>3</sub> to pH 2	6 Mos.
Silica	50	P only	Cool, 4°C	7 Days
Specific Conductance	100	P, G	Cool, 4°C	24 Hrs. <sup>(5)</sup>
Sulfate	50	P, G	Cool, 4°C	7 Days
Sulfide	50	P, G	2 ml zinc acetate	24 Hrs.
Sulfite	50	P, G	Cool, 4°C	24 Hrs.
Temperature	1,000	P, G	Det. on site	No Holding
Threshold Odor	200	G only	Cool, 4°C	24 Hrs.
Turbidity	100	P, G	Cool, 4°C	7 Days

1. More specific instructions for preservation and sampling are found with each procedure as detailed in this manual. A general discussion on sampling water and industrial wastewater may be found in ASTM, Part 23, p. 72-91 (1973).
2. Plastic or Glass
3. If samples cannot be returned to the laboratory in less than 6 hours and holding time exceeds this limit, the final reported data should indicate the actual holding time.



4. Mercuric chloride may be used as an alternate preservative at a concentration of 40 mg/l, especially if a longer holding time is required. However, the use of mercuric chloride is discouraged whenever possible.
5. If the sample is stabilized by cooling, it should be warmed to 25°C for reading, or temperature correction made and results reported at 25°C.
6. It has been shown that samples properly preserved may be held for extended periods beyond the recommended holding time.

### 4.3 Analytical Quality Control

The analytical laboratory is the heart of the water quality monitoring system. It analyses the collected water samples and produces qualitative and quantitative data which are feed back in the water quality management. Therefore, there must be a quality control programme (QC programme) in the analytical laboratory to ensure uniformly high quality of the analytical results. This subject is discussed in detail in the EPA Handbook for Analytical Quality Control in Water and Wastewater Laboratories.<sup>(17)</sup> Only the principles will be discussed herein.

The QC programme in the analytical laboratory<sup>(17)</sup> has two basic functions. The first function is "measurement of quality" and the second function is the control of quality in order to meet the programme requirements for reliability. For example, the analysis of spiked samples is the measurement of quality, while the use of proper grade of reagents is a control measure. In an industrial process, a QC programme will involve both measurement and control of quality at various steps in the process. This principle is also applied to the analytical quality control. The established QC programme also involves both measurement and control of quality at various steps in the analysis; the practices of which will vary with the type of analysis.

Given that the collected samples are truly representative and are properly preserved, quality of the analytical results will depend on the following factors;

- (a) Analytical method,
- (b) Laboratory instrument and glassware,
- (c) Laboratory services,



(d) Reagents, solvents, gases, and

(e) Analytical performance.

#### 4.3.1 Analytical Method

The analytical method is one variable-governing data reliability and accuracy. It is desirable that the analytical laboratories in the same country should employ the same method for the same analysis, to eliminate the analytical method as a variable affecting the validity of the results. If environmental laboratories in ASEAN countries are to cooperate in data exchange, standardization of analytical methods is really needed.

The following criteria should be considered in selecting the analytical methods;<sup>(17)</sup>

(a) The method should have sufficient precision and accuracy to meet the data needs in the presence of the interferences normally encountered in polluted waters.

(b) The procedure should utilize the equipment and skills normally available in the average water quality laboratory.

(c) The selected methods should be conventionally used by many laboratories or have been sufficiently tested to establish their validity.

(d) The method should be sufficiently rapid to permit routine use for the examination of large numbers of samples.

In the field of water and wastewaters analysis, the Standard Methods<sup>(18)</sup> is normally followed by almost all analytical laboratories. However, there might be a need for modification of some methods in the Standard Methods, to suit the local environment. There has been an attempt in Thailand to replace the 20 °C - 5 day BOD by the 30 °C -

3 day BOD. However, the new method has not been widely accepted.

The precision and accuracy of the analytical results depend on the inherent nature of constituents to be analysed, and also on the method itself. Table 4.3 summarizes the precision and accuracy of the analysis of some constituents. The data are taken from the EPA Manual. Similar data for developing countries are not available. The precision and accuracy figures in Table 4.4 can be regarded as temporary standards for analytical quality control in the ASEAN region.

#### 4.3.2 Laboratory Instruments and Glasswares

Needless to say, the modern laboratory depends heavily upon instrumentation. Table 4.5 lists the instruments most commonly used for water and wastewater analysis.

In the QC programme for water and wastewater analysis, instrumentation quality control is one of the most important component. At the beginning, the instruments used must be of standard types and appropriate for the work. The instruments must be properly operated and routinely maintained as specified by the manufacturers. Periodically the instruments must be calibrated and certified by the national standard institution. The lack of national instrument calibration centre will be one of the weakest point in the QC programme. This situation may exist in most ASEAN countries.

In analytical works, laboratory vessels serve three functions; storage of reagents, measurement of solution volumes, and confinement of reactions. Glass laboratory vessels are most widely used in the analytical laboratory. The QC programme demands that proper grade of glassware must be used. Although, laboratory glasswares have inherent error as shown in Table 4.6, the most significant source of error is uncleanliness of the glasswares. Therefore, the QC programme should concentrate in proper cleaning of the glassware.



Table 4.4 Precision and accuracy of the Analysis of some constituents.

Paramter	Analysis Method	Increment as or concentration (mg/l)	Precision as	Accuracy as	
			Standard Diviation (mg/l)	Bias %	Bias (mg/l)
Acidity	Titrimetric	up to 2,000	$\pm 10$	-	
Alkalinity	Titrimetric	122	$\pm 3$	-	
BOD	5 day 20°C	mean value of 2.1 and 175 mg/l	$\pm 0.7$ $\pm 26$	There is no acceptable procedure for determining the accuracy of the BOD test.	
COD	Potassium dichromate (low level 5-50 mg/l)	12.3	$\pm 4.15$	0.3%	
	high Level for Saline water (min. acceptable 250 mg/l)	-	data are no available	available	
Chloride	Titrimetric	17-398	1.32-11.8	(-1.19) (-4.7) - (+3.5) (+0.6)	
		34	$\pm 1.0$	-	-
	Automated	1-250	$\pm 0.3$	-	-
DO	10-100		-	(-0.3) - (+4)%	
	azide modification electrode	7.5	$\pm 0.2$	Exact data are unavalable	
Hardness (total)			0.1	$\pm 1\%$	-
	Titrimetric	31-444	2.52-9.65	(-3.23) (14.3) - (-0.19) (0.003)	
		194	$\pm 3$	-	-
Metals	Automated	19-385	( $\pm 1.5$ ) - ( $\pm 5$ )	-	-
	Atomic Absorption (standard condition)				
Cd		2.9-74 (ug/l)	2.8-21 ug/l	(-5.7) - (135)	
Cr	"	10.2-380 ug/l	7.8-128 ug/l	(-10.2) - (37.7)%	
Cu	"	9.7-324 ug/l	6.1-56 ug/l	(-2.4) - (25.7)%	
Pb	"	31-377 ug/l	22-128 ug/l	(-0.2) - (25.7)%	

Table 4.4 (continued)

Parameter	Analysis Method	Increment or concentration (mg/l)	Precision as Standard Deviation (mg/l)	Accuracy as	
				Bias %	Bias (mg/l)
Hg	Manuel cold Vapor technique	0.35 µg/l	+ 0.16 µg/l	-	-
		1 µg/l	+ 0.14 µg/l	-	-
		3 µg/l	+ 0.08 µg/l	-	-
	Automated Cold Vapor Technique	0.5-20 µg/l	+ 0.04 µg/l + 0.84 µg/l	-	-
Ni	Standard Condition	0.20-5.0	+ 0.011- + 0.04		
Zn	Standard condition	17-308 µg/l	18-114 µg/l	(-0.7) -(206)	- -
Methylene Blue Active substances (MBAS)	Methylene Blue method	2.94 (Filtered River water)	+ 0.272	-	-
		0.48 (tap water)	+ 0.048	-	-
		0.27 (Distilled water)	+ 0.036	-	-
Nitrogen Ammo.	Distillation (Kjel dahl)	0.21-1.92	0.070-0.279	(-18.12) -(0.46)	(-0.05)- (+0.01)
	Ion Electrode	0.13-1.00	+ 0.003- + 0.038	-	-
	Automated Colorimetric Phenate	0.43-1.41	+ 0.005	-	-
Nitrogen (Total)	Kjeldahl	0.20-4.61	0.197-1.191	(-1.67) -(15.54)	(-0.08)- (0.04)
	Automated Phenate	1.89-5.81	0.54-1.85	(-28.3) -(-21.9)	(1.27) (-0.46)
	Automated Selenium	0.32-4.30	+ 0.05 + 0.14	-	-
Nitrogen (Nitrate)	Brucine	0.16-1.24	0.083-0.245	(-6.79) -(8.30)	(-0.01)- (+0.04)
Nitrogen (Nitrite)	diazotation of sulfanilamide	-	data are not available		
Oil and Grease	Soxhlet extraction	14.0	1.1	-	-
	Separatory Funnel	14.0	0.9	-	-
	Extraction	14.0	1.4	-	-



Table 4.4 (continued)

Parameter	Analysis Method	Increment or concentration (mg/l)	Precision as Standard Deviation (mg/l)	Accuracy as	
				Bias %	Bias (mg/l)
Organic Carbon (total+Dissolved)	Wet chemical Oxidation	3.5-8.0	0.10-0.20	(-0.29)	(-0.01)
				-(+1.01)	(+0.07)
Phosphorus (all forms)	Single reagent	Total	0.033-0.130	(-0.92)	(0.008)
		(0.110-0.882)		-(11.99)	(+0.023)
	ortho-	0.008-0.028	(-6.0)	(-0.009)	
	(0.029-0.383)		-(1.76)	(-0.001)	
Automated Colorimetric	ortho-	(0.04-0.30)	0.014-0.087	(-15.5)	(-0.05)
				-(+16.7)	(+0.007)
Residue (Total)	evaporated to dryness			data are not available	

Table 4.5 Lists of instruments commonly used in  
water and wastewater analysis

Analytical Balance

Beam Balance

Potential meter (pH meter)

Conductivity meter

Turbidimeter

Spectrophotometers

- a. Visual
- b. Ultraviolet
- c. Infrared
- d. Atomic absorption

Total Carbon Analyzer

Gas Chromatographs

Miscellaneous

- a. Temperature devices (ovens, hot plate, water bath, etc)
- b. Recorders
- c. Selective Ion Electrodes



Table 4.6 Tolerances for Volumetric Glassware  
 (abridged from National Bureau of  
 Standards Data, 1941)

<u>Capacity (ml)</u> <u>less than and including</u>	<u>Limit of error (ml)</u>
<u>Graduate Flasks</u>	
25	0.03
50	0.05
100	0.08
200	0.10
250	0.11
300	0.12
500	0.15
1,000	0.30
2,000	0.50
<u>Transfer pipets</u>	
2	0.006
5	0.01
10	0.02
25	0.025
30	0.03
50	0.05
100	0.08
200	0.10
<u>Buret</u> <sup>1</sup>	
5	0.01
10	0.02
30	0.03
50	0.05
100	0.10

1 Limits of error are of total or partial capacity Customary practice is to test the capacity at 5 intervals

### 3. The Management of Domestic Sewage and Industrial Effluent

Control of polluting discharges is the most important task of water quality management as previously discussed in Section 2. In the case of urban water quality management, domestic sewage and industrial effluent are two most important polluting discharges. However, in the USA, urban runoff has been found<sup>(2)</sup> to contain significant loads of BOD and heavy metals. This issue should deserve attention in urban water quality management in the ASEAN region.

The management of domestic sewage and industrial effluent can be considered at two levels. The first level of management is within the effluent dischargers; i.e. the industries and the sewage works authorities. Their management goal is to conform to the pollution control laws in the most cost-effective way. This means the industries will attempt to minimize their production losses and to operate their pollution control facilities efficiently and economically. Likewise, the sewage works authority will attempt to operate their sewage collection and treatment systems efficiently and economically.

The second level of management is within the control agency. At this level, the management goal is to efficiently and effectively enforce the effluent standards and other regulations concerning the discharge of effluent from houses, commercial buildings, and industries. The management must aim at the optimum discharge not the minimum discharge which may result in unnecessary waste of limited capital

#### 3.1 Control Approaches

##### 3.1.1 Industrial Wastes

One common characteristics of most urban areas in the ASEAN region is mixed land use in which a multitude of small factories are scattered and located right in residential and commercial areas. Normally, industries are required to treat their wastes before discharging the wastes into public sewers or natural receiving waters. Small



#### 4.3.3 Laboratory Services

In the QC programme, the laboratory services must also be of high quality. An abundant supply of distilled water, free from interferences and other undesirable contaminants, is an absolute necessity. An adequate source of clean, dry, compressed air is needed. Normal contaminants entrained in the compressed air are oil, water, and dirt. These contaminants must be removed from the compressed air stream supplied to the analytical control laboratory.

Since modern analytical instruments have to use electricity; an electrical system for the analytical laboratory must be of high standard. Special attention should be paid to voltage regulation and proper lighting. Constant voltage is important to the operation of most sophisticated analytical instruments and proper lighting is needed for accurate readings of instruments, and glassware graduations, and for colour observation.

#### 4.3.4 Reagents, Solvents, and Gases

The QC programme will have to see that proper grades and purity of reagents, solvents, and gases are used. In addition, it will demand that reagents are prepared and standardized with the utmost of care and technique against reliable primary standards. Care must also be taken in storing and maintaining quality of reagents and solvents to prevent contamination and deterioration before their use. This requires that care must also be taken in selecting appropriate places and containers.

#### 4.3.5 Control of Analytical Performance

Control of analytical performance is needed to ensure that the analytical laboratory is producing valid data. The control can be separated into two tasks. The first task is to establish valid precision and accuracy data on the method and analyst. The second

task is systematic daily checks to show that reproducible results are being obtained, and that the methodology is actually measuring what is in the sample.

In analytical quality control, precision refers to the reproducibility among replicate observations, while accuracy refers to a degree of difference between observed and known, or actual, values. In the QC programme, both precision and accuracy need to be determined using actual water samples which cover a range of concentrations and a variety of interfering materials usually encountered by the analyst. There are a number of different methods available for the determination of precision and accuracy. The EPA Handbook recommends and describes in detail, one method that has been successfully employed by experienced and to analyzer users.

It is necessary that the precision and accuracy data will have to be determined for the various analysts in the analytical laboratory. If the precision and accuracy of the results are within acceptable acceptable range, the analyst in question, is capable of analyzing the water samples for that particular parameter. He has the standard method under control, and is capable of generating valid data. The precision and accuracy data can be used in the preparation of precision control and accuracy control charts.

Even the capability of the analyst has been proved, routine daily quality control of the data is still needed to ensure that valid data are being generated. Daily quality control involves precision control and accuracy control. Data for the precision control are collected from analysis of duplicate samples at least 10 per cent of the time while data for the quality control are collected from analysis of spiked samples at least 10 per cent of time. Therefore, daily quality control of the analytical laboratory requires approximately 15-20 per cent of the analyst's time.

The obtained precision and accuracy data will be plotted



4. Instrument problems

5. Sample interference with the spiked

material

c. Rerun samples represented by that sample set number, including additional duplicate and spiked samples.

d. Begin plotting at sample No. 1 on chart.

(b) In control within the upper and lower limit lines

When data continuously fall in between the upper and lower control limits, the analyses should be continued until an out-of-control trend is detected.

(c) Out of control on the lower limit

When data fall out of control on the lower limit, the following steps should be taken:

a. Continue analyses unless trend changes

b. Construct new control charts on recent data

c. Check analyst's reporting of data

on the precision and accuracy control charts prepared from a set of acceptable precision and accuracy control data. The two charts as recommended in the EPA Handbook, are prepared in the form of cumulative sum charts. The detailed procedure is elaborated in the EPA Handbook. The concept is to establish the upper control limit and the lower control limit using statistical techniques. The daily precision and accuracy data are plotted on the precision control and the quality control charts. Corrective actions are needed when the daily data are off either one of the control limit.

The following guidelines for corrective actions are given,

(a) Out of control on the upper limit

When data goes out of control on the upper limit the following steps should be taken:

- a. Stop work immediately
- b. Determine problems
  - (1) Precision control chart
    1. The analyst
    2. Nature of the sample
    3. Glassware contamination
  - (2) Accuracy control chart
    1. The analyst
    2. Glassware contamination
    3. Contaminated reagents



## 5. References

- (1) Ludwig, R.G., 1980, Industrial Waste Pollution Control Management, NEB's Final Report for Ministry of Industry-Industrial Works Dept. Industrial Environment Division.
- (2) Wilber, W.G., and Hunter, J.V., 1979, Distribution of Metals in Street Sweepings, Stormwater Solids, and urban aquatic sediments. Journal of WPCF, Vol.51, No.12, pp.2811-2822.
- (3) Henstock, M.E., 1979, Report on a visit to Thailand, undertaken at the investigation of the British Council and of the TISTR.
- (4) "Sewerage, Drainage and Flood Protection Systems, Bangkok and Thonburi, Thailand, Master Plan, Vol.I, II, III, Camp Dresser and McKee, for Bangkok sewerage and Drainage Committee, Feb.1968.
- (5) Pradt, A.L., 1971, Some Recent Development in Night Soil Treatment, Water Research Progamon Press, Vol.5, pp.507-521.
- (6) Ligmann K., et al., 1974, Household Wastewater Characterization, J. of The Env. Eng. Div., ASCE, Vol.100, No.EEL, pp.201-213.
- (7) Environmental Protection Agency, Construction Cost for Municipal Wastewater Conveance systems: 1973-1977, US Government Printing Office, Washington D.C., May, 1978.
- (8) Klinsukont, C., 1981, Industrial Wastewater Treatment by Bio-Filter, paper to be presented in Workshop Seminar on Energy Conservation and Efficiency Increase, during Dec.16-17, 1981, at Engineering Institute of Thailand (in Thai).
- (9) Evaluation of Treatment Alternative for Molasses Distillery Stillage, Part I, II. TISTR's Report, Submitted to the Excise Department, Ministry of Finance, Thailand, April 1981, (in Thai with English abstract).

- (10) Evaluation of performance of Sewage Treatment Plants for Housing Estates run by National Housing Authority, TISTR Report, submitted to National Housing Authority of Thailand, Dec., 1980 (in Thai).
- (11) Integrated Planning for Water Quality Management of the Tachin River, NEB Pub. 1981-006, part 1, Sept.1981.
- (12) Leffel, R.E., 1968, Pollution of the Chao Phraya River Estuary, J. of Sanitary Eng. Div., ASCE, Vol.94, No.SA2, pp.295-306.
- (13) Dandy, G.C., and Moore, S.F., 1979, Water Quality Sampling Programs in Rivers, Journal of Environ. Eng. Div., ASCE, Vol.EE4, pp.695-712.
- (14) Browne, F.X., 1980, Water Pollution, Non point sources, Journal WPCF, Vol.52, No.6, p.1506-1510.
- (15) Velz, C.J., 1950, Sampling for effective evaluation of stream pollution, Sewage Ind. Wastes, 22(5), 666-683.
- (16) Environmental Protection Agency, Method for Chemical Analysis of Water and Wastes, U.S. Government Printing Office, Washington D.C., 1971.
- (17) Environmental Protection Agency, Analytical Quality Control in Water and Wastewater Laboratories, U.S. Government Printing Office, Washington D.C., 1972.
- (18) APHA, AWWA, and WPCF, Standard Methods for the Examination of Water and Wastewater (14<sup>th</sup> ed.), American Public Health Association, New York, 1973.



Appendix 1

Effluent Standards for Thailand proposed  
by a USAID expert

Suggested Provisions for Environmental Pollution Control

(1) General Conditions

(1.1) Environmental pollution is defined as the presence, the discharge or the liberation into the waters, air or soil, of all or whatever form of material or energy, with intensity, in quantity, in concentration or with characteristics which produce conditions in the waters, air or soil which are: (a) improper, toxic or offensive to health, (b) inconvenient to the public well-being, (c) damaging to fauna and flora, or (d) prejudicial to the safety, use and pleasure of public property or to normal community activity.

(1.2) Discharge or release of materials or energy which either directly or indirectly causes environmental pollution as defined in (1.1) above is prohibited.

(2) Classification of Waters:

(2.1) Waters situated within the Kingdom of Thailand shall be classified in accordance with the following principal uses.

(2.2) Class I: Waters to be used for:

(a) Domestic water supplies, without pretreatment other than simple disinfection.

(2.3) Class II: Waters to be used for:

- (a) Domestic water supplies after conventional treatment.
- (b) Irrigation of vegetable and fruit crops.
- (c) Primary contact recreation (swimming, water skiing, diving),

(2.4) Class III: Waters to be used for:

- (a) Domestic water supplies after conventional treatment.
- (b) Preservation of fish life in general and of other forms of fauna and flora.
- (c) Watering animals.

(2.5) Class IV: Waters to be used for:

- (a) Domestic water supplies utilizing special treatment procedures to guarantee potability.
- (b) Navigation
- (c) Aesthetic appreciation.
- (d) Industrial water supply, irrigation and other uses of lesser quality requirements.

(2.6) Waters of any class may be utilized for any use of lesser quality requirements providing such use does not prejudice the quality established for such waters.

(2.7) The set of quality standards established for any class of water does not preclude the eventual existence of certain parameters not within the limits provided for that class due to natural conditions.

(2.8) Receiving water bodies utilized for the treatment and transport of waste waters are not included within this system of classification.

(3) Water Quality Standards and Effluent Discharges:

(3.1) No wastewater effluent discharges are permitted into waters of Class I, even though treated.

(3.2) Effluent discharges are permitted into waters of Class II only when such discharges do not cause alteration of the following parameters or values:

(3.2.1) The following materials and substances shall be virtually absent, i.e., floating material including unnatural foam, substances soluble in hexane and substances which impart taste or odor.

(3.2.2) The following potentially toxic substances shall not exceed the maximum values tabulated below:

- (1) Ammonia, 0.5 mg/l as N
- (2) Arsenic, 0.1 mg/l
- (3) Barium, 1.0 mg/l
- (4) Cadmium, 0.01 mg/l
- (5) Chromium (total), 0.05 mg/l
- (6) Copper, 1.0 mg/l



- (7) Cyanide, 0.2 mg/l
- (8) Fluoride, 1.4 mg/l
- (9) Lead, 0.1 mg/l
- (10) Mercury, .002 mg/l
- (11) Nitrate, 10 mg/l
- (12) Nitrite, 1.0 mg/l
- (13) Phenols, .001 mg/l
- (14) Selenium, .01 mg/l
- (15) Tin, 2.0 mg/l
- (16) Zinc, 5.0 mg/l

(3.2.3) Discharge of dyes or artificial colors which are not removable by conventional processes of coagulation, sedimentation and filtration is prohibited.

(3.2.4) The Most Probable Number (MPN) of coliform organisms shall not exceed 5,000/100 ml (total) or 1,000/100 ml (fecal coliforms) in 80% of at least five samples collected during a period of five consecutive weeks.

(3.2.5) Biochemical Oxygen Demand (BOD) in 5 days at 20°C shall not exceed 5 mg/l in any sample.

(3.2.6) Dissolved Oxygen (DO) shall not be less than 5 mg/l in any sample.

(3.3) For waters of Class III, the conditions and limits of pollution parameters are the same as for Class II, with the following exceptions:

(3.3.1) The Most Probable Number (MPN) of coliform organisms shall not exceed 20,000/100 ml (total) or 4,000/100 ml (fecal coliforms) in 80% of at least five samples collected during a period of five consecutive weeks.

(3.3.2) Biochemical Oxygen Demand (BOD) in 5 days at 20°C shall not exceed 10 mg/l in any sample.

(3.3.3) Dissolved Oxygen (DO) shall not be less than 4 mg/l in any sample.

(3.4) For waters of Class IV the following conditions and limits are established:

(3.4.1) Floating material including unnatural foam shall be virtually absent.

(3.4.2) No objectional odors, colour not to exceed 75 units on the platinum-cobalt scale.

(3.4.3) Phenols less than 1.0 mg/l.

(3.4.4) Dissolved Oxygen over 0.5 mg/l in all samples.

(3.4.5) Where waters of Class IV are to be used for domestic supplies and contain coliform organisms in numbers greater than specified for Class III, they may be so utilized only if special treatment methods are incorporated to guarantee potability.

(3.4.6) Where waters of Class IV are to be used for domestic supplies the limits for potentially toxic substances shall be the same as for Class II and Class III as delineated in Section (3.2.2).

(3.5) The limits of BOD established for Classes II and III may be increased where studies are conducted to demonstrate that self purification within the receiving water body will be adequate to maintain the minimum levels of dissolved oxygen (DO) specified for such Classes at any point in the receiving water body under the critical flow conditions.

(4) Effluent Standards for Discharge to Receiving Water Bodies:

(4.1) Effluents of whatever nature can only be discharged into receiving water bodies, either surface or subterranean, which do not produce environmental pollution as defined in Section 1. Discharge is defined as directly to receiving waters or indirectly by means of public or private channels as well as any other means of transport.



(4.2) Effluents from whatever source may be discharged only when in accordance with the following conditions:

(4.2.1) pH between 5.0 and 9.0

(4.2.2) Temperature less than 40°C.

(4.2.3) Settleable materials less than 1.0 ml/l as measured in a one hour Imhoff cone test.

(4.2.4) Absence of floating materials, tar, insecticides and radioactive materials.

(4.2.5) Color and Odor shall not produce objectionable conditions after mixing with receiving waters.

(4.2.6) Mineral oil less than 10 mg/l; Vegetable Oil and animal fat less than 20 mg/l.

(4.2.7) Biochemical Oxygen Demand, 5 days, 20°C (BOD), 20 mg/l up to 60 mg/l depending upon the receiving water conditions. For wastewaters with initial BOD values over 600 the limit of 60 mg/l may be exceeded, up to a maximum of 100 mg/l when treated effluents are discharged and treatment has removed a minimum of 90% of the BOD load exclusive of any dilution.

Interim standards shall apply to certain wastewaters of high organic content as follows: Category numbers refer to the classifications of the Ministry of Industry as delineated in the Ministerial Regulations of the Factory Act (1969).

<u>Category</u>	<u>Waste Type</u>	<u>Approx.</u> <u>Wastewater</u> <u>BOD, mg/l</u>	<u>Effluent</u> <u>Requirement</u> <u>BOD, mg/l</u>	<u>Effective Dates</u>
9 (3)	Tapioca Starch New process	6,000	100	Until 31 Dec. 1981
9 (3)	Tapioca Starch Oil process	3,500	100	Starting as of 1 Jan. 1982.
38	Pulp Manuf.	2,000	150	Until 31 Dec. 1981
38	" "	2,000	100	As of 1 Jan. 1982
10 (3)	Noodle Factory	3,000	150	Until 31 Dec. 1981
10 (3)	" "	3,000	100	As of 1 Jan. 1982
92 and 7 (1)	Sea Food Processing	2,000	200	Until 31 Dec. 1981
92 and 7 (1)	Sea Food Processing	2,000	100	As of 1 Jan. 1982
29	Tanneries	5,000	200	Until 31 Dec. 1981
29	Tanneries	5,000	100	As of 1 Jan. 1982
16 & 17	Molasses Distillery	30,000	90% removal	As of 1 Jan. 1980.

(4.2.8) Suspended Solids shall not exceed 30 mg/l except when dilutions are available in accordance with the following:

<u>Dilution Ratio</u>	<u>Suspended Solids</u>
<u>Min. Flow rate of Stream: Discharge rate</u>	<u>Max. allowable c concentration</u>
Less than 150	mg/l 30
151 - 300	60
Over 301	150

(4.2.9) The concentration of total dissolved solids shall not cause more than a 5% increase in receiving water dissolved solids content.



(4.2.10) Maximum concentrations of the following parameters:

1.	Arsenic	0.25 mg/l
2.	Barium	2.0
3.	Boron	5.0
4.	Cadmium	0.1
5.	Chlorine (free)	1.0
6.	Chromium, hexavalent	0.1
7.	Chromium, total	2.0
8.	Copper	1.0
9.	Cyanide	0.2
10.	Fluoride	10.0
11.	Formaldehyde	1.0
12.	Iron, soluble ( $Fe^{++}$ )	15.0
13.	Lead	0.5
14.	Manganese, soluble ( $Mn^{++}$ )	1.0
15.	Mercury	0.01
16.	Nickel	2.0
17.	Phenols and cresols	1.0
18.	Selenium	0.02
19.	Silver	0.02
20.	Sulfide (as $H_2S$ )	1.0
21.	Tin	4.0
22.	Zinc	5.0

(4.2.11) Maximum concentrations of other potentially detrimental substances shall be fixed for each particular discharge.

(4.2.12) Maximum discharge flow shall not exceed 1.5 times the average daily flow.

(4.2.13) In addition to fulfilling the above stated requirements, the effluents shall not cause water quality characteristics which do not meet the quality requirements of the Class of the receiving waters in question.

(4.2.14) In any situation where the combined effect of a number of individual effluent discharges causes one or more water quality parameters to exceed the maximum limits provided for the Class of the particular receiving water body, the permissible maximum concentrations of such parameters shall be reduced proportionately so as to maintain the desired water quality.

(5) Effluent Standards for Discharge to Public Sewerage Systems Provided with Treatment Facilities:

(5.1) Effluents from whatever source may be discharged to public sewerage systems only when in accordance with the following conditions.

(5.1.1) pH between 5.0 and 9.0

(5.1.2) Temperature less than 40°C

(5.1.3) Settleable materials less than 10 mg/l, 1 hour Imhoff cone test.

(5.1.4) Hexane soluble substances less than 100 mg/l

(5.1.5) Maximum concentrations of the following parameters:

1. Arsenic	0.2 mg/l
2. Barium	5.0
3. Boron	5.0
4. Cadmium	0.2
5. Chromium, hexavalent	0.5
6. Chromium, total	2.0
7. Copper	1.0
8. Cyanide	0.2
9. Fluoride	10.0
10. Iron, soluble (Fe <sup>++</sup> )	30.0
11. Lead	0.5
12. Manganese, soluble (Mn <sup>++</sup> )	1.0
13. Mercury	.01
14. Nickel	2.0



15. Phenols and Cresols	5.0
16. Selenium	0.2
17. Silver	0.1
18. Tin	4.0
19. Zinc	5.0

- (5.1.6) Maximum concentrations of other potentially detrimental substances shall be fixed for each particular case.
- (5.1.7) Maximum discharge flow shall not exceed 1.5 times the average daily flow.
- (5.1.8) No rainwater discharge.
- (5.1.9) Wastes which cause or may cause obstructions in the sewage collection system or whatever interference in the proper operation of the collection system and treatment facility are excluded.
- (5.1.10) For public sewerage systems which are not provided with treatment facilities, the regulations of Section 4 shall apply.
- (5.1.11) In the case of biodegradable oils of animal or vegetable origin, the Value Stipulated in Sub-section 5.1.4 may be exceeded if and when approved by the Agency responsible for treatment plant operation.
- (5.1.12) In any situation where the combined effect of a number of individual effluent discharges to a public sewerage system causes one or more water quality parameters in the system effluent to exceed the maximum limits provided for discharges of system effluent, the permissible maximum concentrations of such parameters shall be reduced proportionately so as to maintain the desired effluent quality.

(5.1.13) The quantities of wastewater flow and organic loadings which may be accepted by a public sewerage system are dependant upon the capacity of the existing system to properly handle such loads.

8.2.2 Modifications Proposed in Effluent Standards:

The following information is presented to delineate the several provisions incorporated in the "Suggested Provisions for Environmental Pollution Control" which would modify existing standards of the MOI.

(a) Items Not Included in Present MOI Standards

1.	Settleable Solid	Less than 1.0 mg/l (one hour Imhoff Cone test)
2.	Floating Material	Nil
3.	Boron	5.0 mg/l
4.	Fluoride	10.0 mg/l
5.	Iron, Soluble	15.0 mg/l
6.	Silver	0.2 mg/l
7.	Tin	4.0 mg/l

(b) Items Which Differ From Present MOI Standards

	<u>MOI Standards</u>	<u>Proposed</u>
8.	Oil and Grease	5 mg/l
	Mineral Oil	10. mg/l
	Vegetable oil and animal fat	20 mg/l
9.	Dissolved Solids	2,000 mg/l {5% increase
10.	Chromium, total	0.5 mg/l 2.0 mg/l
	Chromium, hexavalent	- 0.1 mg/l
11.	Mercury	0.005 mg/l 0.01 mg/l
12.	Cadmium	0.03 mg/l 0.1 mg/l
13.	Barium	1.0 mg/l 2.0 mg/l
14.	Lead	0.2 mg/l 0.5 mg/l
15.	Nickel	0.2 mg/l 2.0 mg/l
16.	Manganese, total	5.0 mg/l -
	Manganese, soluble	- 1.0 mg/l



(c) Items of MOI not included in Proposed Standards

17. Permanganate Value 60 mg/l

(d) In addition, the stream flow/waste water effluent ratios governing the allowable suspended solids content have been modified in the proposed standards by eliminating the lower and upper ratio limiting values.

(e) Discussion

Items 1 to 7 of category (a) above have been included as being desirable additions for the control of industrial effluent discharges.

The limit of 5 mg/l of total oil and grease of item 8 is believed overly restrictive.

Dissolved solids content (item 9) should bear a relation to the quality of the receiving water body.

Hexavalent chromium is the important form for control of overall chromium content. A breakdown is therefore believed desirable for item 10.

The requirements for items 11 to 15, i.e., mercury, cadmium, barium, lead and nickel are somewhat strict in the present MOI standards and could be relaxed.

Soluble manganese is the important parameter for manganese control in item 16.

Item 17, permanganate value, 60 mg/l could cause confusion and possible unnecessary restrictions in as much as BOD values of from 20-60 are also specified in the MOI standards. The consensus of pollution control advisers prefer to limit organic content utilizing the BOD test because BOD simulates the effect a waste will have on receiving water dissolved oxygen. Other tests such as COD and TOC can be advantageously used in monitoring.

The Adviser has reviewed the Suggested Provisions for Environmental Pollution Control with the Dep. Sec. General and Chief/Standards Division of NEB and the final draft as included in this report has received their preliminary approval.

Appendix 2

Effluent Standards in Effect Jan. 1980

Industrial Environment Division

pH Value	Between 5.0 and 9.0
Temperature	Less than 40°C
Color and Odor	Not objectionable when mixed in receiving water
Tar, insecticides and radio active substances	Mil
Oil and Grease	5 mg/l
Arsenic	0.25 mg/l
Barium	1.0 mg/l
Cadmium	0.03 "
Chlorine, free	1.0 "
Chromium, total	0.5 "
Copper	1.0 "
Cyanide	0.2 "
Formaldehyde	1.0 "
Lead	0.2 "
Manganese, total	5.0 "
Mercury	0.005 "
Nickel	0.2 "
Phenols and Cresols	1.0 "
Selenium	0.02 "
Sulfide as H <sub>2</sub> S	1.0 "
Zinc	5.0 "
Total dissolved solids	2,000 mg/l
Permanganate Value	60 mg/l
BOD, 5 days, 20°C	20 mg/l or more but not exceeding 60 mg/l, depending upon geograph. of discharge point.
Suspended solids	30 mg/l or more depending on available dilution as shown below
	<u>Allowable suspended solids</u>
<u>Dilution Ratio</u>	
8 - 150	30 mg/l
151 - 300	60 mg/l
301 - 500	150 mg/l



Table 4.3 Analysis Programme for various uses

Water Quality parameter	Recreation and aesthetic	Public Water Supply	Fish and aquatic wildlife			Agriculture			Industry
			Fresh water organisms	Wildlife	Marine and estuarine organisms	Farm water supply	Live Stock	Irrigation	
Color, units		X (W)	X (M)						X (M)
Temperature °F	X (D)	X (W)	X (M)						X (M)
Fecal coli form no/100 ml.	X (W)	X (D)							X (M)
Alkalinity (CaCO <sub>3</sub> ) ppm.		X (D)	X (M)	X (M)					X (D)
Chloride, ppm.		X (D)							X (D)
Hexavalent Chromium, ppm.		X (W)					X (M)		X (D)
Copper ppm.		X (W)					X (M)		
Dissolved oxygen ppm.		X (D)	X (W)	X (W)					X (S)
Hardness (CaCO <sub>3</sub> ) ppm.		X (D)							
Iron, ppm.		X (W)					X (M)		X (D)
Manganese, ppm.		X (W)					X (M)		X (W)
Nitrates, ppm.		X (W)					X (M)		X (W)
pH	X (D)	X (D)	X (M)	X (M)			X (W)		X (W)
Sulfate ppm.		X (W)							X (D)
Total dissolved solids, ppm.		X (W)					X (M)	X (M)	X (D)
Carbon chloroform extractable, ppm.		X (W)					X (M)		X (W)

Table 4.3 (continued)

Water Quality parameter	Recreation and aesthetic	Public Water Supply	Fish and aquatic wildlife			Agriculture			Industry
			Fresh water organisms	Wildlife	Marine and estuarine organisms	Farm water supply	Live Stock	Irriga-tion	
Pesticide, ppm.		X (W)	X (M)	X (M)	X (M)				
Phenol, ppm.		X (W)							
Gross beta radioactivity $\mu\text{uc}/\text{l}$		X (M.orAn)	X (An)	X (An)	X (M)		X (An.) X (W)	X (An.)	
Cyanide, ppm.		X (M)	X (M)						X (W)
Turbidity, ppm.									X (W)
Suspended solids, ppm.									X (W)
Silica, ppm.									X (W)
Calcium, ppm.									X (W)
Magnesium, ppm.									X (W)
Bicarbonate ( $\text{HCO}_3$ ), ppm.									X (D)

X = Water quality analysis is required

D = Daily M = Monthly An = Annally

W = Weekly S = Seasonally



ANNEX 6

SEVERAL ASPECTS OF WATER QUALITY  
MANAGEMENT IN INDONESIA

**SEVERAL ASPECTS OF WATER QUALITY MANAGEMENT  
IN INDONESIA \*)**

by  
**Badruddin Mahbub \*\*)**

**DECEMBER**

**1981**

---

**\*) Paper to be presented to the ASEAN/UNEP Study Tour cum Technical Workshop on Urban Water Quality Monitoring and Management, Singapore, December 14 - 19, 1981.**

**\*\*\*) Chief of Environment and Water Quality Branch, Institute of Hydraulic Engineering, Directorate General of Water Resources Development, Ministry of Public Works, Republic of Indonesia.**



## 1. INTRODUCTION

The water quality management covers work scopes of various sectors related to water use and waste water discharge, and various types of water resources scattered throughout Indonesia.

This paper is dealing only with part of the mentioned activities, i.e. those that are relevant to water quality management in Indonesia.

The aspects reported in this paper are :

- a) Water Quality monitoring
- b) Water quality management (case study on Citarum River)
- c) Water pollution abatement (case study on Cimahi area)

A major part of the material in this paper is obtained from a study conducted by the Environmental and Water Quality Division of the Institute of Hydraulic Engineering, Directorate General of Water Resources Development, Ministry of Public Works.

As the study is at present still in progress, the data or conclusions submitted in this paper are of temporary nature, and will be improved after the study has been completed. Nevertheless, the material for this report can be used to assist the policy makers in making an evaluation on the water quality in Indonesia for the purpose of finding a just water quality management pattern.

## 2. WATER QUALITY MONITORING

### 2.1. Method of Water Quality Monitoring

The study of water quality is conducted in various ways depending greatly on the requirement for data and the purpose of the study.

a) Making an inventory of the water resources :

Monitoring is conducted periodically, monthly or every three months for a period of one to two years. The Global Environmental Monitoring (G.E.M.) method is used to determine the data and hour of sampling. The sampling is conducted according to the grab system.

b) Monitoring of water pollution :

Monitoring of rivers or reservoirs which may be polluted by domestic, industrial or agricultural waste water is constantly conducted monthly or every three months. Sampling is done by using the G.E.M. method and grab system. However, if the study is made in relation to effluent water study, another method is used, namely the composite method, and we are not bound to periodic periods.

c) Short time monitoring of sedimentation due to erosion is conducted intensively in the rainy monsoon applying the grab sampling method which uses an integrated sampler.

### 2.2. Water Quality Inventory of Natural Water

To obtain data on natural water quality, i.e. the quality of water resources at locations which are relative



ly not yet affected (or very slightly affected) by activities of the inhabitants and industry, we have chosen **12** rivers on the island of Java , 1 river in Sumatera, and 1 river in Kalimantan, further 6 locations of ground water on the island of Java as locations for monitoring. Monitoring at 52 locations have been completed. This monitoring work is at present being extended to an additional number of water sources on other islands of Indonesia (Fig. 1 and Fig. 2).

The aim of the inventory making is to develop the water resources by constructing reservoirs, dams and irrigation canals in the framework of water use for various requirements. Another aim of the inventory is to obtain baseline data on locations which are relatively not yet polluted.

### 2.3. Urban Water Quality Monitoring.

Monitoring of water quality in urban areas assumed to be polluted by domestic and industrial waste water, covers **7** rivers and 1 reservoir on the island of Java, 1 river in Sumatera and 1 river in Kalimantan, which make a total of **20** locations.

Monitoring of the network is at present being extended so as to cover **30** rivers or **56** locations (Fig. 1 and 2).

Fig. 3 , 4 and 5 show the polluted areas of various rivers, which have been chosen for the monitoring study, i.e. the Ciliwung River, polluted downstream after passing Jakarta city, and the Citarum River where pollution start at the upstream part due to industrial and domestic waste water from Bandung and surroundings. The Surabaya River , which

is the branch of the delta Brantas, is polluted also by industrial and domestic waste water. The level of pollution in those rivers has effected beneficial water uses for drinking water supply and fishery.



Monitoring Station

- Existing
- Planning

- 15 Kapuas
- 16 Matakam
- 17 Riam Kiwa
- 18 Riam Kanan
- 19 Maluka
- 20 Jeneberang
- 21 Walanae
- 22 Cenranae
- 23 Saddang
- 24 Menabo
- 25 Tondano lake

- 1 Musi
- 2 Barito
- 3 Deli
- 4 Toba lake
- 5 Asahan
- 6 Siak
- 7 Singkarak lake
- 8 Batanghari
- 9 Maninjau lake
- 10 Tulangbawang
- 11 Sepotih
- 12 Jepara
- 13 Jepara lake
- 14 Sekampung

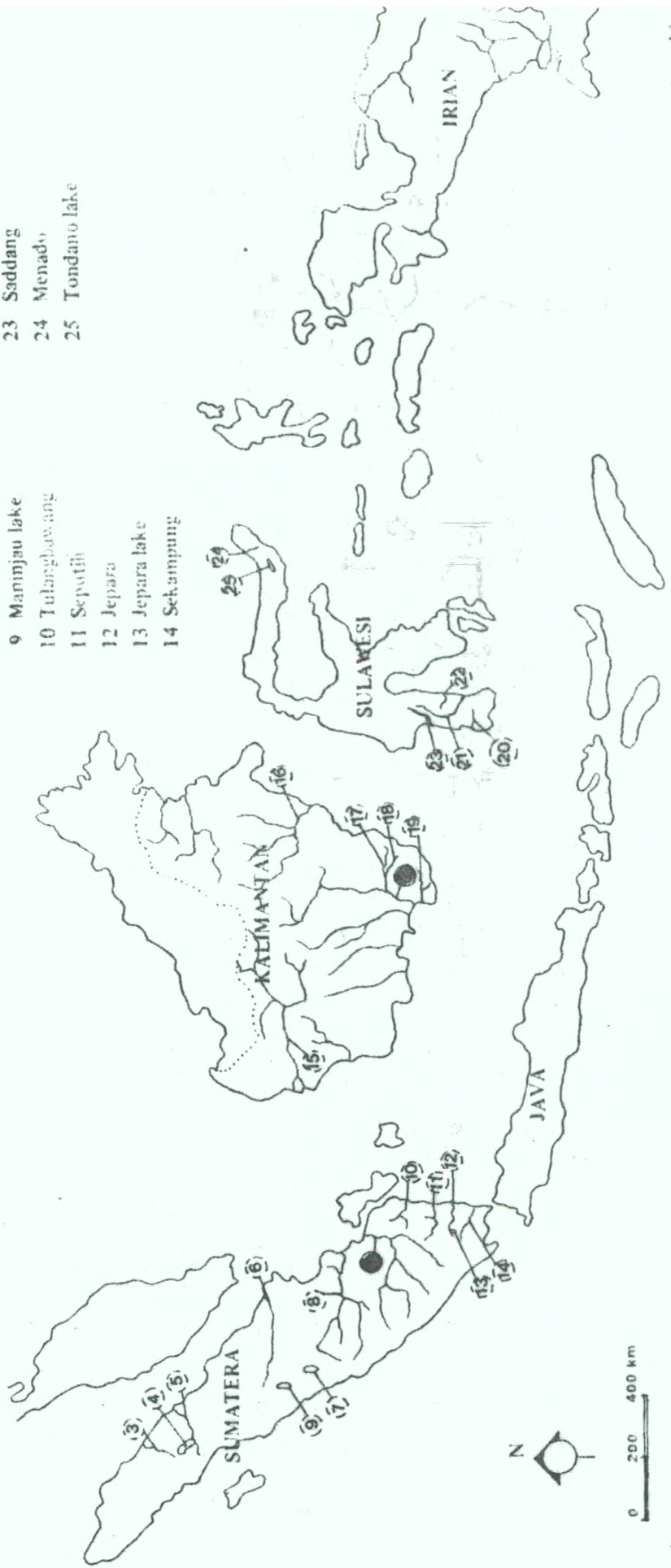


FIG. 1 LOCATION OF WATER QUALITY INVENTORY AND MONITORING.

**Existing**

**Planning**

- 1 Cisadane
- 2 Cihwang
- 3 Citarum
- 4 Cimanuk
- 5 Cisariggarung
- 6 Citanduy
- 7 Donar
- 8 Serayu
- 9 Garang
- 10 Progo
- 11 Bengawan Solo
- 12 Brantas

- 1 Ciliman
- 2 Ciujung
- 3 Cidurian
- 4 Angke
- 5 Banjir Kanal
- 6 Krukut
- 7 Sunter
- 8 Cakung
- 9 Bekasi
- 10 Cikarang
- 11 Cimandiri
- 12 Cikaso
- 13 Jatiluhur
- 14 Cikaranggakan
- 15 Cilaki
- 16 Cimelaya
- 17 Ciasem
- 18 Capanas
- 19 Pemali
- 20 Cacaban
- 21 Comal
- 22 Bodri
- 23 Rawa Pening
- 24 Tuntang
- 25 Serang
- 26 Lokulo
- 27 Pedagolan
- 28 Bogowonto
- 29 Opak
- 30 Bondoyudo
- 31 Bedadung
- 32 Sampean



Scale: 1:4,500,000

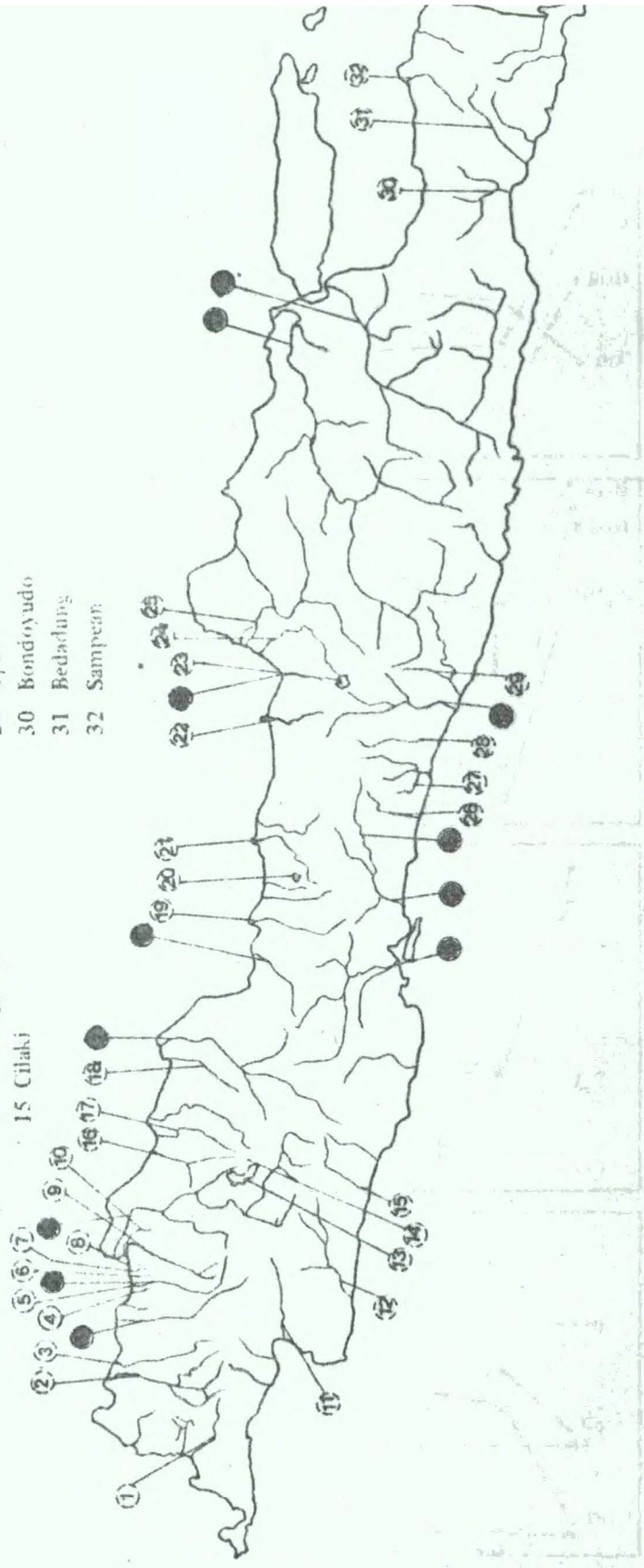


Fig 2 LOCATION OF WATER QUALITY INVENTORY AND MONITORING IN JAVA.



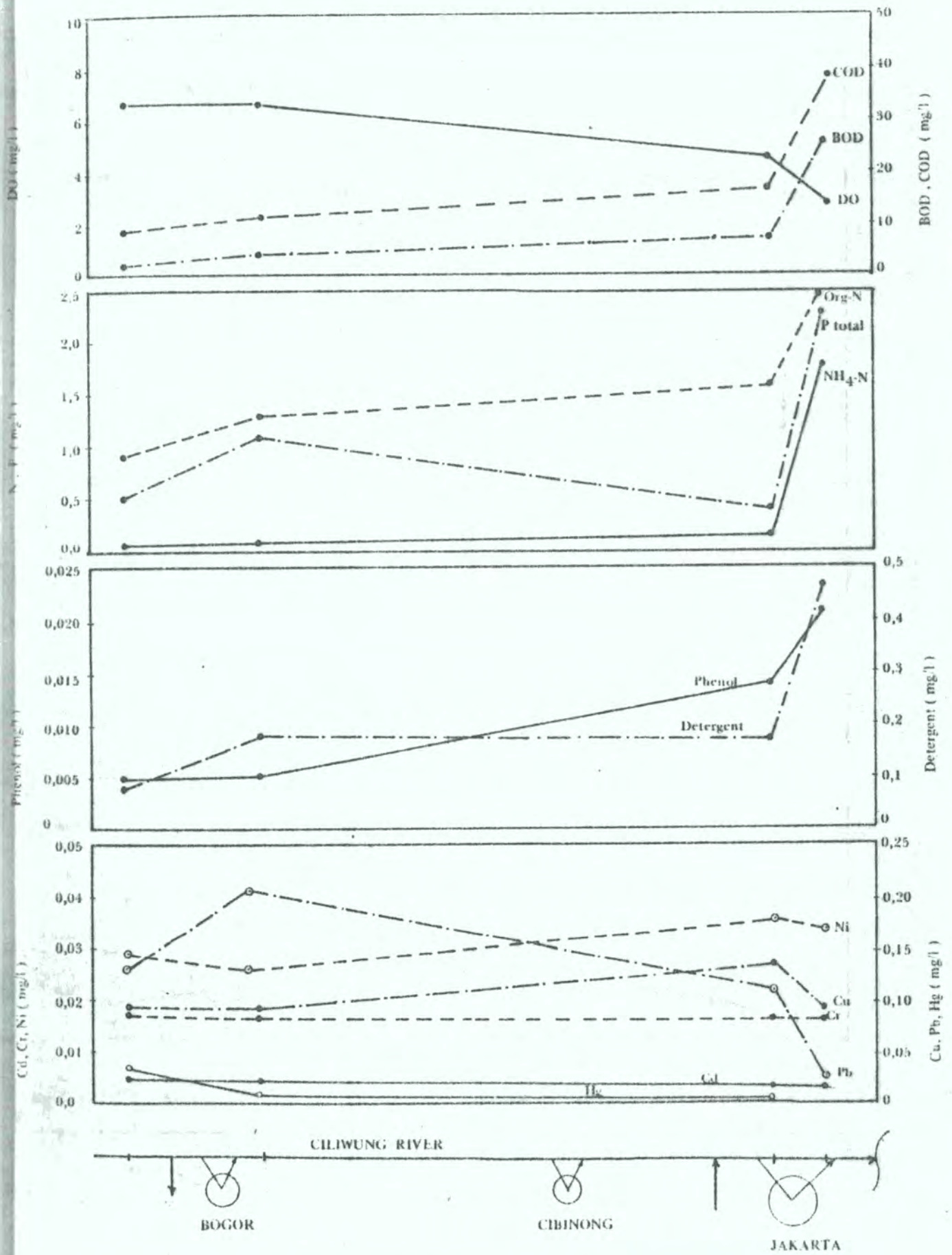


Fig. 3. WATER QUALITY PROFILE OF CILIWUNG RIVER.

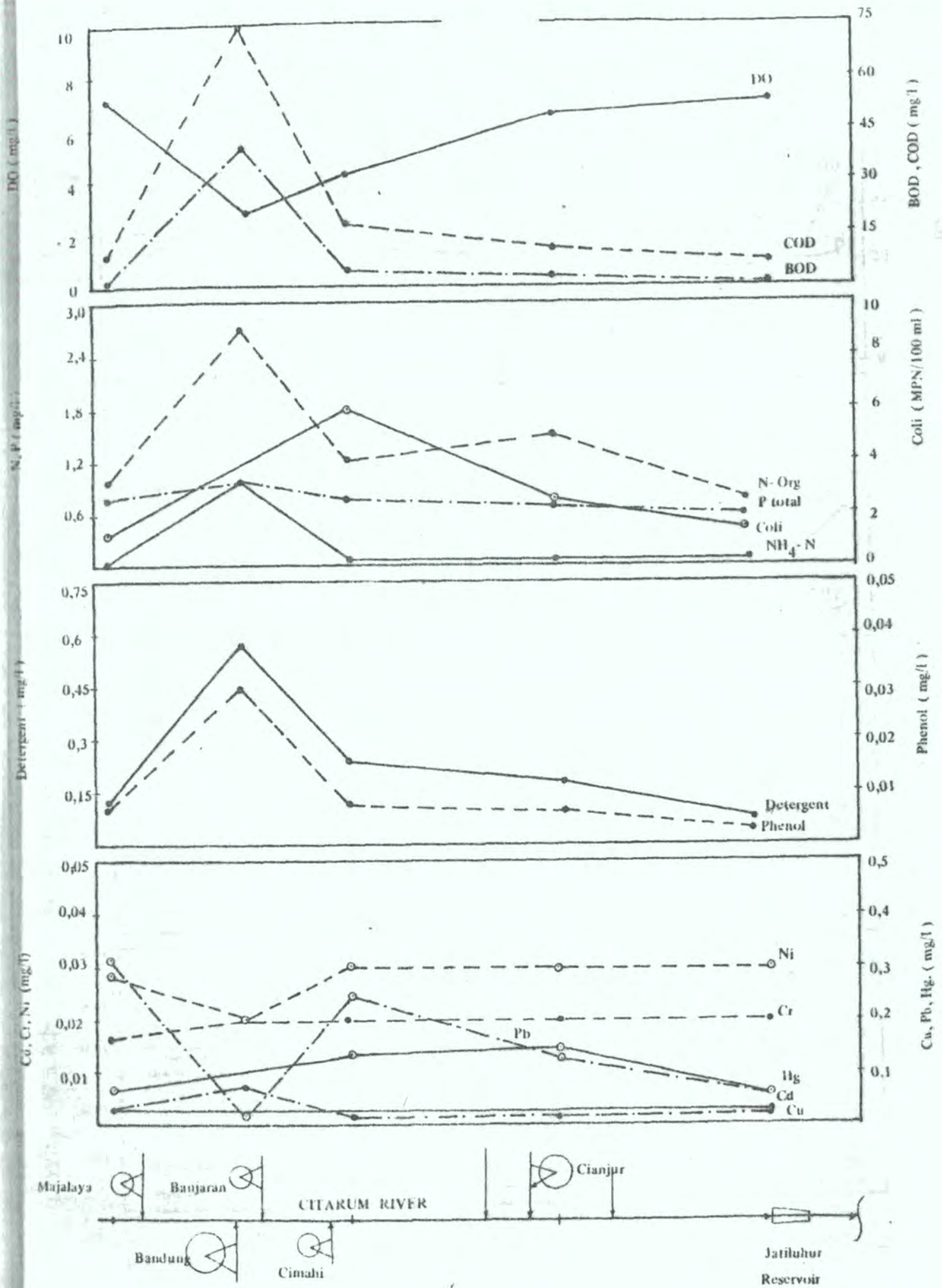


Fig. 4. WATER QUALITY PROFILE OF CITARUM RIVER.



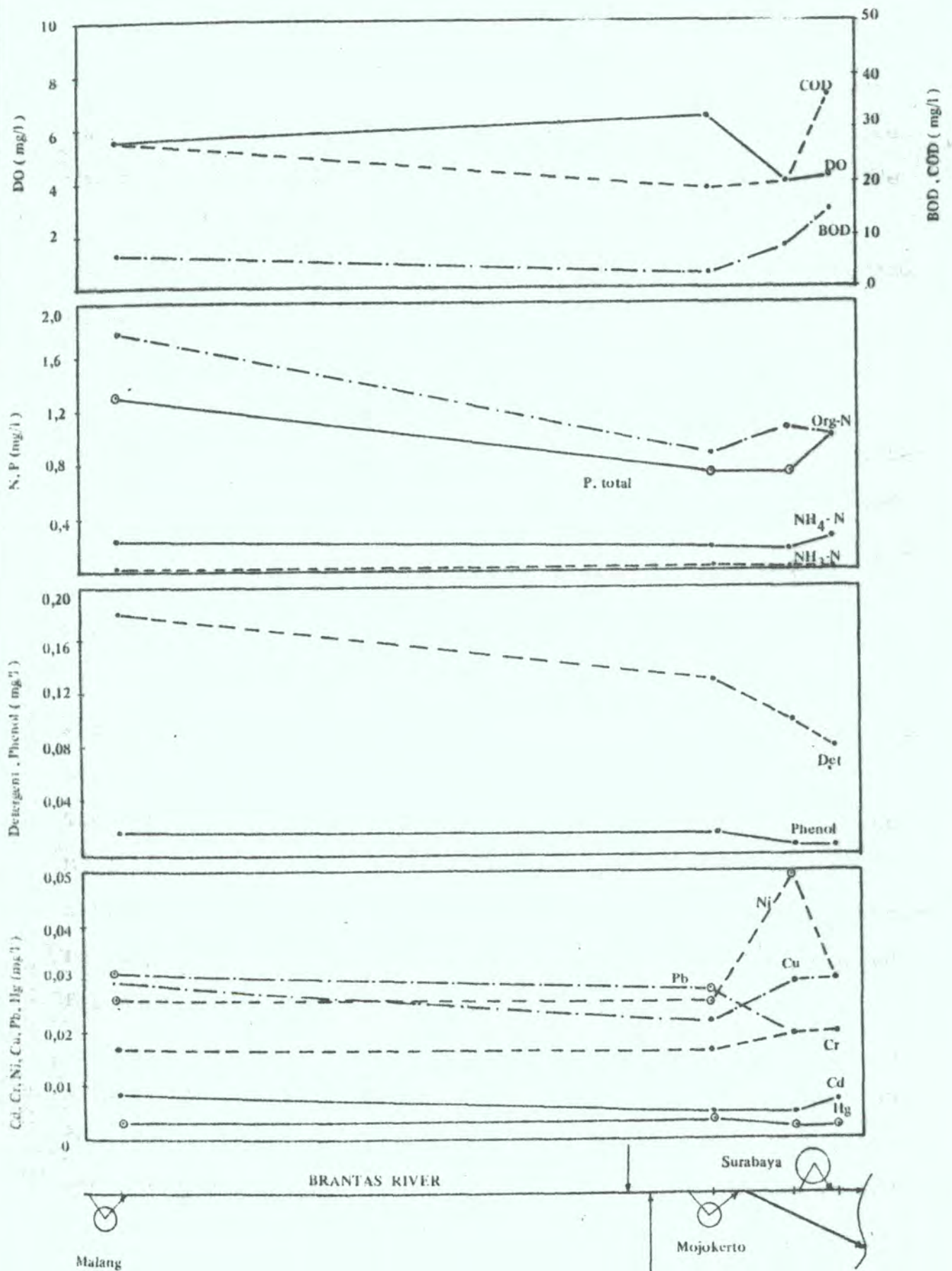


Fig. 5. WATER QUALITY PROFILE OF BRANTAS RIVER.

### 3. STUDY ON WATER QUALITY MANAGEMENT

A water quality management planning is one of the most important and therefore one of the first steps to do, to save water resources and multiple beneficial uses of water to give health and welfare to the people to develop the industry and the agriculture in the country, because they all have a demand on water.

A water quality management planning must be developed from a general to a detailed planning.

In the present most of the studies (feasibility studies, master plans etc) and the activities from this studies are developed only from the actual and regional needs and are related only to one or two beneficial uses of the water.

Therefore there is a strong and immediate need to coordinate all this activities by all beneficial uses covering, general water quality management planning, to take the other beneficial uses into account.

The Directorate General of Water Resources Development of the Ministry of Public Works is therefore presently developing activities for the protection of the quality of water resources, to support this a water quality management plans are required for each river basin in Indonesia.

In execution this task and to get experience in this as a first step a model study of a water quality management plan for one river basin is needed to be carried out which may be used as an example to be applied in other river basins in Indonesia. For this proposed pilot study the Citarum River catchment area has been selected, because this area covers all the local



situation, which may be expected in other river catchment areas, too.

In view of the development of industrialization and new settlements in this area and other pollution sources, it is considered necessary, too, to establish the pilot study to be applied to the mentioned area.

The Citarum River, located in West-Java covers a catchment area of 6,600 square km. It flows from Mount Wayang with an average water discharge of 77 cum/sec at Saguling station, and enters Jatiluhur reservoir with an average discharge of 148 cum/sec. The Jatiluhur reservoir has an average volume of 2.076 and a maximum volume of 3,055 million cum, with a fluctuation of water depths between rainy and dry seasons of 30 m. The surface area of water is 20,000 ha in the dry season, and 80,000 ha in the rainy season.

Beneficial uses of the upper Citarum River and its tributaries are for irrigation of 35,000 ha of land, fisheries and drinking water for rural communities and as drinking water supply to the Bandung municipality.

Beneficial uses of the Jatiluhur reservoir are for irrigation of 256,000 ha of land, fisheries, generation of a hydroelectric power (610 million kwh/year), recreational purposes and additional drinking water supply to Jakarta.

Potential sources of pollution which might influence the beneficial uses of Citarum and Jatiluhur area, as an example (Fig 6 ):

- The Urban population of Bandung and vicinity i.e. about 2 million people, which have a very poor water disposal



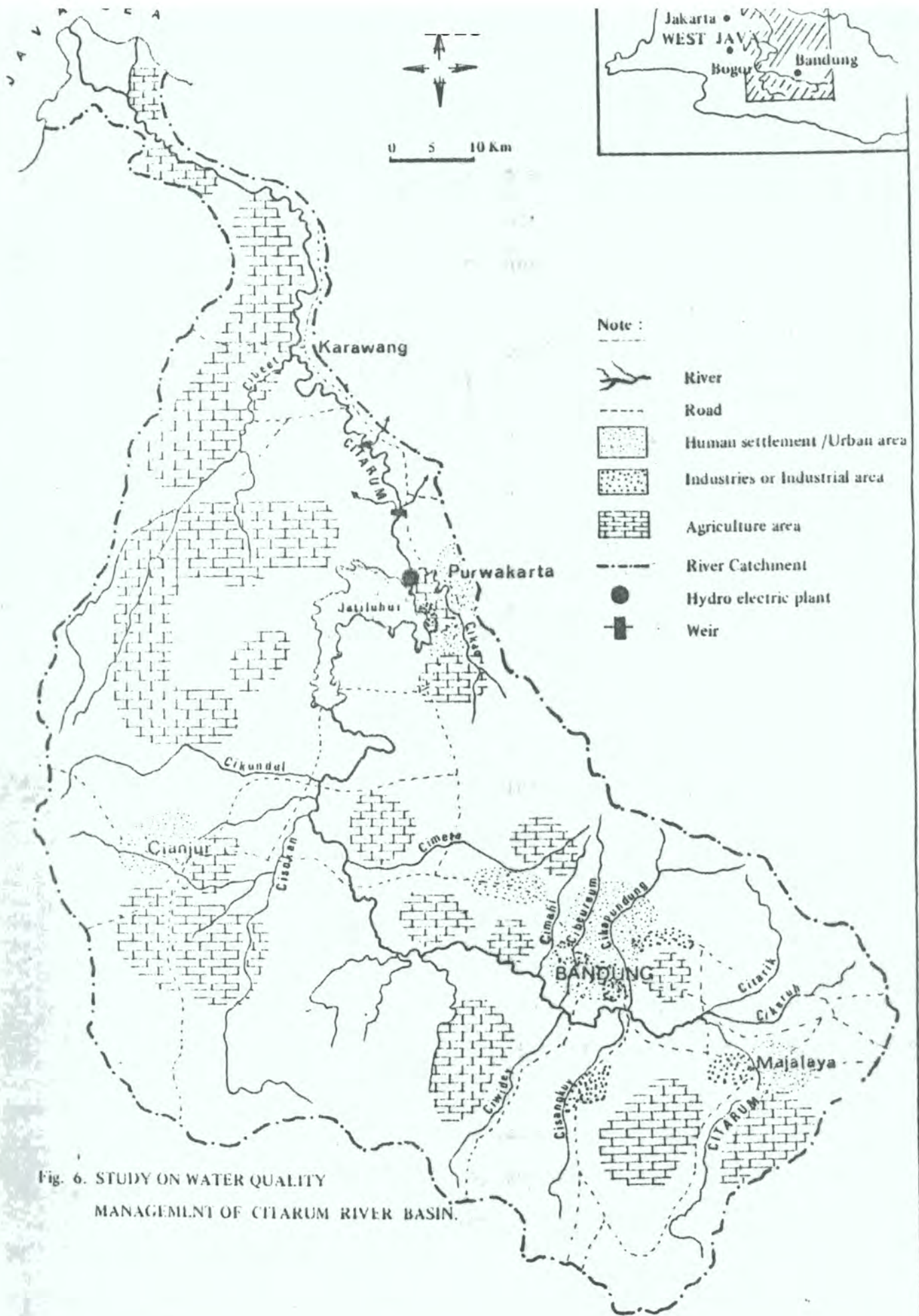


Fig. 6. STUDY ON WATER QUALITY  
MANAGEMENT OF CITARUM RIVER BASIN.



system.

- The Industrial locations upstream of Citarum River : Most are textile industries with a production of 50% of the total textile production in Indonesia.
- Other kinds of industry, such as a paper plant, pipes industry dairy farms, etc. are located in locations spread upstream of the water.
- Some textile industries : located downstream of the Jati-luhur reservoir, dispose their sewage water into the main irrigation channel.

The pilot study has several sub-projects such as :

- Description and quantification of present and projected future human development in the basin, including (i) population and communities, (ii) agricultural development including irrigation and fisheries, (iii) industry, (iv) hydroelectric power, (v) recreational and resort facilities and (vi) other human development projects and activities.
- Delineation, description and quantification of present and future beneficial uses of the river basin and the reservoir water, including (i) water supply for communities, industries and agriculture, (ii) fisheries, (iii) hydroelectric power, (iv) recreation and tourism, (v) preservation of wildlife and natural ecology.
- Quantification of wastes to be generated in the basin from urban areas, rural communities, agriculture, industries, shipping and other sources based on projections for basin development.
- Sampling and analysis of the reservoir and the Citarum River and its tributary streams at selected stations, including

physical, chemical, biological and bacteriological parameters and including both the water column and the benthos, together with associated evaluations of hydrology and climate for key pollution parameters including BOD , Nitrogen, Phosphorus and other pertinent water quality constituents, including a monitoring system.

- Evaluation of the data as described above to estimate the capacities of the river and reservoir waters for receiving and absorbing waste by dilution and self-purification.
- Delineation of pertinent practicable parameters for measuring and assessing the specific levels of water quality relating to each type of beneficial use and the limits of concentration of these parameters which must be maintained, including the developing of appropriate water quality criteria and standards.



#### 4. STUDY ON WATER POLLUTION ABATEMENT

In developing countries, including Indonesia, the use of technology for water pollution abatement is still very limited. Various kinds of technology e.g. the physical, chemical and biological methods concerned have to be evaluated on the possibilities of their application in Indonesia, including research on appropriate technology. In view of the above-mentioned requirements, a pilot plant installation for waste water treatment is presently established for an industrial area, located at Cimahi, near Bandung, West Java.

There are 109 industries located in Cimahi (Fig 7 ) consisting of textile industry (62,5%), metal industry (15,7%), pharmaceutical industry (3,16%), food industry (9,4%). The rest comprises various kinds of other industry.

Sources of water supply are mainly furnished by ground water, amounting to 4300 m<sup>3</sup>/day, while surface water is only benefited by one textile industry by taking water from Cibeureum River amounting to 30 m<sup>3</sup>/day.

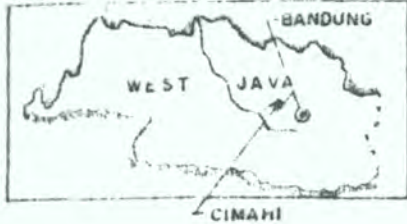
Most of the above-mentioned industries (94,5%) dispose their waste water directly into the river. The rest owns a rather ineffective waste water treatment installation. Waste water receivers are Cimahi River, Cibodas River, Cigugur River and Cibeureum River. These rivers form the tributaries of Citarum River.

The above-mentioned rivers are purposed for the irrigation of 2033 hectares of ricefield area, fishery, and for domestic supply in rural area.

Fig. 7. LOCATION OF PILOT PLANT FOR WATER POLLUTION CONTROL AT CIMAHI



PROJECT LOCATION









TO JAKARTA  
TO JAKARTA

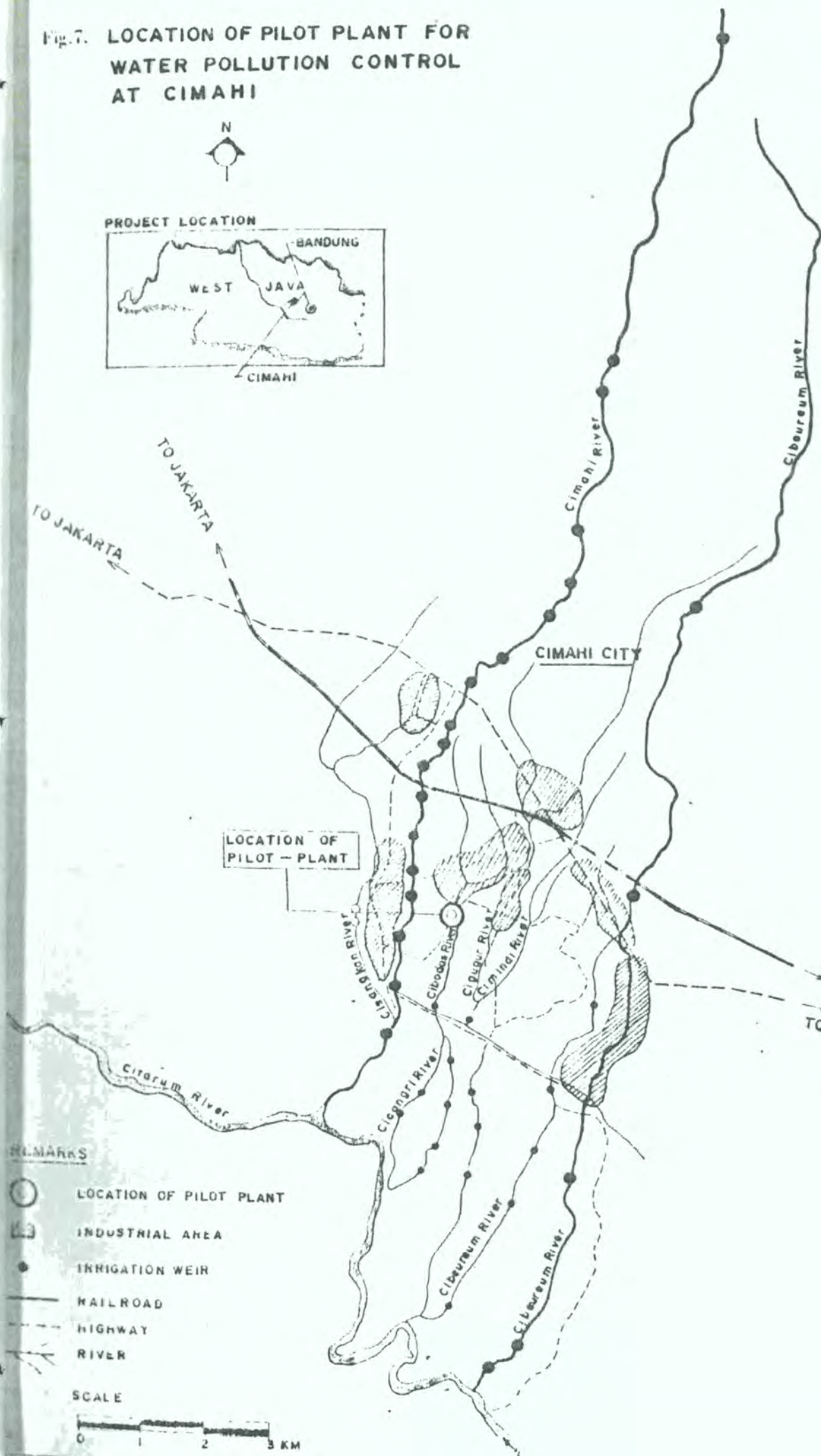
CIMAHI CITY

LOCATION OF PILOT - PLANT

TO BANDUNG  
TO BANDUNG

REMARKS

-  LOCATION OF PILOT PLANT
-  INDUSTRIAL AREA
-  IRRIGATION WEIR
-  RAILROAD
-  HIGHWAY
-  RIVER

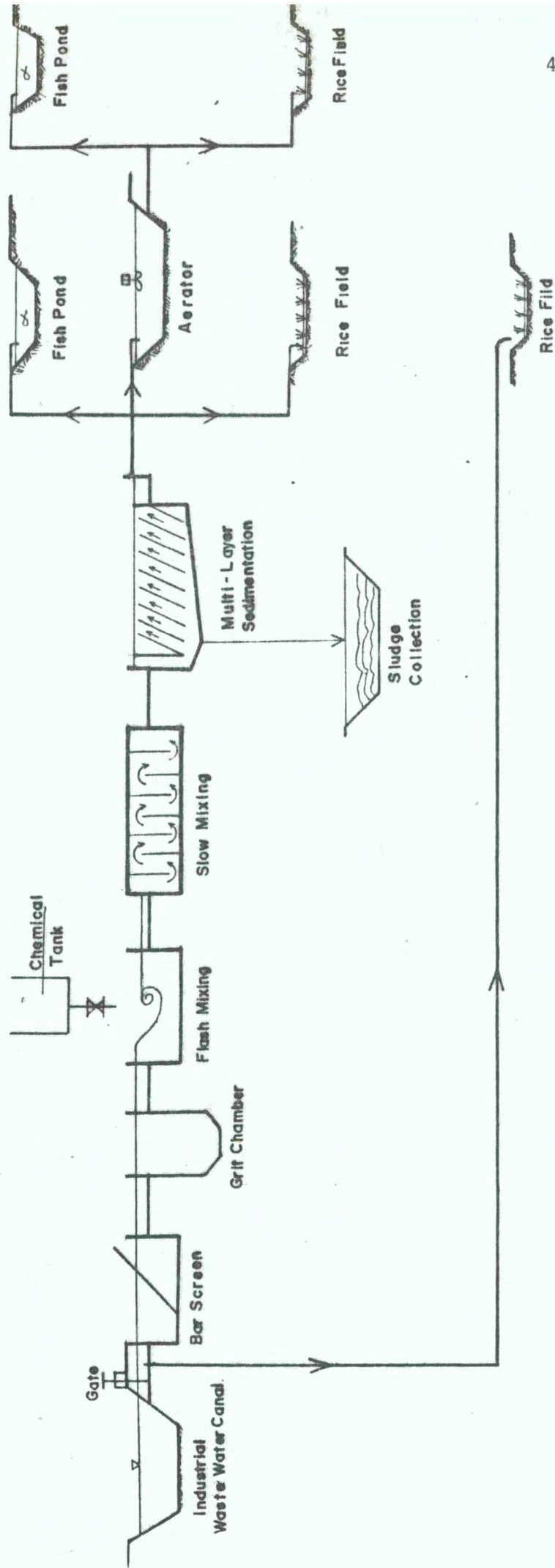




The pilot plant installation which is now already established makes use of a physical-chemical process, to be developed later with a biological process. The presently established physical-chemical process comprises sedimentation, rapid mixing (water fall system), slow mixing (baffle channel system) and multi-layer sedimentation and is operated by means of gravitational method, without electric power. It has a capacity of 1 - 3 lt/sec. The above-mentioned system (Fig 8 ) results in a decrease of COD pollution loading as much as 55 using mixed coagulant of calcium oxide and ferrosulphate.

Fig. 8

PILOT PLANT FOR  
WATER POLLUTION CONTROL  
AT CIMAH I





ANNEX 7

DEVELOPMENT OF WATER RESOURCES AND WATER  
POLLUTION CONTROL IN SINGAPORE

## DEVELOPMENT OF WATER RESOURCES & WATER POLLUTION CONTROL IN SINGAPORE

### INTRODUCTION

In 1950, the population of Singapore was about 1 million and there were only about 580 industrial establishments with 10 or more employees/industry.

Today, the population is 2.4 million and there are more than 2,900 industrial establishments.

Due to population growth, rapid industrial growth and rising standard of living, the water consumption has increased by 4.4 times, from 142,000 m<sup>3</sup>/day in 1950 to more than 630,000 m<sup>3</sup>/day in 1981. With continuing growth, the water consumption is expected to increase to 820,000 m<sup>3</sup>/day by 1985.

The corresponding wastewater generated has not only increased in volume but also in complexity.

Singapore is a relatively small country. Its area is less than 700 sq km. Its water resources is therefore limited.

This paper highlights how Singapore develops and manages its water resources to meet the demand and how Singapore manages the vast volume of domestic sewage and industrial effluent.

### DEVELOPMENT OF WATER RESOURCES

Prior to 1968, water was collected only from protected catchments which are used exclusively for the purpose of



collecting and impounding rain water. These are the central catchments.

To meet the increasing demand for water, areas which were inhabited by people had to be explored for use as catchment areas. These are known as unprotected catchments.

The first such unprotected water supply scheme was the Seletar Reservoir Scheme where water from eight streams was pumped to a reservoir for storage. The catchments of these streams occupied a total area of 3,300 hectares in which there was a farming population of 30,000.

To further increase the water resources, Singapore had to dam up its rivers and convert them into reservoirs. Examples of these are the Kranji River and four rivers in the western part of Singapore which were converted into reservoirs recently. Plans are in hand to dam up the Seletar River and also to form additional catchments in the Bedok area. When all these are completed, about 45% of Singapore's land area will become water catchments.

To ensure that the water impounded in the reservoirs of the unprotected catchments are not polluted, pollution control measures and cleaning up programmes were implemented.

The most pollutive source was the pig farms. The waste produced by one pig is equivalent to about 6 times that of a human being. As it was not economically feasible to treat the pig wastes to standards acceptable for discharge into the watercourse, the pigs had to be phased out from the Water Catchment. Farmers intending to continue with pig

rearing had to do so in areas designated for pig farming outside water catchments.

The next source of pollution was the duck farms. The traditional method of rearing ducks i.e. in open areas with ponds for the ducks to swim around was found to be pollutive. When it rains, the wet duck-droppings and the left over duck feed accumulated in the open areas are washed into the receiving streams causing pollution. To control pollution, it was proposed that the ducks be reared in duck houses similar to rearing chickens. This was tried out by the Primary Production Department and was found to be feasible. The duck droppings deposited on the floor of the duck houses were collected and mixed with sawdust or other absorbent materials and disposed of as solid wastes. In this way pollution could be minimised. The duck farmers were given one year to phase out wet duck rearing. Today, almost all the ducks are reared in duck houses. Ducks reared in duck houses were found to grow faster and fatter.

Unsewered premises in the rural areas were required to install low cost sewerage system costing S\$1200 each to control pollution. These low cost sewerage systems are basically septic tanks with soakaway systems.

Pollutive industries that could not feasibly treat their wastes had to be resettled to sewerred areas.



## MANAGEMENT OF DOMESTIC SEWAGE & INDUSTRIAL EFFLUENT

To control pollution from domestic sewage and industrial effluents, the Government has over the years invested millions of dollars in constructing and extending the sewerage infrastructure.

Today, there is an extensive network of sewers totalling 1,430 km of sewers ranging from 150mm to 2100mm in diameter and six municipal sewage treatment works with a total treatment capacity of 780,000 m<sup>3</sup>/day.

The sewage treatment works are designed to produce effluent complying with if not exceeding the Royal Commission Standard of 20 mg/l BOD and 30 mg/l Suspended Solids.

The sewer network covers about 35% of Singapore's land area. About 81% of the population enjoys modern sanitation.

To keep pace with the accelerated development in the public and private sectors, capital expenditure on sewerage schemes has increased from \$72 M in 1976 to \$165 M in 1980. A total of \$630 M has been spent in the last five years. It is estimated that another \$140 M will be spent in 1981 and more than \$600 M will be spent over the next 5 years.

## STATUTORY CONTROL

The main legislative instruments for the control of water pollution are :-

- (a) Water Pollution Control & Drainage Act, 1975;
- (b) Trade Effluent Regulations, 1976; and
- (c) Trade Effluent (Amendment) Regulations, 1977.

CONTROL OF DOMESTIC SEWAGE

All premises are required under these legislations to have adequate sanitary facilities and to be connected to the sewers. In areas where sewers are not available, individual sewage treatment plants have to be provided to treat the wastewater.

CONTROL OF TRADE EFFLUENT

All industries are required to discharge their trade effluent into the public sewers where sewers are available. Industries are required to pretreat their trade effluent to prescribed standards before discharging them into public sewers. In non-sewered areas, trade effluents must be treated to watercourse standards which are more stringent. The discharge of trade effluents into watercourse in water catchment areas are governed by even stricter requirements. The concentration limits for the discharge of trade effluents are stipulated in the Trade Effluent Regulations, 1976.

Where it is neither practical nor economical to set up a trade effluent treatment plant within factory premises, they may be permitted to discharge the waste direct into the public sewers subject to payment of trade effluent tariffs. However, this applies only to industries discharging biodegradable waste. With this provision, industries are spared the costs of installing, operating and maintaining a trade effluent treatment plant. As such, it is often cheaper for some industries to discharge their wastes direct into the public sewers without providing treatment. Industries discharging non-biodegradable wastes,



however, must treat the waste to acceptable standards prior to discharge.

#### CONCLUSION

To meet the increasing demand for water, areas outside the protected catchments have to be tapped to increase our water resources. Pollution control measures and cleaning up programmes have to be implemented to ensure that the water collected in the unprotected water catchments are not polluted. The sewerage infrastructure have to be expanded to keep pace with the increasing volume of domestic sewage and trade effluent.

The success of the programme will depend not only on the provision of sewerage facilities and legislations but also to a great extent on public awareness and cooperation.



REPUBLIC OF SINGAPORE  
**GOVERNMENT GAZETTE**  
**ACTS SUPPLEMENT**

*Published by Authority*

---

NO. 23 ]

FRIDAY, AUGUST 29

[ 1975

---

No. A 23—The following Act passed by Parliament on 29th July, 1975 and assented to by the President on 26th August, 1975 is hereby published for general information.

**THE WATER POLLUTION CONTROL AND  
DRAINAGE ACT, 1975.**

(No. 29 of 1975).

ARRANGEMENT OF SECTIONS.

PART I.

PRELIMINARY.

Section.

1. Short title and commencement.
2. Interpretation.

PART II.

ADMINISTRATION.

3. Appointment of Director and Deputy and Assistant Directors.

PART III.

DRAINAGE.

4. Director to construct and maintain drains and other drainage structures.
5. Adoption of private drains.



---

Section.

6. Drains not to be constructed without permission.
7. Drains not to be interfered with.
8. Director may require works to be executed in respect of premises not properly drained.
9. Earth works, etc., adversely affecting drainage system.
10. Construction and maintenance of private drains.
11. Director may cause an area to be provided with effectual drainage.
12. Declaration to vest drainage reserves in Government.

PART IV.

WATER POLLUTION CONTROL.

13. Prohibition on extraction of water.
14. Penalty for polluting water.

PART V.

SEWERAGE.

15. Director may make, construct and maintain sewerage systems.
16. Director to maintain every public sewerage system.
17. Sewer may be emptied into the sea.
18. Premises to be provided with adequate sewerage system.
19. Plant for treatment of trade effluent.
20. Director may take over control, etc., of sewerage system.
21. Declaration to vest sewerage systems in Government.
22. Adoption of private sewer.
23. Sewerage systems to be kept in order at cost of owners.
24. Prohibition on construction, etc., of sewerage system and sanitary facilities, without Director's permission.
25. Director may require the provision, alteration and resiting of sanitary facilities.
26. Inspection of sewerage systems and sanitary facilities.
27. No building etc., to be erected over, across or adjacent to any sewer.
28. Farm premises to have such sanitary facilities and sewerage system as Director may require.

---

**Section.**

29. A system of removal of sewage and trade effluent may be applied to premises.
30. Discharge of trade effluent.
31. Charges to be levied on sanitary appliances, etc.

**PART VI.****MISCELLANEOUS PROVISIONS.**

32. Mandatory order.
33. Provision as to appeal against order.
34. Proceedings where owner is unknown.
35. In case of urgency order may be made *ex parte*.
36. Director may act in cases of emergency.
37. Power to prohibit work and processes in certain circumstances.
38. Power to enter upon lands for the purposes of this Act.
39. Power to enter on lands adjacent to works.
40. Penalty for obstructing Director in his duty.
41. Compensation, damages and costs to be determined by Magistrate's Court.
42. Occupier may execute work where owner defaults in execution of work required by Act.
43. Recovery of costs and expenses payable by owners.
44. Recovery of costs and expenses by instalments.
45. Proceedings for recovery of arrears.
46. Attachment.
47. Application of proceeds.
48. Title conferred by purchaser at sale under section 45 (1) (b).
49. Costs of proceedings for recovery of arrears.
50. Power to stop sale.
51. Application to Court.
52. Security to be given.
53. Liability of transferor who has not given notice.
54. Proceedings if any occupier opposes the execution of works.
55. Receipts and notices may be given by officer authorised thereunto.
56. Service of notices.



## Section.

57. Appeal to Minister against notices and declarations.
58. Penalty for default in compliance with notice.
59. Power to demand for names and addresses.
60. Powers of arrest.
61. Saving of prosecutions under other laws.
62. Penalties.
63. Furnishing of deposits.
64. Inaccuracies in documents.
65. Evidence.
66. Exemption.
67. Forms.
68. Regulations.
69. Repeal.
70. Transitional and savings provisions.  
First Schedule.  
Second Schedule.

## REPUBLIC OF SINGAPORE

No. 29 of 1975.

I assent.

LS

B. H. SHEARES,  
*President.**26th August, 1975.*

An Act to make provision for effectual drainage of inland areas and for maintaining or restoring the cleanliness of rivers and watercourses and to regulate and control the collection, treatment and disposal of sewage and for matters connected therewith; and to repeal certain provisions of the Local Government Integration Act (Chapter 210 of the Revised Edition) and the Environmental Public Health Act (Chapter 155 of the Revised Edition).

Be it enacted by the President with the advice and consent of the Parliament of Singapore, as follows:—

## PART I.

## PRELIMINARY.

1. This Act may be cited as the Water Pollution Control and Drainage Act, 1975 and shall come into operation on such date as the Minister may, by notification in the *Gazette*, appoint. Short title and commencement.

2. In this Act, unless the context otherwise requires — Interpretation.  
“analyst” means an analyst appointed by the Government;



“building” includes any house, hut, shed or roofed enclosure, whether used for the purpose of human habitation or otherwise;

“Director” means the Director of Water Pollution Control and Drainage appointed under section 3 and includes a Deputy Director and an Assistant Director of Water Pollution Control and Drainage;

“drain” includes any watercourse or river;

“drain-line” means any pipe or sewer which is connected to the sewerage system of any premises;

“drainage reserve” means the land set aside for drainage works pursuant to development proposals approved by the competent authority;

“drainage works” includes any engineering works in the improvement, maintenance and construction of any drain, canal, culvert, bridge, railings enclosing a canal or drain, sump, canal or river wall, tide-gate, pumping station used to control the level of water in a drain, weir, gauge, and any other structure built for the purpose of conveying, storing or measuring storm water and flood alleviation;

“house” includes any dwelling-house, warehouse, office, counting-house, shop, school and any other building in which persons are employed;

“occupier”, in relation to any premises, means the person in occupation of any premises or having the charge, management or control thereof and, in relation to any part of any premises different parts of which are occupied by different persons, means the person in occupation or having the charge, management or control of that part;

“owner” means the person for the time being receiving the rent of any premises, whether on his own account or as agent or trustee or as receiver, or who would receive the same if the premises were let to a tenant and includes the person whose name is entered in the Valuation List authenticated under the provisions of section 13 of the Property Tax Act;

“premises” includes messuages, houses, buildings, lands, tenements, easements and hereditaments of any tenure, whether open or enclosed, whether built on or not, whether public or private, and whether maintained or not under statutory authority;



“public drains” means all drains —

- (a) which, by virtue of the Local Government Integration Act, were immediately before the date of the commencement of this Act vested in the Government; Cap. 210.
- (b) constructed by the Government at its expense or acquired by the Government; and
- (c) with respect to which a declaration of vesting has been made under section 5;

“public officer” includes any officer of any statutory board or body who is authorised in writing in that behalf by the Director to carry out all or any of the powers conferred on the Director by any of the provisions of this Act;

“public sewers and sewerage systems” means all sewers and sewerage systems —

- (a) which, by virtue of the Local Government Integration Act, were immediately before the date of the commencement of this Act vested in the Government;
- (b) constructed by the Government at its expense or acquired by the Government; and
- (c) with respect to which a declaration of vesting has been made under section 21;

“sanitary facilities” includes toilets, wash basins, bathrooms, sinks and facilities for washing clothes which connect, directly or otherwise, with a private sewage treatment plant or with a public sewerage system;

“sewage” means any liquid waste and includes water-borne sullage and trade effluent;

“sewerage system” means any sewer, drainline, cesspit, septic tank, treatment plant, privy or any appurtenance thereof;

“toilet” means a facility for urinating and defecating which is water flushed, and which connects, directly or otherwise, with a private sewerage system or with the public sewerage system;

“trade effluent” means any liquid, either with or without particles of matter in suspension therein, which



is wholly or in part produced in the course of, or is the waste or refuse of, any trade, business or manufacture or of any building construction.

## PART II.

### ADMINISTRATION.

Appoint-  
ment of  
Director  
and Deputy  
and  
Assistant  
Directors.

3.—(1) The Minister may, by notification in the *Gazette*, appoint a Director of Water Pollution Control and Drainage and such number of Deputy and Assistant Directors of Water Pollution Control and Drainage as he may think fit.

(2) The Director shall have the superintendence of all matters relating to this Act subject to the general or special directions of the Minister.

(3) A Deputy or an Assistant Director of Water Pollution Control and Drainage shall have and may exercise all the powers conferred on the Director by or under this Act, subject to such limitations as the Director may deem fit to impose.

## PART III.

### DRAINAGE.

Director to  
construct  
and main-  
tain drains  
and other  
drainage  
structures.

4.—(1) The Director may cause to be made, constructed and maintained drains and other drainage structures and, if necessary, the Director may, after reasonable notice in writing in that behalf, carry them across, through, along or under any premises or any cellar, basement or vault, doing as little damage as may be and making full compensation for any damage done.

(2) If any dispute arises relating to the amount or apportionment of compensation, it shall be settled in the manner provided in section 41.

Adoption  
of private  
drains.

5.—(1) Subject to the provisions of this section, the Director may at any time declare that any private drain shall, as from such date as may be specified in the declaration, become vested in the Government:

Provided that the Director who proposes to make a declaration under this subsection shall give notice of his proposal to the owner or owners of the drain in question and shall take no further action in the matter until either one month has lapsed without an appeal against his proposal being lodged under subsection (2), or, as the case may be, until an appeal so lodged has been disposed of.



(2) An owner aggrieved by the proposal of the Director to make a declaration under this section may appeal to the Minister within one month after the notice of the proposal is served upon him. On the hearing of an appeal under this subsection the Minister may allow or disallow the proposal of the Director or, as the case may be, make any declaration which the Director might have made and any declaration so made shall have the same effect as if it had been made by the Director under this section.

(3) A declaration under this section may be made with respect to a part only of a drain.

(4) Where any declaration has been made in respect of a private drain, the Director shall maintain the drain and, if he sees fit, enlarge, alter or otherwise improve such drain and may discontinue, close up or destroy such drain as he deems necessary as if it is a drain constructed by the Director.

6.—(1) No person shall, without the permission of the Director, construct, alter or repair any drain so as to affect the drainage of any area.

Drains not to be constructed without permission.

(2) An application for permission to construct, alter or repair any drain shall be made in such form as the Director may require and shall be accompanied by plans showing details of the design and specifications of the drain when constructed, altered or repaired, as the case may be.

(3) The Director may in granting any permission under this section impose such conditions as he thinks fit.

7.—(1) If any person without the permission of the Director makes or causes to be made any drain or diverts, obstructs, covers, fills up, damages or in any way interferes with any drain so that it is prejudicial to health or a nuisance, the Director may by notice in writing require the person to demolish, alter, remake, repair, or otherwise deal with such drain as the Director thinks fit within a reasonable time fixed by him.

Drains not to be interfered with.

(2) If any person erects or causes or permits to be erected any house, structure, building or obstruction over, across or adjacent to any drain or drainage reserve, without the permission of the Director, the Director may by notice in writing require that person to demolish or remove the same within the period fixed by him (which shall not be less than fourteen days after the date of service of the notice).



(3) If any person fails to comply with any requirement of a notice issued under subsection (1) or (2) the Director may, at the expiration of the period specified in the notice, execute the works specified in the notice and may recover from that person the expenses reasonably incurred in so doing.

Director may require works to be executed in respect of premises not properly drained.

8.—(1) If it appears to the Director that any premises is not properly drained, he may by notice in writing require the owner or occupier of the premises to remedy the defect within two weeks from the date of service of the notice.

(2) If the notice is not complied with, the Director may carry out the work necessary to remedy the defect and may, subject to subsection (3), recover the expenses reasonably incurred in so doing from the person on whom the notice was served.

(3) In any proceedings to recover expenses under this section the court may inquire—

(a) whether any requirement specified in a notice served under this section was reasonable; and

(b) whether those expenses ought to be borne wholly or in part by some person other than the defendant in the proceedings,

and the court may make such order concerning the expenses or their apportionment as appears to the court to be just:

Provided that the court shall not order the expenses or any part thereof to be borne by any person other than the defendant in the proceedings unless the court is satisfied that that other person has had due notice of the proceedings and an opportunity of being heard.

Earth works, etc., adversely affecting drainage system.

9.—(1) No person shall carry out any earth works or construction works which will adversely affect any drain or drainage system in the vicinity either directly or indirectly without seeking the prior permission of the Director who may impose such conditions as he thinks fit in granting the permission.

(2) Where any person contravenes the provisions of subsection (1), the Director may by notice in writing require such person or the owner or occupier of any premises in respect of which the earth works or construction works are carried out to carry out such drainage works as he may deem necessary at their expense.

(3) If the notice is not complied with, the Director may carry out the drainage works described in the notice and



may, subject to subsection (4), recover the expenses reasonably incurred in so doing from the person on whom the notice was served.

(4) In any proceedings to recover expenses under this section the court may inquire —

- (a) whether any requirement specified in a notice served under this section was reasonable; and
- (b) whether those expenses ought to be borne wholly or in part by some person other than the defendant in the proceedings,

and the court may make such order concerning the expenses or their apportionment as appears to the court to be just:

Provided that the court shall not order the expenses or any part thereof to be borne by any person other than the defendant in the proceedings unless the court is satisfied that that other person has had due notice of the proceedings and an opportunity of being heard.

10.—(1) The Director may authorise any person to construct any drain through, across or under any private property or to alter, repair or otherwise deal with such drain as the Director thinks fit.

Construction and maintenance of private drains.

(2) Any authority given under subsection (1) may be subject to such conditions as the Director thinks fit and the Director may require a deposit to be furnished for the purposes of ensuring that such person complies with the provisions of subsection (3).

(3) A person authorised under subsection (1) to construct any drain shall make full compensation to the owner or occupier of the land for any damage caused to the land and any loss suffered by him.

(4) If any dispute arises concerning the amount of compensation payable, the dispute shall be determined in accordance with section 41.

(5) The Director shall, before authorising any person to construct any drain under subsection (1), serve a notice on the owner or occupier of the land stating the nature of the works to be done and that if no objections are received within twenty-one days of the date of service of the notice the works will be carried out on the date specified in the notice.

(6) A person served with a notice under subsection (5) shall submit his objections, if any, to the Director within



the prescribed time and the Director may allow or disallow the objections or allow the objections in part.

(7) A person aggrieved by a decision of the Director may within twenty-one days appeal to the Minister whose decision thereon shall be final.

Director may cause an area to be provided with effectual drainage.

11.—(1) If it appears to the Director that an area is not provided with effectual drainage, the Director may cause to be executed such drainage works as he considers necessary to provide for the effective drainage of the area and may apportion as he deems just the costs and expenses of such drainage works among the owners of the premises in such area and recover the sums apportioned from such owners.

(2) If any dispute arises relating to the amount or apportionment of such costs and expenses, it shall be settled in the manner provided in section 41.

Declaration to vest drainage reserves in Government.

12.—(1) Where any premises have been set aside as drainage reserve pursuant to any development proposals approved by the competent authority, the Director may by an instrument in the form approved by the Registrar of Titles or the Registrar of Deeds, as the case may be, declare that the drainage reserve shall vest in the Government.

Cap. 276.

(2) Any plan prepared by the Director under subsection (1) shall comply with the requirements of the Land Titles Act in respect of registered land and of the Registration of Deeds Act in respect of other land and shall show thereon the premises which will vest in the Government.

Cap. 281.

(3) Such a declaration shall be published in the *Gazette*.

(4) Where any drainage reserve that has become vested in the Government under the provisions of this section is comprised of premises included in separate lots already set aside as part of a drainage reserve, the declaration shall be registered against those lands under the provisions of the Land Titles Act in respect of registered land and under the provisions of the Registration of Deeds Act in respect of other land.

(5) Where any drainage reserve that has become vested in the Government under the provisions of this section is comprised of premises included in an existing lot or lots, the premises forming the drainage reserve shall be excised from the existing lot or lots and the declaration shall be registered in respect of excised portions under the provisions of the Land Titles Act in respect of registered land and under



the provisions of the Registration of Deeds Act in respect of other land. Cap. 281.

(6) Upon such registration the premises forming the drainage reserve shall vest in the Government free from all encumbrances and where the premises are held under a statutory land grant such vesting shall not be deemed to create a subdivision within the meaning of the State Lands Act. Cap. 285.

(7) No compensation shall be payable for any premises vested in the Government pursuant to this section.

(8) When the Director has pursuant to the provisions of this section registered any instrument, he may take possession of the premises described therein and may proceed to demolish and remove any building or portion of any building forming part thereof.

#### PART IV.

#### WATER POLLUTION CONTROL.

13.—(1) No person shall, without the permission of the Director, construct any works for taking or intercepting water from any place or sea, within the territorial limits of Singapore. Prohibition on extraction of water.

(2) An application for permission to construct any works for taking or intercepting water from any such place or sea shall be made in such form as the Director may require.

(3) In considering an application made under this section the Director may require the applicant to furnish such particulars and plans for the proposed works as he thinks fit.

(4) In granting any permission under this section, the Director may impose such conditions as he thinks fit.

(5) Any person who contravenes the provisions of subsection (1) shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five thousand dollars or to imprisonment for a term not exceeding three months.

(6) The provisions of this section shall not apply to the lands, buildings and installations of the Public Utilities Board.

14.—(1) The Minister may control the quality of and regulate the storage and use of any water in any water-course, river, reservoir, lake or pond and may prescribe such regulations as he deems necessary to provide for such control and regulation. Penalty for polluting water.



(2) Any person who causes any oil, chemical, sewage, trade effluent or any noxious or polluting matter to be discharged into any drain, lake, pond or reservoir shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five thousand dollars and in the case of a second and subsequent conviction to a fine not exceeding ten thousand dollars.

(3) Subject to the provisions of subsection (5) any person who causes or suffers any oil, chemical, sewage, trade effluent or other impurities, whether solid or liquid, to enter or pass into any drain, river, lake, pond, or reservoir, whether wilfully or by accident, shall forthwith inform the Director of such occurrence.

(4) Any person who fails to comply with the provisions of subsection (3) shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five hundred dollars.

(5) The requirements of subsection (3) may be waived by the Director in any case where the amount of oil, chemical, sewage, trade effluent or other impurities referred to in subsection (3) is, in the opinion of the Director, not of a substantial nature.

#### PART V.

#### SEWERAGE.

Director may make, construct and maintain sewerage systems.

15.—(1) The Director may cause to be made, constructed and maintained any sewerage system and, if necessary, the Director may, after giving reasonable notice in writing in that behalf, carry it across, through, along or under any premises or any cellar, basement or vault, doing as little damage as may be and making full compensation for any damage done.

(2) If any dispute arises relating to the amount or apportionment of compensation, it shall be settled in the manner provided in section 41.

Director to maintain every public sewerage system.

16.—(1) The Director shall maintain and keep in repair and, as he sees fit, enlarge, alter or otherwise improve every public sewerage system and may discontinue, close up or destroy any such system as he deems useless or unnecessary:

Provided that the Director shall, before entering any private property for the purpose of carrying out any work under this subsection, give reasonable notice in writing in that behalf and shall do as little damage as may be and shall make full compensation for any damage done.



(2) If by reason thereof or of any such alteration as hereinbefore provided any person who is deprived of the lawful use of any sewer the Director shall with due diligence provide some other sewer as effectual as the one of which he is so deprived.

17. The Director may cause any sewer to be emptied into the sea or other fit place, or may cause the sludge from them to be conveyed by a proper channel to the most convenient site for its deposit, and may sell or otherwise dispose of the sludge for any agricultural or other purposes as are deemed most expedient but so that it shall not become a nuisance.

Sewer may be emptied into the sea.

18.—(1) If it appears to the Director that any premises is not provided with an adequate sewerage system, he may by notice in writing require the owner of the premises to construct or alter such sewerage system as he deems necessary.

Premises to be provided with adequate sewerage system.

(2) The Director may at any time require the owner of any sewerage system to make a sufficient drain-line emptying into any public sewer and to disconnect and demolish at his own expense any sewerage system rendered useless or unnecessary thereby.

(3) The Director may by notice in writing require the owner of any premises to cause all sewage other than trade effluent therefrom to be discharged into such sewerage system as he may direct.

19.—(1) The owner of any premises shall treat any trade effluent discharged therefrom in such manner as may be prescribed before such trade effluent is discharged into any sewer or drain.

Plant for treatment of trade effluent.

(2) A person using, working or operating any plant for the purpose of treating any trade effluent shall use, work or operate and maintain such plant in such manner as the Director may require.

20.—(1) The Director may take over the control, supervision, maintenance and repair of any private sewerage system to such extent as he thinks fit and may charge fees therefor.

Director may take over control, etc., of sewerage system.

(2) Any such decision may from time to time be varied or rescinded.

(3) Fees for such control, supervision, maintenance and repair shall be payable by the owner of the sewerage system and may be recovered in the manner provided in section 43.



Declaration  
to vest  
sewerage  
systems in  
Govern-  
ment.

21.—(1) Where any premises has been set aside or is being used for any sewerage system pursuant to any development proposals approved by the competent authority and the owner of the said premises has agreed to surrender the premises to the Government, the Director may by an instrument in the form approved by the Registrar of Titles or the Registrar of Deeds, as the case may be, declare that the said premises shall vest in the Government.

Cap. 276.

Cap. 281.

(2) Any plan prepared by the Director under subsection (1) shall comply with the requirements of the Land Titles Act in respect of registered land and of the Registration of Deeds Act in respect of other lands and shall show thereon the premises which will vest in the Government.

(3) Such declaration shall be published in the *Gazette*.

(4) Where any premises that has become vested in the Government under the provisions of this section is comprised of premises included in separate lots already set aside for a sewerage system, the declaration shall be registered against those lots under the provisions of the Land Titles Act in respect of registered land and under the provisions of the Registration of Deeds Act in respect of other lands.

(5) Where any premises that has become vested in the Government under the provisions of this section is comprised of premises included in an existing lot or lots, the premises forming the sewerage system shall be excised from the existing lot or lots and the declaration shall be registered in respect of the excised portions under the provisions of the Land Titles Act in respect of registered land and under the provisions of the Registration of Deeds Act in respect of other lands.

Cap. 285.

(6) Upon such registration the said premises including every sewerage system installed therein shall vest in the Government free from all encumbrances and where the premises is held under a statutory land grant such vesting shall not be deemed to create a subdivision within the meaning of the State Lands Act.

(7) No compensation shall be payable for any premises vested in the Government pursuant to this section.

Adoption  
of private  
sewer.

22.—(1) Subject to the provisions of this section, the Director may at any time declare that any private sewer shall, as from such date as may be specified in the declaration, become vested in the Government:



Provided that the Director who proposes to make a declaration under this subsection shall give notice of his proposal to the owner or owners of the sewer in question and shall take no further action in the matter until either one month has lapsed without an appeal against his proposal being lodged under subsection (2), or as the case may be, until an appeal so lodged has been determined.

(2) An owner aggrieved by the proposal of the Director to make a declaration under this section may appeal to the Minister within one month after the notice of the proposal is served upon him. On the hearing of an appeal under this subsection the Minister may allow or disallow the proposal of the Director or, as the case may be, make any declaration which the Director might have made and any declaration so made shall have the same effect as if it has been made by the Director under this section.

(3) A declaration under this section may be made with respect to a part only of a sewer.

(4) Where any declaration has been made in respect of a private sewer, the Director shall maintain the sewer and, if he sees fit, enlarge, alter or otherwise improve such sewer and may discontinue close up or destroy such sewer as he deems necessary as if it is a sewer constructed by the Director. If by reason of the alteration or closing up of any such sewer any person is deprived of the lawful use of the sewer, the Director shall with due diligence provide some other sewer as effectual as the one of which he is so deprived.

23.—(1) Every sewerage system shall be altered, repaired and kept in proper order at the cost and expense of the owner of the land and building to which the same belong or for the use of which they are maintained.

Sewerage systems to be kept in order at cost of owners.

(2) If the owner of any land or building to which any sewerage system belongs neglects after notice in writing for that purpose has been given by the Director to alter, repair or put the same in good order in the manner required by the Director, and within the time and date specified in the notice, a Magistrate's Court may, on the application of the Director, make a mandatory order requiring him to alter, repair and put the same in good order as required by the Director.

(3) Where the Director is satisfied that it is necessary immediately to alter, repair or put in good order and condition any sewer, drain, privy, cesspool, septic or other tank,



toilet, urinal, water-closet, sink, bath or lavatory or any appurtenance thereof, he or any public officer authorised in writing by the Director in that behalf may enter with such assistants and workmen as are necessary, upon any land or building and may do or cause to be done such alterations, repairs, works, acts or things as are necessary for any of those purposes, and the expenses reasonably and necessarily incurred in so doing may be recovered from the person who is the owner of the land or building when the work is completed, and in default of agreement the amount of such expenses may be determined under section 41 and the provisions of section 43 shall apply to the amount for which judgment is given:

Provided that no entry shall be made under this section into any dwelling-house in actual occupation, unless with the consent of the occupier, without six hours' previous notice to such occupier.

Prohibition on construction, etc., of sewerage system and sanitary facilities, without Director's permission.

24. No person shall, without the permission of the Director, —

- (a) construct any sewerage system or alter or in any way interfere with any sewerage system; or
- (b) construct or alter any sanitary facilities.

Director may require the provision, alteration and resiting of sanitary facilities.

25.—(1) If it appears to the Director that any building or part thereof is without adequate sanitary facilities, he may by notice in writing require the owner, occupier or developer thereof —

- (a) to provide, fix or install such sanitary facilities as the Director may consider adequate; or
- (b) to alter, improve, demolish or resite any sanitary facilities thereof in such manner as the Director may require.

(2) All sanitary facilities provided or installed in any building shall be maintained, repaired and renewed to the satisfaction of the Director by the owner, occupier or developer of the premises as the Director may require.

(3) All costs and expenses incurred by an owner, occupier or developer of a building or part thereof pursuant to this section shall be borne by him.

Inspection of sewerage systems and sanitary facilities.

26.—(1) The Director or any public officer authorised by him in that behalf may inspect any sewerage system or sanitary facilities and for that purpose at any time may enter



upon any premises with such assistants and workmen as are necessary and cause the ground to be opened, doing as little damage as may be.

(2) No entry shall be made under this section into any dwelling-house in actual occupation, unless with the consent of the occupier, without six hours' previous notice to the occupier.

27.—(1) No person shall erect or cause or permit to be erected any house, structure or building over, across or adjacent to any sewer without the permission of the Director.

No building etc., to be erected over, across or adjacent to any sewer.

(2) If any person erects or causes or permits to be erected any house, structure or building over, across or adjacent to any sewer without the permission of the Director, the Director may by notice in writing require that person to demolish or remove the same within a reasonable time fixed by him.

(3) If any person fails to comply with any requirement of a notice issued under subsection (2) the Director may, at the expiration of a time specified in the notice which shall not be less than fourteen days after the service of the notice, do the work required by the notice and may recover from such person the expenses reasonably incurred in so doing.

(4) Any person who contravenes the provisions of subsection (1) or fails to comply with any requirement of a notice issued under subsection (2) shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five thousand dollars.

28.—(1) The owner or occupier of any premises used as a farm shall install, operate and maintain such sanitary facilities and sewerage system as the Director may require.

Farm premises to have such sanitary facilities and sewerage system as Director may require.

(2) The Director may require the owner or occupier of the premises to provide such facilities for the removal, treatment and disposal of waste matter as the Director thinks fit.

29.—(1) The Director may at any time apply any system of sewage and trade effluent removal to such premises as he thinks fit and charge such fees as may be prescribed therefor.

A system of removal of sewage and trade effluent may be applied to premises.

(2) Such fees shall be payable by the occupier of the premises so served and by the owner thereof when the premises are vacant and shall be recoverable in the manner provided in section 43.



Discharge  
of trade  
effluent.

30.—(1) Subject to the provisions of subsection (4), no trade effluent shall be discharged from any premises into a public sewer without the written consent of the Director.

(2) Subject to the provisions of subsection (3), any person who causes or suffers any trade effluent to enter or pass into any public sewerage system without the written consent of the Director (whether wilfully or by accident) shall forthwith inform the Director of such occurrence.

(3) The requirements in subsection (2) may be waived by the Director in any case where the amount of trade effluent is in the opinion of the Director not of a substantial nature.

(4) The provisions of subsection (1) shall not apply to such trade effluent as may be prescribed which may be discharged into any public sewerage system without seeking the prior written consent of the Director.

(5) If any trade effluent is discharged in contravention of this section or without the consent, if any, as is necessary for the purposes of this Act the occupier of the premises shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five thousand dollars.

(6) Any person who fails to comply with the provisions of subsection (2) shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five hundred dollars.

Charges to  
be levied  
on sanitary  
appliances,  
etc.

31.—(1) The Minister may make regulations to levy such charges as may be prescribed in respect of —

(a) sanitary appliances which are installed in any premises; and

(b) the amount of water used in any premises.

(2) The charges levied under subsection (1) shall be payable by the occupier of the premises and by the owner thereof when the premises are vacant.

(3) The charges shall be payable at such times and in such manner as may be prescribed and shall be recoverable in the manner provided in section 43.

## PART VI

### MISCELLANEOUS PROVISIONS.

Mandatory  
order.

32.—(1) Whenever any owner or occupier is required under this Act to erect or remove any building or thing or to perform any other work and after due notice fails to erect or remove the building or thing or to perform the work



within the prescribed time, the Director may make a complaint and the Magistrate's Court hearing the complaint may make on the owner or occupier a summary order, (hereinafter in this Act referred to as a "mandatory order") requiring the owner or occupier to execute the required work.

(2) A mandatory order shall require the person to whom it is directed to execute any work which the Court is authorised to require to be executed within a time to be specified in the order and may also require that person to pay to the Director a sum for costs and expenses incurred in obtaining the order.

(3) Any person to whom a mandatory order is addressed who fails to comply with the requirements of the order shall, unless he satisfies the Court that he has used all due diligence to carry out the order, be guilty of an offence and shall be liable on conviction to a fine not exceeding two hundred dollars for every day during the non-compliance with the order, and the Court may direct the Director to enter the premises and execute the work so required to be executed and the expenses thereby incurred by the Director shall be paid by the person in default and, if that person is the owner, the provisions of section 43 shall apply to those expenses, and in any other case the provisions of section 41 shall apply thereto.

33.—(1) Where a person appeals to the High Court against a mandatory order, no liability to a fine shall arise nor, save as provided in this section, shall any proceedings be taken or work done under the order until after the determination or abandonment of the appeal.

Provision  
as to  
appeal  
against  
order.

(2) Where a mandatory order is made and a person does not comply with it and appeals against it to the High Court and the appeal is dismissed or is abandoned, the appellant shall be liable on conviction to a fine not exceeding two hundred dollars for every day during the non-compliance with the order, unless he satisfies the Court before which proceedings are taken for imposing a fine that there was substantial ground for the appeal and that the appeal was not brought merely for the purpose of delay and, where the appeal is heard by the High Court, that Court may, on dismissing the appeal, impose the fine as if the Court were the Court before which the summons was returnable.

(3) Where a mandatory order is made on any person and appealed against and the Court which made the order is of the opinion that the non-execution of the mandatory order



will be injurious or dangerous to health and that the immediate execution of the order will not cause any injury which cannot be compensated by damages, that Court may authorise the Director immediately to execute the work.

(4) If the Director has executed the work and the appeal is successful, he shall pay the cost of the work and the damages, if any, sustained by that person by reason of the work, but, if the appeal is dismissed or abandoned, the Director may recover the cost of the work from the person and, if that person is the owner of the premises in respect of which the order is made, the provisions of section 43 shall apply to any sum recoverable from him hereunder and in any other case the provisions of section 41 shall apply thereto.

Proceedings  
where  
owner is  
unknown.

34.—(1) Where the name or address of the owner of any premises with regard to which a Magistrate's Court is empowered to make a mandatory order is unknown and cannot with reasonable diligence be discovered, the Court may issue a summons addressed to the owner of the premises.

(2) The summons may be served in the manner specified in section 56.

(3) If the owner does not appear on the date of the hearing of the summons, the Court may make such an order upon him in his absence as it might have made in his presence except that it shall not inflict any fine upon him.

In case of  
urgency  
order may  
be made  
*ex parte*.

35.—(1) If in any case in which a Magistrate's Court has jurisdiction to make a mandatory order, the Court is of opinion that the matter complained of will be injurious or dangerous to health or safety and the immediate work sought to be done will not cause any injury which cannot be compensated for by damages, the Court may, by an *ex parte* order, authorise the Director immediately to do the work sought to be done.

(2) If the Director does the work and the application for a mandatory order is subsequently refused, he shall pay the cost of the work and the damages, if any, sustained by any person thereby, but if the mandatory order is subsequently granted the Director may recover the cost of the work if it had been executed by him in pursuance of the powers conferred by section 33.

Director  
may act in  
cases of  
emergency.

36. In cases of emergency the Director may direct the immediate execution of any work or the doing of any act being any work or act authorised under this Act which is in his opinion necessary for the service or safety of the public.



37.—(1) Where the Director reports to the Minister that any trade effluent which is being discharged from any premises into the public sewerage system, or any drain, river, lake, pond or reservoir, is dangerous to health or safety or will cause damage to the public sewerage system, the Minister may by order direct the occupier of the premises —

Power to prohibit work and processes in certain circumstances.

- (a) to cease forthwith the discharge of such trade effluent into the public sewerage system or any drain, river, lake, pond or reservoir;
- (b) to take such steps as may be specified in the order to treat the trade effluent which is complained of; and
- (c) to cease forthwith the carrying on of any process or work which produces the trade effluent either indefinitely or until such steps have been taken, as is specified in the order, to treat such trade effluent before it is discharged into the public sewerage system or any drain, river, lake, pond or reservoir.

(2) The occupier of any premises who fails to comply with an order under subsection (1) shall be guilty of an offence and shall be liable on conviction to a fine not exceeding ten thousand dollars or to imprisonment for a term not exceeding three months or to both such fine and imprisonment and, in the case of a continuing offence, to a further fine not exceeding one thousand dollars for every day during which the offence is continued after conviction.

(3) Where the occupier of any premises has failed to comply with an order under subsection (1), the Director may at all reasonable times enter upon the premises and take such measures and do such work as may be necessary to comply with the order.

(4) Any person who is aggrieved by an order made by the Minister under subsection (1) may within twenty-eight days from the date of the order appeal to the High Court which may rescind or vary the order.

(5) Notwithstanding that an appeal has been made under subsection (4), an aggrieved person shall comply with the order pending the outcome of the appeal to the High Court and the Director may exercise the powers conferred under subsection (3).

38.—(1) The Director and any person authorised in writing by the Director in that behalf may, for the purposes of this Act, enter at all reasonable hours in the daytime

Power to enter upon lands for the purposes of this Act.



into and upon any building or land for the purpose of making any survey, soil investigation or inspection and executing any work authorised by this Act to be executed by the Director without being liable to any legal proceedings or molestation on account of such entry or of anything done in any part of that building or land in pursuance of this Act.

(2) No person shall, pursuant to this section, enter into any dwelling-house in actual occupation, unless with the consent of the occupier thereof, without six hours' previous notice to the occupier.

(3) For the purposes of this section the Minister may declare that any class of premises is liable to night inspection, and thereupon any public officer, employee, agent or contractor duly authorised in writing in that behalf may, at any time of the day or night and without notice, enter using such force as may be necessary into and search or inspect any premises of the class specified in the declaration.

Power to enter on lands adjacent to works.

**39.—**(1) The Director and any person authorised by him in that behalf may enter upon any land, adjoining or being within a hundred metres of any works by this Act authorised to be made, for the purpose of depositing upon that land any soil, gravel, sand, lime, brick, stone or other materials or for any other purposes connected with the formation of those works without making any previous payment, tender or deposit, doing as little damage as may be in the exercise of the several powers hereby granted and making compensation for such temporary occupation or temporary damage of the land to the owner and the occupier thereof from time to time and as often as any such temporary occupation is taken or any such temporary damage done and making compensation to the owner also for the permanent injury, if any, to the land.

(2) If any dispute arises relating to the amount or apportionment of such compensation, it shall be settled in the manner provided in section 41.

(3) Before the Director makes any use of any land pursuant to subsection (1), he shall give seven days' notice of his intention to the owners and occupiers of the land.

Penalty for obstructing Director in his duty.

**40.** Any person who at any time hinders, obstructs or molests the Director or any person authorised by him in that behalf, in the performance and execution of his duty or of anything which he is empowered or required to do under this Act or interferes with any work authorised to be done under this Act, shall be guilty of an offence and shall be



liable on conviction to a fine not exceeding five thousand dollars or to imprisonment for a term not exceeding three months or to both such fine and imprisonment.

41.—(1) Except as herein otherwise provided, in all cases when compensation, damages, fees, costs or expenses are by this Act directed to be paid the amount and, if necessary, the apportionment of the same and any question of liability shall, in case of dispute, or failure to pay, be summarily ascertained and determined by a Magistrate's Court or, if the compensation claimed exceeds five thousand dollars, by a District Court.

Compensation, damages and costs to be determined by Magistrate's Court.

(2) If the amount of compensation, damages, costs or expenses is not paid by the party liable to pay it within seven days after demand, that amount may be reported to a Magistrate's Court and recovered in the same way as if it were a fine imposed by a Magistrate's Court.

(3) An appeal shall lie to the High Court from any decision of a Magistrate's or District Court under this section, and the provisions of the Criminal Procedure Code shall *mutatis mutandis* apply to all such appeals.

Cap. 113.

42. Whenever default is made by an owner of any premises in the execution of any work required under this Act to be executed by him, an occupier of the premises may, with the approval of the Director, cause the work to be executed and the expense thereof shall be paid to him by the owner or the amount may be deducted out of the rent from time to time becoming due from him to the owner and the occupier may, in the absence of any special agreement to the contrary, retain possession until that expense has been fully reimbursed to him.

Occupier may execute work where owner defaults in execution of work required by Act.

43.—(1) All sums payable by or recoverable from the owner or owners in respect of costs and expenses incurred by the Government in or about the execution of any work which are under this Act recoverable from the owner or owners of any premises shall, subject and without prejudice to any other rights of the Government, be a charge on the premises in respect of which the costs and expenses were incurred.

Recovery of costs and expenses payable by owners.

(2) In addition to any other remedies conferred by this Act any such sum may be recovered in the manner hereinafter provided, and the person or persons liable to pay it shall be the owner or owners at the time when the work was completed.



(3) An occupier who when requested by or on behalf of the Director to state the name of the owner of premises refuses or wilfully omits to disclose or wilfully mis-states the name shall, unless he shows cause to the satisfaction of the Court for his refusal or mis-statement, be guilty of an offence and shall be liable on conviction to a fine not exceeding five hundred dollars.

(4) If any such sum remains unpaid at the expiration of the prescribed time, a notice shall be served upon the person or any one of the persons, if more than one, liable to pay it, calling on him to pay that sum together with a fee of such amount as may be prescribed for the cost of the notice, within fifteen days of the service of such notice.

(5) If no person liable to pay the sum can be found, such notice shall be deemed to have been duly served by the posting thereof at the office of the Director and by fixing a copy thereof on some conspicuous part of the premises in respect of which the costs and expenses were incurred.

(6) At the expiration of the period of fifteen days or such further period as may be allowed by the Director, if any such sum or part thereof remains due and unpaid, it shall be deemed to be arrears and may be recovered as hereinafter provided.

(7) The charge hereinbefore mentioned shall attach, and the powers and remedies hereinbefore conferred shall become exercisable as from the date of completion of the work, and thereafter those powers and remedies may be exercised against the premises or against any movable property or crops for the time being found thereon, notwithstanding any change or changes in the ownership or occupation of the premises subsequent to that date.

Recovery of  
costs and  
expenses  
by instal-  
ments.

44.—(1) When the Director has incurred costs and expenses in or about the execution of any work, which are, under this Act, payable by or recoverable from the owner or owners, the Director may either recover those costs and expenses in the manner provided in section 43 or, if he thinks fit, may take an engagement or engagements from the owner or owners for the payment of such instalments as will be sufficient to defray the whole amount of the costs and expenses with interest thereon at a rate not exceeding six per cent per annum, within a period not exceeding ten years.

(2) Upon default in payment of any instalment or interest upon the date appointed for payment thereof by any such engagement the whole of the balance then outstanding of that amount, together with any interest in arrear, shall



immediately become due and payable and, notwithstanding any change in the ownership or occupation of the premises since the date of the engagement, may be recovered by the same means and in like manner as provided in section 43.

45.—(1) For the recovery of arrears the Director shall have and may exercise, either successively or concurrently, in addition to any other remedies conferred by this Act either or both of the following powers, that is to say:—

Proceedings  
for recovery  
of arrears.

(a) the Director may issue a warrant of attachment and may seize by virtue thereof any movable property and crops of any person liable to pay the arrears and may also seize any movable property or crops to whomsoever belonging which are found on the premises in respect of which the arrears are due and may, after service of the prescribed notice, sell the same by public auction in the prescribed manner;

(b) the Director may, by notice of sale to be served or published in the prescribed manner, declare his intention of selling, at the expiration of three months from the date of the notice of sale, the premises in respect of which the arrears are due and, if, at the expiration of that period, the arrears have not been paid or satisfied, the Director may sell by public auction, in lots or otherwise, the whole of the premises or such portion thereof or such interest therein as it deems sufficient for recovery of the arrears and costs.

(2) The Director shall not proceed under paragraph (b) of subsection (1) to sell the premises in respect of which the arrears are due, or any portion thereof or interest therein, where there is or are upon the premises and liable to be seized and sold under paragraph (a) of that subsection movable property or crops belonging to the owner of a value estimated by the Director to be sufficient to realize the sum required to satisfy the arrears and costs.

(3) Any tenant, sub-tenant or occupier who, in order to avoid the seizure or sale of his property for non-payment of arrears payable by the owner of the premises, pays the arrears and costs may thereafter, in the absence of any written agreement to the contrary, deduct the amount so paid by him from the rent due or to become due by him to his immediate landlord on account of the premises or such



part thereof as is held or occupied by him, and may retain possession until that amount has been fully reimbursed to him whether by deduction from the rent or otherwise.

(4) Any tenant or sub-tenant who has reimbursed, whether by allowing a deduction from his rent or otherwise, any sub-tenant or occupier holding or occupying under him the amount so paid by that sub-tenant or occupier shall have a similar right to deduct the amount from the rent due or to become due to his immediate landlord and to retain possession until similarly reimbursed.

(5) The receipt of any public officer duly authorised in writing by the Director in that behalf for any amount so paid by any such tenant, sub-tenant or occupier shall be deemed an acquittance in full for the like amount of rent.

(6) If any premises in respect of which arrears are due, or any such movable property or crops as are mentioned in subsection (1) or the proceeds of sale thereof are already in the custody of the law under any process of execution whereby the Director is unable to exercise the remedies hereinbefore conferred, the Director may notify the Sheriff or the bailiff of the court concerned of the amount of the arrears, and shall be entitled without obtaining a judgment to be paid that amount out of the proceeds of sale of the premises or property in priority to the judgment debtor and to the judgment creditor and to any other creditor except the Government.

(7) A certificate from the Director shall, unless it is disputed by the judgment debtor, be conclusive evidence of the amount of such arrears, and, in case of dispute, the amount shall be summarily determined by a Magistrate's Court.

(8) Where any premises is sold pursuant to paragraph (b) of subsection (1), the Director shall have the power to execute the conveyance and the purchaser of the premises shall not be concerned to inquire whether the provisions of this Act relating to the sale and the conveyance have been complied with nor otherwise to inquire into the regularity or validity of the sale and conveyance.

(9) Subsection (8) shall not affect the application of section 123 of the Land Titles Act in relation to registered land.

Cap. 276.

Attachment.

46.—(1) The attachment mentioned in paragraph (a) of subsection (1) of section 45 may be made by a person appointed for the purpose by the Director who shall publicly notify the attachment in the prescribed manner and shall take an inventory of the property attached.



(2) Such a person shall be deemed to be a public servant within the meaning of the Penal Code.

Cap. 103.

(3) That person may break open in the daytime any house or building for the purpose of effecting the attachment.

47.—(1) The proceeds of a sale under subsections (1) and (2) of section 45 shall be applied in the first place in satisfaction of the arrears together with interest thereon at the rate of six per cent per annum and costs.

Application of proceeds.

(2) In the event of there being any surplus remaining the Director shall, if satisfied as to the right of any person claiming the surplus, pay the amount thereof to that person or, if not so satisfied, shall hold the amount in trust for the person who may ultimately succeed in due course of law in establishing his title thereto.

(3) If no title is established to the surplus within a period of five years from the date of the sale, it shall be paid into the Consolidated Fund.

48.—(1) The purchaser at a sale held under paragraph (b) of subsection (1) of section 45 shall be deemed to have acquired the right offered for sale free from all encumbrances created over it and from all subordinate interests derived from it except such as are expressly reserved by the Director at the time of sale.

Title conferred by purchaser at sale under section 45 (1) (b).

(2) The Director shall notify by an advertisement in the *Gazette* the result of the sale and the conveyance to the purchaser of the property or right offered for sale.

49. All costs of any proceedings for the recovery of arrears may be recovered as if they formed part of the arrears.

Costs of proceedings for recovery of arrears.

50. If any person having any interest in any property liable to be sold at any time previous to such sale tenders to the Director the arrears with interest and costs, the Director shall thereupon desist from all further proceedings in respect thereof.

Power to stop sale.

51.—(1) If any person whose movable property, crop or land has been attached or advertised for sale disputes the propriety of the attachment or sale, he may apply to the High Court or, where the arrears do not exceed five thousand dollars, to a District Court for an order to stay the proceedings.

Application to Court.

(2) The Court, after hearing the Director and making such further inquiry as is necessary, shall make such order as is just.



Security  
to be given.

52. No application shall be entertained by the Court under section 51 unless the applicant has deposited in Court the amount of the arrears and costs or given security for them to the satisfaction of the Court.

Liability  
of trans-  
feror who  
has not  
given notice.

53.—(1) Every person who sells or transfers any property in respect of which costs and expenses have been incurred by the Government in or about the execution of any work which are, under this Act, recoverable from the owner or owners thereof shall continue to be liable for the payment of all the costs and expenses payable in respect of the property and for the performance of all other obligations imposed by this Act upon the owner of the property which become payable or are to be performed at any time before such notice of transfer as is required by section 17 of the Property Tax Act has been given.

Cap. 144.

(2) Nothing herein shall affect the liability of the purchaser or transferee to pay such costs and expenses in respect of the property or affect the right of the Director to recover such costs and expenses or to enforce any obligation under this Act.

Proceedings  
if any  
occupier  
opposes the  
execution  
of works.

54.—(1) If the occupier of any premises prevents the owner thereof from carrying into effect in respect of the premises any of the provisions of this Act after notice of his intention so to do has been given by the owner to that occupier, a Magistrate's Court, upon proof thereof and upon application by the owner, may make an order in writing, requiring the occupier to permit the owner to execute all such works with respect to the premises as are necessary for carrying into effect the provisions of this Act and may also, if it thinks fit, order the occupier to pay to the owner the costs relating to the application or order.

(2) If after the expiration of eight days from the date of the order the occupier continues to refuse to permit the owner to execute the works, the occupier shall be guilty of an offence and shall be liable on conviction to a fine not exceeding two hundred dollars for every day during which he so continues to refuse, and every such owner shall, during the continuance of such refusal, be discharged from any penalties to which he might otherwise have become liable by reason of his default in executing the works.

Receipts  
and notices  
may be  
given by  
officer  
authorised  
thereunto.

55.—(1) All notices, orders, receipts, warrants and other documents of any nature which the Director is empowered to give by this Act or under any regulations made thereunder may be given by any public officer authorised thereunto by the Director.



(2) Where any such notice, order, warrant or document requires authentication, the signature or a facsimile thereof of the Director or any public officer authorised thereunto by the Director affixed thereto shall be sufficient authentication.

56.—(1) Every notice, order or document required or authorised by this Act or any regulations made thereunder to be served on any person may be served — Service of notices.

- (a) by delivering it to that person or by delivering it at the last known place of abode of that person to some adult member or servant of his family;
- (b) by leaving it at the usual or last known place of abode or business of that person in a cover addressed to that person; or
- (c) by forwarding it by post in a prepaid letter addressed to that person at his usual or last known place of abode or business.

(2) A notice, order or document required or authorised by this Act or any regulations made thereunder to be served on the owner or occupier of any premises shall be deemed to be properly addressed if addressed by the description of the "owner" or "occupier" of the premises without further name or description.

(3) A notice, order, summons or document required or authorised by this Act or any regulations made thereunder to be served on the owner or occupier of any premises may be served by delivering the same or a true copy thereof to some adult person on the premises or, if there is no such person on the premises to whom the same can with reasonable diligence be delivered, by affixing the notice, order or document to some conspicuous part of the premises.

57.—(1) Any person who is aggrieved by any notice or declaration by the Director under this Act may, within fourteen days or one month of the date of such notice or declaration, respectively, appeal in writing to the Minister, whereupon the execution of the notice or the doing of the thing required to be done shall be stayed. Appeal to Minister against notices and declarations.

(2) The Minister may confirm, vary or rescind the notice or direct that the thing shall be proceeded with, varied or abandoned, as the case may be, or make any order which the Director is competent to make under this Act and the decision of the Minister thereon shall be final.



Penalty for default in compliance with notice.

58.—(1) When any notice under this Act or any regulations made thereunder requires any act to be done or work to be executed by the owner or occupier of any premises and default is made in complying with the requirements of the notice, the person in default shall, where no fine is expressly provided for such default, be liable on conviction to a fine not exceeding five thousand dollars.

(2) Where any such notice requires any act to be done or work to be executed for which no time is fixed by this Act or any regulations made thereunder, the notice shall fix a reasonable time for compliance with the requirement.

Power to demand for names and addresses.

59.—(1) The owner or occupier of any premises shall, if required by the Director or any public officer authorised by him in that behalf, give his name and address and such other proof of identity as the Director or public officer may require and furnish such other particulars as the Director or public officer may require for the purposes of this Act.

(2) Any person who upon being required by the Director or a public officer to give his name and address or to furnish any particulars under subsection (1) wilfully mis-states his name and address or furnishes false particulars shall be guilty of an offence and shall be liable on conviction to a fine not exceeding one thousand dollars.

Powers of arrest.

60.—(1) The Director, or any public officer authorised in writing by the Director generally or in any particular case, or any police officer, may arrest any person committing in his view or who he has reason to believe has committed any offence punishable under this Act or any regulations made thereunder —

- (a) if the name and address of the person are unknown to him;
- (b) if the person declines to give his name and address; or
- (c) if there is reason to doubt the accuracy of the name and address, if given.

(2) A person arrested under this section may be detained until his name and address are correctly ascertained.

(3) No person so arrested shall be detained longer than is necessary for bringing him before a court unless the order of a court for his detention is obtained.

Saving of prosecutions under other laws.

61. Nothing in this Act shall prevent any person from being prosecuted under any other law for any act or omission which constitutes an offence under this Act or any



regulations made thereunder or from being liable under that other law to any other or higher punishment or penalty than that provided by this Act or any regulations made thereunder:

Provided that no person shall be punished twice for the same offence.

62. Any person who contravenes or fails to comply with any of the provisions of this Act or any regulations made thereunder for which no penalty is expressly provided shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five thousand dollars or to imprisonment for a term not exceeding three months and in the case of a continuing offence to a further fine not exceeding one hundred dollars for every day or part thereof during which the offence is continued after conviction. Penalties.

63.—(1) Where any permit, consent or approval is given by the Director under this Act for the execution of any works, the Director may require a deposit to be furnished by the person applying for the permit, consent or approval to secure the execution of the works. Furnishing of deposits.

(2) Where any such work is not executed to the satisfaction of the Director, he may utilise the deposit or any part thereof to make good the defects.

64. No misnomer or inaccurate description of any person, premises, building, holding, street or place named or described in any document prepared, issued or served under, by virtue of or for the purposes of this Act or any regulations made thereunder shall in any way affect the operation of this Act or any such regulations as respects that person or place if that person or place is so designated in the document as to be identifiable, and no proceedings taken under or by virtue of this Act or any such regulations shall be invalid for want of form. Inaccuracies in documents.

65.—(1) The contents of any document prepared, issued or served under, by virtue of or for the purpose of this Act shall until the contrary is proved be presumed to be correct and the production of any book purporting to contain any apportionment made under or by virtue of this Act shall, without any other evidence, be received as *prima facie* proof of the making and validity of the apportionment mentioned therein. Evidence.

(2) All records, registers and other documents required by this Act or any regulations made thereunder to be kept by the Director or any public officer authorised by him in



that behalf shall be deemed to be public documents and copies thereof or extracts therefrom certified by the officer responsible for the custody thereof to be true copies, or extracts, as the case may be, subscribed by that officer with his name and his official title shall be admissible in evidence as proof of the contents of the documents.

(3) The production by the prosecutor of a certificate of analysis purporting to be under the hand of an analyst shall be sufficient evidence of the facts stated therein, unless the defendant requires the analyst to be called as witness, in which case he shall give notice thereof to the prosecutor not less than three clear days before the day on which the summons is returnable.

(4) In like manner the production by the defendant of a certificate of analysis purporting to be under the hand of an analyst shall be sufficient evidence of the facts stated therein, unless the prosecutor requires the analyst to be called as a witness.

(5) A copy of such last-mentioned certificate shall be sent to the prosecutor at least three clear days before the day fixed for the hearing of the summons, and, if it is not so sent, the Magistrate's Court may adjourn the hearing on such terms as it thinks proper.

**Exemption.**

66. The Director may, either permanently or for such period or periods as he may think fit, exempt any person or premises or any class of person or premises from any of the provisions of this Act.

**Forms.**

67. The Director may design and utilise such forms as he may think fit for any of the purposes of this Act and any regulations made thereunder, and may require any person to complete any of the same for any such purpose.

**Regulations.**

68.—(1) The Minister may make regulations for or in respect of every purpose which is deemed by him necessary for carrying out the provisions of this Act, for the prescribing of any matter which is authorised or required under this Act to be prescribed, and in particular and without prejudice to the generality of the foregoing for or in respect of all or any of the matters specified in the First Schedule.

(2) The Minister may from time to time, by notification in the *Gazette*, add to, alter or amend the First Schedule.

(3) The Minister may in making any regulations provide that any contravention of or failure to comply with any regulations shall be an offence and may prescribe the fine



with which an offence shall be punishable but so that no such fine shall exceed for any one offence the sum of five thousand dollars, or, in the case of a continuing offence, the sum of one hundred dollars for every day or part thereof during which the offence is continued after the date of the conviction thereof.

(4) All such regulations shall be published in the *Gazette* and shall be presented to Parliament as soon as may be after publication.

69. The provisions of the Acts specified in the First Column of the Second Schedule are hereby amended in the manner set out in the Second Column thereof. Repeal.

70. In so far as any application or objection made, permit granted, consent, designation, direction or notice issued, given or delivered, prohibition or requirement imposed or attached, or other thing done, under an enactment repealed by this Act could have been made, granted, issued, given, delivered, imposed, attached or done under a corresponding provision of this Act, it shall not be invalidated by the repeal effected by section 69, but shall have effect as if made, granted, issued, given, delivered, imposed, attached or done under that corresponding provision. Transitional and savings provisions.

## FIRST SCHEDULE.

Section 68 (1).

1. The construction, maintenance and repair in any building or on any premises of a water supply, sanitary accommodation, sink accommodation, bathing and washing accommodation and refuse bin centres.
2. The construction, maintenance and repair of drain-lines and their connections to sewers, and the construction, maintenance and repair of drainage structures.
3. The construction, maintenance and repair of sewerage systems.
4. The prevention of misuse or contamination of water.
5. The prescribing of fines for late payment of any charges or fees.
6. The prescribing of standards and limits for trade effluents which may be discharged into sewers and drains.
7. The control of discharge of any trade effluent into sewers, drains and sea.
8. The prescribing of fees for the collection and disposal of domestic and farm wastes flushed by water and for the maintenance and operation of sewage purification plants, cess-pits, and other waste water treatment plants.
9. The prescribing of fees for the collection and disposal of any trade effluent.
10. The prescribing of standards and specifications for the construction, maintenance and repair of drainage structures and sewerage works.



**FIRST SCHEDULE — continued.**

11. The prescribing of forms for permits and notices and for other purposes of this Act.

12. The prescribing of fees for permits and the prescribing of fees and charges for any of the purposes of this Act or any regulations made thereunder and the prescribing of any matter which by this Act is required to be or may be prescribed.

13. The prescribing of fees for the collection, treatment or disposal of sludge from any premises.

**SECOND SCHEDULE. Section 69.***First Column.*

The Local Government  
Integration Act  
(Chapter 210)

The Environmental Public  
Health Act (Chapter 155)

*Second Column.*

Delete sections 37 to 51.

Delete the expression "a water supply, sanitary accommodation, sink accommodation, bathing and washing accommodation and" appearing in paragraph 6 under the heading "Public Works Department" in the Second Schedule.

Delete paragraphs 7, 8 and 9 appearing under the heading "Public Works Department" in the Second Schedule.

Delete sections 74 and 79.

Printed for the Government of Singapore  
by the Singapore National Printers (Pte) Ltd (Government Printers)

Available from

Singapore National Printers (Pte) Ltd., 303 Upper Serangoon Road, Singapore 13  
and S.N.P. Publications Sales Division, Fullerton Building, Ground Floor, Singapore 1

Price: \$6



(Vide Notification No. S 122 in the Gazette Subsidiary Legislation Supplement No. 27 of 11th June, 1976).

**THE WATER POLLUTION CONTROL AND DRAINAGE  
ACT, 1975.  
(ACT 29 OF 1975).**

**THE TRADE EFFLUENT REGULATIONS, 1976.**

In exercise of the powers conferred by subsection (1) of section 14. and section 68 of the Water Pollution Control and Drainage Act, 1975, the Minister for the Environment hereby makes the following Regulations:—

1. These Regulations may be cited as the Trade Effluent Regulations, 1976, and shall come into operation on the 15th day of June, 1976.

2. In these Regulations, unless the context otherwise requires —

“controlled watercourse” means a water course from which water supplied by the Public Utilities Board under the Public Utilities Act is obtained but does not include a water course from which water is pumped into a main of the Public Utilities Board;

Cap. 211.

“natural catchment area of the MacRitchie, Peirce and Seletar Reservoirs” means the area described in the Schedule;

“watercourse” includes a reservoir, lake, river, stream, canal, drain, spring or well or a part of the sea abutting on the foreshore and any other natural, artificial or sub-surface body of water.

3. Notwithstanding the provisions of these Regulations, no person shall discharge trade effluent either directly or indirectly into any watercourse or land within a natural catchment area of the MacRitchie, Peirce and Seletar Reservoirs.

4.—(1) The Director may by notice in writing require the owner of any premises to cause all trade effluents from those premises to be discharged into a public sewer in accordance with the provisions of these Regulations.

(2) No person shall, without the written permission of the Director, discharge trade effluent into a public sewer, a sewerage system other than a trade effluent treatment plant, a watercourse or any land, or therefrom into the sea.

(3) An application for such permission shall be in such form as the Director may require.

(4) The applicant shall furnish the Director —

(a) particulars of the trade, manufacture, business or building construction carried on or to be carried on by him and in the course of which the trade effluent is wholly or in part produced or of which the trade effluent is the waste or refuse;

(b) details of all the processes or operations employed or to be employed by him, to produce the final products of the trade or manufacture, or in the course of the business or building construction;



- (c) particulars of the materials and chemicals used or to be used in the processes or operations;
- (d) details of the lay out of all the machinery, plant and equipment used or to be used in the premises in which the trade, manufacture, business or building construction is or shall be carried on, as the case may be;
- (e) an estimate of the amount of water consumed or used or to be consumed or used in the trade, manufacture, business or building construction;
- (f) particulars of the physical, organic and chemical nature of the trade effluent; and
- (g) such other information relating to the trade effluent as the Director may require.

(5) In his application, the applicant shall furnish the Director such other information as the applicant deems to be relevant to the consideration of the application.

(6) A person who has obtained such permission shall not discharge trade effluent into a public sewer, a sewerage system other than a trade effluent treatment plant, a watercourse or any land, or therefrom into the sea otherwise than in accordance with the provisions of these Regulations and shall, within fourteen days of a change in —

- (a) a process or operation employed by such person and referred to in sub-paragraph (b) of paragraph (4); or
- (b) the lay out of the machinery, plant and equipment used by such person and referred to in sub-paragraph (d) of that paragraph,

which affects the amount or the physical, organic or chemical nature of the trade effluent discharge and which has been made after the Director has given his permission, notify him in writing of the change in the process or operation, or the lay out of the machinery, plant and equipment, as the case may be.

(7) Any permission given by the Director to discharge trade effluent into a public sewer, a sewerage system other than a trade effluent treatment plant, a watercourse or any land, or therefrom into the sea —

- (a) shall be subject to such conditions as the Director may impose;
- (b) may be revoked, or suspended for any period, by the Director without assigning any reason therefor; and
- (c) shall cease to be valid when the person fails to comply with a provision of these Regulations or a condition imposed by the Director in granting such permission.

5. All trade effluents shall be treated before it is discharged into a public sewer or watercourse, if the Director so requires.



6. A person who discharges trade effluent into any sewerage system, watercourse, sea or land shall, in connection with such discharge, install such sampling test points, inspection chambers, flow-meters, and recording and other apparatuses as the Director may, from time to time, require.

7. A person shall obtain the prior permission in writing of the Director before he makes or causes to be made any drain or other connection to a public sewer or watercourse for the purpose of discharging trade effluent into the public sewer or watercourse; and in every such case the position and design of the outlet for the discharge of the trade effluent into the public sewer or watercourse shall be approved by the Director and shall not be altered or changed without his prior approval.

8. A person who discharges trade effluent into a sewerage system, watercourse, sea or land shall, at such times as the Director may require, submit particulars of—

- (a) the amount of water consumed or used for the purposes of a trade, manufacture, business or building construction carried on by him and in the course of which the trade effluent is wholly or partly produced or of which the trade effluent is the waste or refuse;
- (b) the physical, organic and chemical nature of the trade effluent;
- (c) the raw materials and chemicals used in the trade, business, manufacture or building construction and the direction of the flow of any liquid or the trade effluent from or produced by the machinery, plant and equipment used in the trade, business, manufacture or building construction; and
- (d) such other matters relating to the discharge of the trade effluent as may be required by the Director.

9.—(1) No trade effluent other than that of a nature or type approved by the Director shall be discharged into a public sewer or watercourse.

(2) The temperature of the trade effluent at the point of entry into the public sewer or watercourse shall not exceed 45° Celsius.

(3) The pH value of the trade effluent at the point of its entry into the public sewer or watercourse shall not be less than 6 nor more than 9.

(4) The caustic alkalinity of the trade effluent shall not be more than 2,000 milligrams of calcium carbonate per litre at the point of its entry into the public sewer or watercourse.

10.—(1) The trade effluent discharged into a public sewer shall not contain any of the following:—

- (a) rain-water, storm-water, ground water or other water from street drainage, sub-surface drainage, roof drainage or yard drainage;
- (b) calcium carbide;
- (c) petroleum spirit or other inflammable solvent;



- (d) a liquid, solid or gas which by reason of its quantity is likely or is sufficient to cause fire or explosion or to cause damage to the public sewer or a sewerage system to which the public sewer is connected;
- (e) a substance that either by itself or in combination or by reaction with other waste or refuse may give rise to any gas, fume, odour or substance which is or is likely to be a hazard to human life, a public nuisance, injurious or otherwise objectionable, or which prevents or is likely to prevent entry into the public sewer by workmen maintaining or repairing it;
- (f) yeast, spent or unspent molasses, crude tar, tar oil, crude oil, carbon disulphide, hydro-sulphide and poly-sulphide;
- (g) a radioactive material;
- (h) any waste or refuse liable to form a viscous or solid coating or deposit on any part of the public sewer or sewerage system;
- (i) an excessively discolouring substance;
- (j) a substance of a nature and quantity likely to damage the public sewer or to interfere with the proper working of any sewerage treatment works, machinery or equipment or to interfere with a process of treating the trade effluent, or other waste or refuse from the public sewer; and
- (k) any pesticide, fungicide, herbicide, insecticide, rodenticide or fumigant.

(2) The trade effluent discharged into a watercourse shall not contain any of the following substances:—

- (a) a radioactive material;
- (b) any pesticide, fungicide, herbicide, insecticide, rodenticide or fumigant;
- (c) refuse, garbage, sawdust, timber, human or animal waste or solid matter;
- (d) any petroleum or other inflammable solvent; and
- (e) a substance that either by itself or in combination or by reaction with other waste or refuse may give rise to any gas, fume or odour or substance which is or is likely to be a hazard to human life, a public nuisance, injurious or otherwise objectionable.

11. For the purposes of these Regulations, the trade effluent discharged into a public sewer or watercourse shall be analysed in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation of the United States, as amended from time to time, or in accordance with such other method of analysis as the Director thinks fit.



12.—(1) Any trade effluent analysed in accordance with regulation 11 shall not contain the following substances in concentrations greater than those stated below:—

	<i>Limit for Discharge into a Public Sewer in milligrams per litre of trade effluent.</i>	<i>Limit for Discharge into a Watercourse other than a Controlled Watercourse in milligrams per litre of trade effluent.</i>	<i>Limit for Discharge into a Controlled Watercourse in milligrams per litre of trade effluent.</i>
(a) Total Suspended Solids ...	400	50	30
(b) Total Dissolved Solids ...	3,000	2,000	1,000
(c) Chloride (as chloride ion) ...	1,000	600	400
(d) Sulphate (as SO <sub>4</sub> ) ...	1,000	500	200
(e) Sulphide (as sulphur) ...	1	0.2	0.2
(f) Cyanide (as CN) ...	2	0.1	0.1
(g) Detergents (linear alkylate sulphonate as methylene blue active substances) ...	30	15	5
(h) Grease and Oil ...	60	10	5
(i) Arsenic ...	5	1	0.05
(j) Barium ...	10	5	5
(k) Tin ...	10	10	5
(l) Iron (as Fe) ...	50	20	1
(m) Beryllium ...	5	0.5	0.5
(n) Boron ...	5	5	0.5
(o) Manganese ...	10	5	0.5
(p) Phenolic Compounds (expressed as phenol) ...	0.5	0.2	Nil



(2) The 5-day Biochemical Oxygen Demand at 20°C (hereinafter referred to as "BOD") and the Chemical Oxygen Demand (hereinafter referred to as "COD") of any trade effluent analysed in accordance with regulation 11 shall not be in proportions greater than those stated below:—

- (a) 400 milligrams per litre of BOD and 600 milligrams per litre of COD where the trade effluent is discharged into a public sewer;
- (b) 50 milligrams per litre of BOD and 100 milligrams per litre of COD where the trade effluent is discharged into a watercourse other than a controlled watercourse.
- (c) 20 milligrams per litre of BOD and 60 milligrams per litre of COD, where the trade effluent is discharged into a controlled watercourse.

(3) The concentrations of the following metals in the trade effluent shall not exceed those set out below:—

	<i>Limit for Discharge into a Public Sewer in milligrams per litre of trade effluent.</i>	<i>Limit for Discharge into a Watercourse other than a Controlled Watercourse in milligrams per litre of trade effluent.</i>	<i>Limit for Discharge into a Controlled Watercourse in milligrams per litre of trade effluent.</i>
(a) Cadmium ...	1	0.1	0.01
(b) Chromium (trivalent and hexavalent) ...	5	1	0.05
(c) Copper ...	5	0.1	0.1
(d) Lead ...	5	0.1	0.1
(e) Mercury ...	0.5	0.05	0.001
(f) Nickel ...	10	1	0.1
(g) Selenium ...	10	0.5	0.01
(h) Silver ...	5	0.1	0.1
(i) Zinc ...	10	1	0.5

(4) Where two or more of the metals specified in paragraph (3) are present in the trade effluent, the concentration of the metals shall not be more than —

- (a) ten milligrams per litre where the trade effluent is discharged into a public sewer;
- (b) one milligram per litre where the trade effluent is discharged into a watercourse other than a controlled watercourse; and
- (c) 0.5 milligram per litre where the trade effluent is discharged into a controlled watercourse.



## (5) The concentration of —

- (a) free chlorine shall not exceed 1 milligram per litre where the trade effluent is discharged into a watercourse;
- (b) colour shall not exceed 7 Lovibond Units where the trade effluent is discharged into a watercourse;
- (c) phosphates, expressed as  $\text{PO}_4$ , shall not exceed 5 milligrams per litre where the trade effluent is discharged into a watercourse other than a controlled watercourse and 2 milligrams per litre where it is discharged into a controlled watercourse;
- (d) calcium and magnesium, expressed as Ca and Mg respectively, shall not exceed 200 milligrams per litre where the trade effluent is discharged into a watercourse other than a controlled watercourse and 150 milligrams per litre where it is discharged into a controlled watercourse; and
- (e) nitrate, expressed as  $\text{NO}_3$ , shall not exceed 20 milligrams per litre where the trade effluent is discharged into a controlled watercourse.

(6) The Director may stipulate the maximum volume and quantity of a substance which may be discharged into a public sewer or watercourse under this regulation, and the maximum rate at which the substance may be so discharged.

(7) Where the Director stipulates the maximum volume and quantity of a substance which may be discharged into a sewer or watercourse under this regulation and the maximum rate at which the substance may be so discharged, no person who has been informed by the Director by notice in writing of the volume, quantity or rate may discharge the substance into a public sewer or watercourse in a volume or quantity or at a rate in excess of that so stipulated.

13. A person who contravenes or fails to comply with any of these Regulations shall be guilty of an offence and shall be liable on conviction to a fine not exceeding five thousand dollars and, in the case of a continuing offence, to a further fine of one hundred dollars for every day or part thereof during which the offence is continued after conviction.

14. The Director may exempt a person or class of persons from one or more of the provisions of these Regulations.

15.—(1) The Local Government (Disposal of Trade Effluents) Regulations, 1970, and the Environmental Public Health (Prohibition on Discharge of Trade Effluents into Watercourses) Regulations, 1971, are hereby revoked. G.N. No.  
S 195/70.  
G.N. No.  
S 58/71.

(2) Any permission granted or other thing done under the Local Government (Disposal of Trade Effluents) Regulations, 1970, or the Environmental Public Health (Prohibition on Discharge of Trade Effluents into Watercourses) Regulations, 1971, which, immediately before the coming into operation of these Regulations, was of force or effect shall continue in force and have effect as if granted or done under the corresponding provision of these Regulations.



THE SCHEDULE. (Regulation 2)

All those pieces of land situated in the Mukims of Sembawang, Mandai, Ulu Kallang, Bukit Timah and Toa Payoh in Singapore forming parts of the catchment area described as follows:—

Location.	Lot No.	Mukim.	Approximate Areas.			
			Acres.	Roods.	Perches.	
MacRitchie Reservoir Catchment Area	115-1	Toa Payoh XIII	1	0	24	
	115-2 pt	Toa Payoh XVII	911	3	29	
	116	Toa Payoh XVII	3	1	05	
Peirce Reservoir Catchment Area	28	Ulu Kallang XV	3	2	34	
	29	Ulu Kallang XV	0	0	12	
	30	Ulu Kallang XV	5	1	14	
	3-1	Ulu Kallang XV	1	3	25	
	13-4	Ulu Kallang XV	1	0	29.3	
	13-5	Ulu Kallang XV	1	1	16.8	
	13-6	Ulu Kallang XV	41	0	30	
	13-14	Ulu Kallang XV	20	1	29	
	14-3	Ulu Kallang XV	4	3	04	
	153	Ulu Kallang XV	0	1	06.5	
	155 pt	Ulu Kallang XV	2695	0	00	
	159	Ulu Kallang XV	56	2	03	
	66	Bukit Timah XVI	576	0	00	
	Seletar Reservoir Catchment Area	13-2	Sembawang XIII	3	3	13.60
		13-3	Sembawang XIII	667	2	00
11-1		Mandai XIV	0	3	11	
30		Mandai XIV	14	2	39	
	31-2 pt	Mandai XIV	3144	0	00.	

Made this 3rd day of June, 1976.

LEE EK TIENG,  
Acting Permanent Secretary,  
Ministry of the Environment,  
Singapore.

[ENV. Cf. 02A/73; AG./L./63/75]

(To be presented to Parliament under section 68 (4) of the Water Pollution Control and Drainage Act, 1975).

(Vide Notification No. S 207 in the Gazette Subsidiary Legislation Supplement No. 39 of 26th August, 1977).

**THE WATER POLLUTION CONTROL AND DRAINAGE  
ACT, 1975.  
(ACT 29 OF 1975).**

**THE TRADE EFFLUENT (AMENDMENT) REGULATIONS, 1977.**

In exercise of the powers conferred by subsection (1) of section 14 and section 68 of the Water Pollution Control and Drainage Act, 1975, the Minister for the Environment hereby makes the following Regulations:—

1. These Regulations may be cited as the Trade Effluent (Amendment) Regulations, 1977, and shall come into operation on the 1st day of September, 1977.

G.N. Nos.  
S 122/76  
S 167/76.

2. Regulation 2 of the Trade Effluent Regulations, 1976 (hereinafter in these Regulations referred to as "the principal Regulations") is hereby amended—

(a) by deleting the word "Schedule" appearing at the end of the definition of "natural catchment area of the MacRitchie, Pierce and Seletar Reservoirs" appearing therein and substituting therefor the words "First Schedule"; and

(b) by inserting immediately after the definition of "natural catchment area of the MacRitchie, Pierce and Seletar Reservoirs" appearing therein the following new definition:—

"organic sludge" means the organic matter in trade effluents which has a minimum solid content of three per cent by weight or a maximum moisture content of ninety-seven per cent by weight;".

3. Regulation 4 of the principal Regulations is hereby amended by inserting immediately after paragraph (7) thereof the following new paragraphs:—

"(8) The Director may permit any person to discharge into a public sewer trade effluent containing the 5-day Biochemical Oxygen Demand at 20°C (hereinafter in these Regulations referred to as "BOD") and Total Suspended Solids in proportions greater than those specified in paragraph (2) of regulation 12 if such person pays to the Director a fee according to the scale set out in the Second Schedule.

(9) The Director may permit any person to dispose organic sludge at any of the sewage treatment works as may be specified by the Director if such person pays to the Director a fee according to the scale set out in the Third Schedule.

(10) The Director may in granting any permission under paragraph (8) or (9) impose such conditions as he thinks fit".



4. The Schedule to the principal Regulations is hereby amended by deleting the word "The" appearing in the heading thereto and substituting therefor the word "First".

5. The principal Regulations are hereby amended by inserting immediately after the First Schedule thereto the following new Schedules:—

"SECOND SCHEDULE. Regulation 4 (8).

<i>Concentration in milligrams per litre</i>	<i>Fee for Total</i>	
	<i>Fee for BOD.</i>	<i>Suspended Solids.</i>
	<i>Cents per cubic metre or part thereof</i>	<i>Cents per cubic metre or part thereof</i>
(a) exceeding 400 but not exceeding 600	10	4
(b) exceeding 600 but not exceeding 800	20	9
(c) exceeding 800 but not exceeding 1,000	31	13
(d) exceeding 1,000 but not exceeding 1,200	41	18
(e) exceeding 1,200 but not exceeding 1,400	53	23
(f) exceeding 1,400 but not exceeding 1,600	65	29
(g) exceeding 1,600 but not exceeding 1,800	78	34

THIRD SCHEDULE. Regulation 4 (9).

A fee of \$3.80 per cubic metre or part thereof shall be payable for the disposal of organic sludge at any of the specific sewage treatment works."

Made this 24th day of August, 1977.

LEE EK TIENG,  
Permanent Secretary,  
Ministry of the Environment,  
Singapore.

[ENV. CF. 02A./73 Vol. I; AG./L./63/75]

(To be presented to Parliament under section 68 (4) of the Water Pollution Control and Drainage Act, 1975).

ANNEX 8

A REVIEW OF THE ANALYTICAL METHODS USED  
IN SINGAPORE FOR WATER POLLUTANTS



A REVIEW OF THE ANALYTICAL METHODS USED IN  
SINGAPORE FOR WATER POLLUTANTS

Synopsis

Water samples taken from sea, drains, canals, streams and river, industrial effluents and sewage are analysed for water pollutants.

Salinity, conductivity, turbidity, pH, colour and Dissolved oxygen are determined by using different types of meters. Whilst tests for metal contents and total organic carbon contents are carried out by the use of atomic absorption spectroscopic method and total organic carbon analyser.

Analytical methods used for the determination of total solids, total suspended solids, total dissolved solids, BOD<sub>5</sub>, COD, ammonia-N, TKN, nitrite-N, nitrate-N, phosphorus, detergent, sulphate, sulphite, chloride, cyanide, phenol, aluminium, arsenic, and oil and grease are done in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Water Works Association and Water Pollution Control Federation of the United States.

However, pollutants like COD, ammonia-N, nitrite-N, nitrate-N, chloride, sulphate, phosphorus are also analysed by means of Automatic analyser using different analytical cart-ridge.

## 1 Introduction

1.1 In Singapore, the control of water pollution is given high priority. To ensure that the objectives of water management are achieved, a relatively intensive monitoring programme is carried out with the back up of well equipped and staffed laboratories.

The main laboratory is the Water Pollution Control Laboratory headed by a Senior Scientific Officer. Besides this, there are seven other quality control laboratories at various sewage treatment works. These laboratories are set up to carry out physico-chemical analyses of the following :

- a) seawater samples
- b) water samples taken from drains, canals, streams and rivers in water catchments as well as those in non-water catchments;
- c) industrial effluents; and
- d) sewage

Types of parameter selected for the analysis depend on the source of samples to be tested and the objectives of such analyses. A list of parameters analysed for various source of sample are shown in the Appendix 1.

1.2 The main objective in the analysis of water samples is the determination of the water quality or the extent of pollution. As there are countless types of substances that may be considered as pollutants, methods of analyses must be devised to give good indications of the undesirable characteristics of pollutants rather than the exact concentrations of each and every substance present in the water.



1.3 In this paper, a review of the analytical method is only confined to the physico-chemical analysis for the following water pollutants :-

- 1) Oxygen Consuming matter;
- 2) non-toxic salts;
- 3) Poisons;
- 4) Inorganic solids;
- 5) Unaesthetic wastes

Bacteriological examination of wastewater will not be discussed.

## 2 Philosophy of Analytical Methods

The analytical methods adopted for the testing of water pollutants are based on the latest edition of the "American Standard Methods for the Examination of Water and Wastewater" as stipulated in the Trade Effluent Regulation, 1976. These methods are chosen because they satisfy the following criteria :-

- a) They have been sufficiently tested to establish their validity and are widely used in most laboratories in the world;
- b) They give a good measurement of the required parameter and also with such precision and accuracy that they meet the data needed in the presence of interferences normally encountered in polluted water;
- c) The methods utilises simple equipment that are readily available and also the skills required to manipulate these equipment or to perform the analysis are normally available in an average water pollution control laboratory;

- d) The methods are fairly rapidly performed and can be used routinely for the examination of large numbers of samples. Moreover, the chemicals and glasswares used in the methods are inexpensive and are readily available in the market;
- e) These methods are constantly revised and the methodology is constantly being improved so that its scope includes techniques suitable for examination of many types of samples encountered in the assessment and control of water quality and water pollution in Singapore.

### 3 Determination of Water Pollutants by Wet Methods

#### 3.1 Oxygen-consuming matter

3.1.1 Any waste organic matter, that can be biologically decomposed, will deplete the dissolved oxygen in water. As a result it can cause odour and also affect aquatic life.

3.1.2 BOD<sub>5</sub>, COD and TOC tests are most commonly used to determine the amount of oxygen consuming pollutants in wastewater, natural water and industrial wastes.

3.1.3 BOD<sub>5</sub> test is carried out so as to provide a rough indication of the amount of oxygen required to decompose the biodegradable carbonaceous compounds in the wastewater or receiving water. In conjunction with the COD data, the amount of the oxidisable compounds can also be estimated.



3.1.4 In BOD test, for samples that need to be diluted, due the presence of toxic substances, or to be seeded, the results obtained are always unreliable as the rate of acclimatisation for different groups of micro-organisms to the new environment differs and thus the microbial activities in the test samples are greatly affected. As such, COD or TOC tests are carried out on these samples.

3.1.5 For the BOD test, it has been found that  $20^{\circ}\text{C}$  is the most suitable temperature for the activities of most microorganisms in wastewater. A study was carried out on the final effluent collected from Kim Chuan Sewage Treatment Works and it showed that the values obtained from the BOD tests carried out for 5 days at  $20^{\circ}\text{C}$  are contributed by the decomposition of 75 to 80% of the biodegradable carbonaceous organic compounds with no interference of nitrification. Another study showed that  $\text{BOD}_3$  at  $29^{\circ}\text{C}$  is 1.3515 times  $\text{BOD}_5$  at  $20^{\circ}\text{C}$ . Since higher temperature accelerates the activity of the nitrifying bacteria, the result of  $\text{BOD}_3$  at  $29^{\circ}\text{C}$  obtained is therefore the amount of oxygen consumed by the decomposition of both the carbonaceous and nitrogenous compounds. In Singapore,  $\text{BOD}_5$  at  $20^{\circ}\text{C}$  is used so that our water quality can be compared with the standards set by the World Health Organisation. As our ambient temperature is about  $29^{\circ}\text{C}$ , so in the near future,  $\text{BOD}_3$  at  $29^{\circ}\text{C}$  may be used instead because this figure will give us the true oxygen consuming tendency of our wastewater.

3.1.6 In the case of chemical analysis for the oxygen consuming matter, COD test is used in preference to 4 hour PV test as the oxidising agent, dichromate, used in the COD test is capable of oxidizing a wide variety of organic substances to carbon dioxide and water, and almost 100% of the oxidisable compounds are oxidised. Whilst oxidation caused by permanganate is highly variable with respect to various types of compounds present and the degree of oxidation varies considerably with the strength of reagents used. Study has shown that only 65% of the oxidizable compounds are determined.

3.1.7 TOC is measured by the use of a TOC analyser. This test can be performed rapidly. Due to the shortage of such equipment, TOC is only analysed for water samples which contain small concentration of organic compound such that BOD<sub>5</sub> and COD tests cannot be carried out effectively. However, the test has its limitation, as certain resistant organic compounds may not be oxidised by the analyser, thus the measured TOC value will be slightly lower than the actual amount present in the sample. However, the TOC data obtained still indicate the amount of the oxidisable organic carbonaceous compounds present.

### 3.2 Non-toxic salts

3.2.1 Salts from domestic wastes and waste brines can interfere with water reuse for industries and irrigation.

Inorganic phosphorus and nitrogen are determined because :-

- (1) they are the most important elements contributed by the fertilizers for plants and;
- (2) they are used as nutrients by microorganisms.

The excess phosphorus and nitrogen are normally discharged together with the effluent or leached from farm land into the nearby river and stream, as such, they induce the growth



of algae and aquatic weeds in surface water. Furthermore, the nitrogen compounds like organic nitrogen and ammonia-nitrogen, also seriously reduce the dissolved oxygen level in water.

3.2.2 Phosphorus, be it in the form of organic or inorganic phosphates, is slowly decomposed or hydrolysed to a more stable ortho form. Therefore, a total phosphorus content is usually measured by acid hydrolysis of all forms of phosphates to ortho form; which is then determined spectrophotometrically. In this test, stannous chloride is used in preference to amino-naphthol-sulphonic acid as the latter reagent is difficult to dissolve and also must be prepared freshly. Whilst stannous chloride is easily prepared and has a longer effective life.

3.2.3 Common forms of nitrogen pollutant are organic, ammonia, nitrite and nitrate, of which free ammonia is the most serious pollutant.

3.2.4 Singapore is not an agricultural country, as such, nitrogenous compound is largely contributed by domestic waste, mainly from human waste and to a small extent animal waste. These wastes contain high amount of organic-nitrogen which can then be decomposed into free ammonia. Therefore TKN and ammonia-N contents are usually measured to determine the state of water pollution caused by nitrogenous waste. Tests for  $\text{NO}_2^-$ -N and  $\text{NO}_3^-$ -N are only carried out on sewage effluent samples and samples collected in the areas where vegetable or fruit farms are located.

3.2.5 TKN method is used as it is the revised and improved method used to determine the total

nitrogen contents excluding the nitrite and nitrate concentrations. It is used in preference to albuminoid-Nitrogen test as the latter test only measures a certain form of organic nitrogen that can be released as ammonia under the working condition. In both TKN and ammonia-N tests, the free ammonia collected by distillation is free of interference and also a large percentage of ammonia is recovered and absorbed by using boric acid as the absorber. Furthermore, titration of borate ions with sulphuric acid is used instead of nesslerisation as the former procedure can cover a wider range of ammonia-N values.

### 3.3 Inorganic salts

3.3.1 Inorganic salts are those inert substances that are either in dissolved or suspended form. TDS and chloride are usually used as the analytical parameters.

3.3.2 Both TDS and chloride tests require simple analytical technique, and the results obtained are reproducible. Furthermore, TDS data can serve as a check to see whether such water can be reused, as certain industries required to use water of low TDS value. However, data obtained for chloride tests on samples of river, water-catchment and non-water catchment areas can tell whether infiltration of seawater to these areas takes place. On the contrary, chloride data for seawater samples can indicate whether dilution of seawater by inland river water or effluent discharges takes place



### 3.4 Poisons and heavy metals

3.4.1 Acids, alkalis and toxic chemicals in water are analysed as they can adversely affect aquatic life and impair recreational use of water. Sharp deviation of pH at the point of discharge into a river or lake eliminates less tolerant animal and plant species and has considerable influence on the toxicity of some poisons. Therefore pH is determined to measure the intensity of acidic or alkaline condition in water.

3.4.2 Whilst toxic chemicals are analysed mainly for industrial effluents, the types of chemicals or heavy metals tested vary from industry to industry. For instance, cadmium, chromium, iron, copper, nickel, silver, zinc are tested for electroplating wastes, sulphite and phenolic compounds are tested for waste water samples taken from oil refineries, plywood factories and glue manufactures. Heavy metals such as mercury, cadmium and lead are serious pollutants, since they form stable compounds that persist in nature and are concentrated in the aquatic food chain, are therefore must be analysed.

Except for aluminium, arsenic and boron which are tested by wet methods in our laboratory, all other heavy metals are analysed rapidly by use of the atomic absorption method.

### 3.5 Unaesthetic Wastes

3.5.1 Foam producing matter such as detergents and coloured substances which cause undesirable appearance to receiving streams are considered as indicators of contaminations.

3.5.2 There are three types of surfactants, of which only the degradable linear alkylate sulphonate is allowed to be used in Singapore. The determination of linear alkylate sulphonate is simple and accurate.

3.5.3 In our laboratories, colour of the samples are measured by either Lovibond comparator or Tintometer. Colour of sewage samples, river or seawater samples which are usually yellowish can be measured accurately by using Lovibond comparator. Whilst the industrial effluent samples are usually quite colourful, and they are measured by using Tintometer.

#### 4 The Use of Automatic Analyzer

4.1 As the analytical methods used in the laboratory are rather time consuming and involve with a lot of manpower, some of the analytical procedures are therefore automated to minimise the man-hours required and random errors in carrying out analyses.

4.2 The Auto Analyser is an automated system used to perform a variety of chemical analyses such as determination of COD, TKN, ammonia-nitrogen, nitrite, nitrate, phosphate, chloride, anionic surfactant, sulphate and silica. In this system, a few parameters of each sample can be analysed simultaneously and rapidly. It automates the normally time consuming, tedious procedures of manual analyses, that is, sampling, dilution, filtering, mixing, heating, colour measurement. It does all these procedures in a straight forward, logical way, automatically, and at a rate of speed and degree of precision once considered unattainable



4.3 By preselected programming, sample fluids, reagents and standards are brought together under controlled sequenced conditions to cause a chemical reaction and in most instances, colour development. With a colorimetric procedure, the optical density of the fluid, being related to fluid concentration is photo-electrically determined in a colorimeter. The colorimeter-output concentration values will appear as a series of curves or peaks on moving graph paper. Then by means of graph overlay, the recorded peaks of the samples are compared with those of known standard.

4.4 The results obtained by this system are comparable to that of the manual analytical methods as described in the 14th edition American Standard Methods.

4.5 Details of the analytical methods are in Appendix II.

## 5 Field Equipment

5.1 Each portable kit provides a fairly sensitive spectrophotometric detection of pH, colour, turbidity, conductivity, suspended solids, dissolved oxygen and chemical substances like chloride, bromide, phosphate, sulphate characteristic of the samples analysed. The advantage of the instrument lies in the convenience in use as its portable size enables it to be carried to the sites where water samples are to be analysed. However, its main drawback is its relative inaccuracy. The measurement obtained by it usually indicates a rough estimation and as a matter of fact, one cannot rely upon the data obtained confidently.

5.2 Furthermore, the chemicals stored in the kit can decompose easily and need to be replaced regularly. It is not economical to use unless it is of necessity.

5.3 As far as Singapore is concerned, the country is small in size, the water samples obtained from various places can be transported to the laboratories for detailed analysis easily and quickly. Hence the Hach portable kit is not frequently used locally.

## 6 Conclusion

6.1 Qualitatively data obtained by manual analyses closely resemble those obtained by automatic analysers. Technically and quantitatively, automatic analyser provides immediate results by analysing a few parameters of the same sample simultaneously. It is not only time saving, but also it does not carry errors caused randomly and at the same time, it eliminates all possible systematic errors. The main limitation of the Automatic analyser is its selectivity, as not all parameters of a sample can be analysed directly, for example, BOD<sub>5</sub> test. However, manual analyses of BOD<sub>5</sub> can be carried out satisfactorily.

6.2 In view of this, it is obvious that at present, Automatic Analysis cannot fully replace manual analytical techniques. A compromise is sought where manual analyses are jointly used in our laboratories for maximum output of results and minimum time.

6.3 At present, due to the lack of sophisticated equipment, some of the tests for parameters like pesticides and petroleum waste are not carried out in our laboratories. However, they are analysed by the Department of Scientific Services.

With the purchase of sophisticated equipment, such as the gas-chromatographic-mass-spectroscope, our main laboratory at Princess House will be able to analyse for such parameters in the near future. This equipment can also enhance our



monitoring ability in our modern industries such as the petrochemical and the special chemical industries.

Analyses commonly carried out in the Laboratory for Water Pollutants

Parameters	Types of Samples					
	Sea Water	Catchment	Non Catchment	Reservoir	Trade Effluent	Sewage
pH	✓	✓	✓	✓	✓	✓
Colour	✓	✓	✓		✓	✓
Turbidity	✓					
Conductivity	✓					
Salinity	✓					
Total Solids						✓
Suspended Solids	✓	✓	✓	✓	✓	✓
Total dissolved solids		✓	✓	✓	✓	
BOD <sub>5</sub>		✓	✓	✓	✓	✓
COD		✓	✓	✓	✓	✓
TOC	✓	✓				
Phosphorus	✓	✓		✓		✓
Surfactant	✓					✓
Amn-N	✓	✓	✓	✓		✓
TKN	✓	✓	✓	✓		✓
NO <sub>2</sub> <sup>-</sup> -N		✓		✓		✓
NO <sub>3</sub> <sup>-</sup> -N	✓	✓		✓		✓
Cl <sup>-</sup>	✓	✓		✓		✓
Sulfide						✓
Cyanide						
Oil & grease	✓				✓	
Phenol						
Heavy metals	✓			✓		✓
Silica		✓		✓		
Pesticides	✓					
As	✓			✓		

for  
treat-  
ed  
effluent  
only



ANALYTICAL METHOD FOR WATER POLLUTANTS

The analytical methods used are in accordance with the latest edition of "Standard Methods for the Examination of Water and Wastewater" published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation of the United States.

1      pH Value

1.1      pH is a term used to express the intensity of acid or alkaline condition of a solution. It is a way of expressing the  $H^+$  ion concentration. i.e.  $H^+$  activity.

1.2      Methods of Measurement

pH value can be measured by electrometrically or colorimetrically.

The electrometric test is a recommended procedure and is relatively immune to interferences from turbidity, colour, colloidal matter, free chlorine, high salt content and oxidizing and reducing agents.

## 2 Colour

2.1 Colour which is caused by suspended solids is referred to as apparent colour whilst that which are colloidal in nature due to organic extracts is referred to as true colour.

### 2.2 Methods of Determination

#### (i) For Hazen Unit

The colour produced by 1 mg/l of platinate ( $K_2Pt.Cl_6$ ) in combination with  $\frac{1}{2}$  mg/l of metallic cobalt (cobalt Chloride) is taken as 1 standard colour unit. The colour measurement is usually carried out by comparing the colour of the sample to that of the standard colour disc using the Lovibond comparator.

#### (ii) Lovibond Unit

The Lovibond Unit of colour is an arbitrary one, but through long and worldwide use has received international acceptance. The colour of the sample



is usually matched with the visual colours produced by a combination of lovibond glasses, which comprises the three basic colours, red, yellow, and blue of varying intensities. The instrument for this is called Tintometer.

### 3 Turbidity

3.1 It refers to the interference of light passage through water by scattering and absorbing the rays caused by insoluble particles of soil, organics, microorganisms and other materials.

#### 3.2 Analytical Method

It is determined by the Nephelometric method which is based on a comparison of the intensity of light scattered by the sample under defined conditions with the intensity of light scattered by a standard reference suspension under the same conditions.

For the measurement of turbidity  $< 40$  NTU, a well-shaken sample is poured into the turbidimeter tube and the result is read from the instrument scale.

For the measurement of turbidity  $> 40$  NTU, the procedure is the same except that the sample has **first** to be diluted with turbidity-free water until the turbidity falls between 30 and 40 NTU.

$$\text{Nephelometric Turbidity Unit, NTU} = \frac{\text{NTU found in diluted water} \times \left( \frac{\text{Vol diluted water}}{\text{Sample vol taken for dilution}} \right)}{\text{Sample vol. taken for dilution}}$$

Turbidity should be determined on the day the sample is taken. However, if storage is unavoidable, the sample should be stored in the dark for up to 24 hrs. only because prolong storage may cause irreversible changes in the turbidity.

Dirty glassware, the presence of air bubbles and the effects of vibrations that disturb the surface visibility of the samples will lead to false results. Also the colour of the water due to dissolved substances that absorb light will cause measured turbidities to be low.

#### 4 Conductivity

4.1 Conductivity is defined as a numerical expression of the ability of a water sample to carry an electric current.

#### 4.2 Analytical Method

To determine the conductivity of the sample, the cell constant has to be determined first. This is done by rinsing the conductivity cell with at least three portions of 0.1 MKCl solution. The temperature of a fourth portion is then adjusted to  $25.0 \pm 0.1^\circ \text{C}$  and the resistance of this portion is measured, taking note of the temperature. The cell is then



rinsed with one or more portions of the sample to be tested. Again, the temperature of the final portion of the sample is adjusted to  $25 \pm 0.1^\circ \text{C}$ . The resistance of the sample is measured, taking note of the temperature.

$$\text{Cell constant } C = \frac{0.001413 R_{\text{KCl}}}{1 + 0.0200 (t_1 - 25)}$$

$$\text{Conductivity } (\mu\text{mhos/cm}) = \frac{1,000,000 C}{R \quad 1 + 0.02 (t_2 - 25)}$$

where : R : Resistance of sample

RKCl : Resistance of 0.01 MKCl solution

$t_1$  : Tempt. when cell constant is measured

$t_2$  : Tempt. when conductivity is measured

## 5 Salinity

5.1 It is defined as the total solids in water after all the carbonates have been converted to oxides. All bromides and iodides have been replaced by chloride and all organic matter has been oxidised. It is numerically smaller than the filterable residue (dissolved solid) and is usually reported as gm/kg or parts per thousand (%).

## 5.2 Analytical Method

It is determined by Electrical Conductivity Method by using an S-C-T meter, ie. salinity - Conductivity - Temperature meter.

## 6 Total Solids

6.1 Refer to both suspended and dissolved solids in wastewater, which remain as residues upon evaporation and drying to 103° to 105°C.

### 6.2 Analytical Method

It is determined by evaporation method. A well mixed sample is evaporated in a weighed dish and dried to constant weight in an oven at 103°C to 105°C. The increase in weight over that of the empty dish gives the amount of total solids of the sample.

$$\text{Total Solids (mg/l)} = \frac{(\text{Wt of sample} + \text{Wt of dish}) - \text{Wt of dish}}{\text{Vol of sample used}} \times 1000$$

The sample for total solid test must be analysed as soon as possible. Plastic bottles are satisfactorily used to contain the samples for analyses if the materials in suspension in the sample do not adhere to the walls of the containers.

Care has to be taken to exclude any large, floating particles or submerged agglomerates of non-homogeneous materials from the sample during the test. Also, it is necessary to dispose visible floating oil and grease with a blender before withdrawing a sample portion for analysis.

Furthermore, the temperature at which the residue is dried has an important bearing on the results. At higher temperature, volatilization of organic matter,



removal of mechanically occluded water, water of crystallization and gases from heat induced chemically decomposition would cause additional lost of weight of sample, as a result, the analytical result gives a lower value of the actual weight of the sample. However, if oxidation of sample takes place due to employment of high temperature and long period of heating, would result in gain of weight of the sample.

## 7 Total Suspended Solid

7.1 It refers to those solids that can be filtered off from the wastewater sample.

### 7.2 Analytical Method

It is determined by filtration and evaporation method. A well mixed, sample of known volume is filtered through a glass fibre filter paper. The residues on the filter paper is then dried in an oven at 103° to 105°C till constant weight. The increase in weight over that of the clean filter paper gives the amount of total suspended solids of the sample.

$$\text{Total Suspended Solid (mg/l)} = \frac{(\text{Wt of sample} + \text{Wt of filter paper}) - \text{Wt of filter paper}}{\text{Vol. of sample used}} \times 100$$

In this test, the same precaution has to be taken as discussed for the analysis of total solids.

## 8 Total Dissolved Solid

8.1 It refers to the materials that pass through a glass fibre filter paper and remains after evaporation and drying.

8.2 Analytical Method

It is determined by filtration and evaporation method. A unknown volume of well mixed sample is filtered through a weighed glass fibre filter paper. The filtrate is collected and after evaporation, it is allowed to dry to constant weight at 103 - 105°C.

$$\text{Total dissolved solid (mg/l)} = \frac{(\text{Wt of dried residue+dish}) - \text{Wt of dish}}{\text{Vol. of filtrate}} \times 1000$$

Samples that contain a considerable calcium, magnesium, chloride or sulphate content may be hygroscopic, so such samples normally require longer drying periods. Apparently, proper desiccation and rapid weighing of dried samples are required.

9 BOD<sub>5</sub> - 5 Days Biochemical Oxygen Demand

9.1 It is a measure of unstable organic matter present and is defined as the quantity of oxygen required by bacteria to biologically oxidize the decomposable organic materials in a 5 day period at 20°C. Because the amount of oxygen required to convert a given quantity of biologically oxidizable organic compound to CO<sub>2</sub> and H<sub>2</sub>O is fixed, it is possible to interpret BOD data semi-quantatively in terms of gross concentrations of organic matter as well as oxygen consuming tendencies.



9.2 Analytical Method

It is essentially a bio-assay method involving measurement of quantities of oxygen consumed during biologically oxidation of organic matter for 5 days at 20°C. This is compared to the amount of oxygen consumed by a reservoir of dilution water. The difference of the two values multiply by a dilution factor gives the BOD<sub>5</sub> result of the sample.

$$\text{BOD}_5 \text{ (mg/l)} = (I_{D.O} - F_{D.O}) - (B_{IDO} - B_{FDO}) \times \frac{300}{\text{Volume of sample}}$$

As the test involves the activities carried out by microorganisms of the wastewater, therefore, it is important to ensure that there is a significant population of mixed organisms to be present in the sample. If there is lack of such organisms as in the case of industrial waste, the sample to be tested must be seeded. The microorganisms must be provided with favorable living environments, suitable pH (~7), osmotic condition and temperature must be provided for the biological activities of the microorganisms to proceed. Furthermore, a supply of sufficient nutrients for the growth of microorganisms is required. However, any toxic substances which are detrimental to the growth of the microorganisms must be absent. If residual chlorine is present, the sample must be allowed to stand for 1 to 2 hours to dissipate the chlorine.

Samples for BOD analysis may undergo significant degradation during handling and storage. To reduce the change in oxygen demand that occurs between sampling and testing, all samples are to be kept at or below 4°C and the analyses must be carried out not more than 24 hours after the samples are collected.

Distinct disadvantages are (a) relatively long period of time (5 days) is required to obtain results. (b) It is assumed that the oxygen utilization by nitrification is of little consequence during the 1st 5 days. However, this is not the case as incipient nitrification often may account for a considerable portion of 5 days oxygen demand. (c) BOD test is subject to interference from certain substances which exhibit toxic effects on the microorganisms involved in the biological breakdown of organic matter. (d) The standard dilution method for determining the BOD of wastewater is based on the general observation that the rate of biochemical degradation of organic matter is proportional to the amount remaining to be oxidized.

It is important to note that, the rate at which oxygen is consumed in a series of dilution of a particular sample of wastewater should be proportionate to the respective dilution factors, provided that all the other factors are equal. eg. 10% dilution uses  $O_2$  at  $1/10$  the rate of 100% sample.

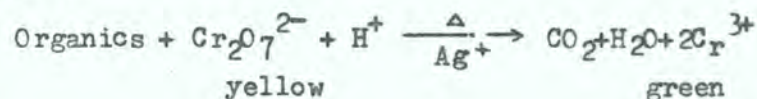


## 10 COD : Chemical Oxygen Demand

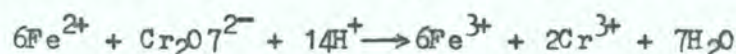
10.1 The COD measures the amount of oxygen required for chemical oxidation of organic matter in a sample of wastewater to carbon dioxide and water by a hot solution of acidified potassium dichromate.

### 10.2 Analytical Method

COD is determined by reflux and titration method. A sample is refluxed with known amount of potassium dichromate and sulphuric acid in the presence of silver sulphate as catalyst. As a result, yellow dichromate is reduced and in turn green chromic is produced.



The excess dichromate is then titrated with ferrous ammonium sulphate (FAS) using ferroin (ferrous, 1, 10-phenanthroline sulphate) as indicator. Ferrous ion reacts with dichromate ion with an end point colour change from blue-green to reddish brown.



The amount of oxidizable organic matter measured as oxygen equivalent, is proportional to the potassium dichromate consumed.

$$\text{COD (mg/l)} = \frac{(\text{Vol of FAS blank} - \text{Vol of FAS sample}) \times N_{\text{FAS}} \times 8,000}{\text{Vol of sample}}$$

where 8,000 multiplier is to express the results in units of mg/l of oxygen, since 1 l contains 1,000 ml and the equivalent mass of oxygen is 8 and  $N_{\text{FAS}} = 0.1N$

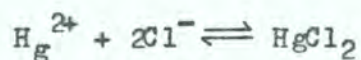
A blank sample of distilled water is carried through the same COD testing procedure as the wastewater sample, to compensate for any error that may result because of the presence of extraneous organic matter in the reagents.

Since ferrous ammonium sulphate is an unstable reagent which slowly oxidises from  $\text{Fe}^{2+}$  to  $\text{Fe}^{3+}$  and thus giving a lower COD result than the true value, therefore, it is necessary to standardise the reagent before use.

$$N_{\text{FAS}} = \frac{\text{ml } \text{K}_2\text{Cr}_2\text{O}_7 \times N_{\text{K}_2\text{Cr}_2\text{O}_7}}{\text{ml FAS}} \quad \text{Where } N \text{ of } \text{K}_2\text{Cr}_2\text{O}_7 = 0.25N$$

Sample that contains straight chain low molecular weight fatty acid can be oxidized in the presence of silver sulphate as catalyst, whilst the aromatic hydrocarbon and pyridine are not oxidized under any circumstances.

The presence of chloride ion can cause erroneously high results to be obtained.  $6\text{Cl}^- + \text{Cr}_2\text{O}_7^{2-} + 14\text{H}^+ \rightarrow 3\text{Cl}_2 + 2\text{Cr}^{3+} + 7\text{H}_2\text{O}$ . But this interference can be eliminated by the addition of mercuric sulphate to sample prior to the addition of other reagents.



poorly ionized

Furthermore, the oxidation of nitrite to nitrate in dichromate solution can be overcome by adding sulphamic acid.

To obtain a reliable result, unstable samples are to be analysed without delay. However if there is to be a delay before analysis, the samples are to be preserved by acidification with sulphuric acid.



The advantage of this test for determining organic load is that shorter time is required for evaluation and the presence of toxic substances do not affect the determination.

## 11 Total Organic Carbon Analyses

The total organic carbon analyser provides a rapid analysis of micro sample of aqueous solution for the determination of total carbon (ie organic carbon plus carbon in carbonates) and inorganic carbon (ie carbonates). For the determination of total organic carbon, the two analyses are performed on successive identical samples. The desired quantity is the difference between the two values obtained. Both analyses are based on the conversion of simple carbon into carbon dioxide for measurement by a non-dispersive infra-red analyser.

## 12 Methylene Blue Stability Test

12.1 It is a measure of the time needed for wastewater especially sewage, to use up its oxygen supply.

### 12.2 Analytical Method

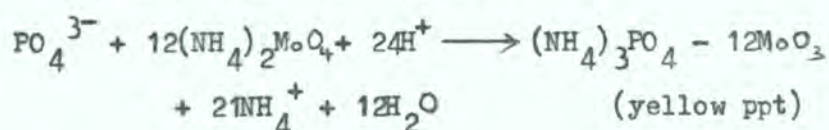
300 ml of 0.5 gm/l of methylene blue is used for the test. This test is based upon the fact that organic matter in sewage takes up free oxygen first and when no more is available, the organic matter will take the combined oxygen from methylene blue. Thus disappearance of the blue colour in methylene blue indicates that free oxygen is used up.

13 Phosphorus

13.1 The common compounds are orthophosphates ( $\text{H}_2\text{PO}_4^-$ ,  $\text{HPO}_4^{2-}$ ,  $\text{PO}_4^{3-}$ ), polyphosphates and organic phosphorus. All polyphosphates gradually hydrolyze in water to the stable ortho form, while decaying organic matter decomposes biologically to release phosphate.

13.2 Analytical Method

It is determined by stannous chloride colorimetric method. Total phosphorus content of a sample can be determined by digesting a known volume of sample with concentrated sulphuric acid in the presence of nitric acid to convert all the phosphorus into orthophosphate form, which then can be measured quantitatively by colorimetric methods. Phosphate ion combines with ammonium molybdate under acid conditions to form a yellow complex compound known as ammonium phosphomolybdate



In the presence of stannous chloride as reducing agent, the molybdenum contained in ammonium phosphomolybdate is readily reduced to produce a blue coloured sol. that is proportional to the amount of phosphate present. Excess ammonium molybdate does not interfere with colour formation. The colour of the treated sample is compared against that of the blank at 690 m $\mu$  in Spectronic 20, using long range phototube with green filter.

$$\text{PO}_4^{3-} \text{ -P (mg/l)} = \frac{\text{Absorbance} \times \tan \left( \frac{\mu\text{g standard}}{\text{Absorbance Standard}} \right)}{\text{Vol of sample used}}$$



If the reducing agent, stannous chloride is in contact with air for a longer time, oxidation of stannous to stannic takes place. As a result, a turbidity due to hydrolysis of  $\text{SnCl}_4$  to  $\text{Sn(OH)}_4$  may result when the reducing agent is added to the sample therefore it should not be used.

The presence of silica and arsenic give positive interference when the sample is heated whilst the presence of arsenate, fluoride, thorium, bismuth, sulphide, thiosulphate, thiocyanate give negative interference. However, sulphide interference may be removed by oxidation with bromine water.

Samples for total phosphorus test can be preserved by freezing or by addition of  $40 \text{ mgHgCl}_2/1$  when the samples are to be stored for long period.

Samples that contain low phosphorus concentration must not be stored in plastic bottles as adsorption of phosphorus onto the walls of bottles may take place. All glass containers must be rinsed with hot dilute hydrochloric acid followed by distilled water before use.

#### 14 Surfactants-Detergents

14.1 There are three types of surfactants-anionic, non-ionic and cationic. Detergents are further classified as hard and soft. A hard detergent is not readily degradable eg. alkyl benzene sulphonate, whilst a soft detergent is degradable eg. linear alkylate sulphonate. The latter is commonly used in Singapore.

#### 14.2 Analytical Method

The standard analysis for anionic detergent eg linear alkylate sulphonate, is the formation of a chloroform soluble coloured complex with methylene blue. The intensity of the blue colour is measured photometrically at a wavelength of 652 nm. Organic sulphates, sulphonates and phenols as well as inorganic cyanates, chlorides, nitrates and thiocyanites would interfere with the test. Amines would also complete with methylene blue to give negative interference.

$$\text{Total apparent LAS (mg/l)} = \frac{\mu\text{g LAS}}{\text{ml sample}} = \frac{\text{Absorbance} \times \text{Extan} \times \frac{\mu\text{g standard}}{\text{Absd. Standard}}}{\text{ml of sample used}}$$

#### 15 Ammonical Nitrogen

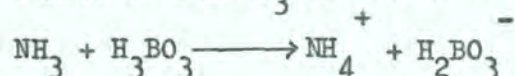
15.1 Inorganic nitrogen, principally in the ammonia and nitrate forms, is used by green plants in photosynthesis. Since nitrogen in natural waters is limited, pollution from nitrogen wastes can promote the growth of algae, causing green-coloured water. Ammonia is also considered a serious water pollutant because of its toxic effect on fishes.

#### 15.2 Analytical Method

Ammonia-N is determined by distillation and titration method. A known volume of sample is distilled to separate the  $\text{NH}_3$  from the interfering substances. At pH level above 7, the equilibrium  $\text{NH}_4^+ \rightleftharpoons \text{H}^+ + \text{NH}_3$  is displaced far enough to the right with the liberation of  $\text{NH}_3$  as gas along with steam produced when sample is boiled. Apparently, the removal of  $\text{NH}_3$  results in the drop in pH. However, the excess  $\text{H}^+$  is then neutralized by phosphate buffer solution to maintain a solution of pH range 7.2 to 7.4.



The  $\text{NH}_3$  gas is then collected in the presence of boric acid which combines with  $\text{NH}_3$  to form ammonium and borate ions.



This causes the increase in pH, however the pH is held in a favourable range for excess boric acid is used for the absorption of  $\text{NH}_3$  gas.

The ammonia is then measured by titration with a strong sulphuric acid to determine the amount of borate ion formed.

$$\text{Amm-N(mg/l)} = \frac{(\text{Vol of } \text{H}_2\text{SO}_4 \text{ used for sample} - \text{Vol } \text{H}_2\text{SO}_4 \text{ used for blank}) \times 280}{\text{ml of sample}}$$

$$\text{Where } N_{\text{H}_2\text{SO}_4} = 0.02 \text{ N}$$

The determination of ammonia-N can be interfered by the presence of magnesium and calcium bicarbonate, but these interferences can be removed by distilling free ammonia into boric acid in the presence of mixed indicators. Samples that contain more than 250 mg/l Ca will cause low  $\text{NH}_3$  recovery from distillation unless pH is properly adjusted before distillation. Furthermore, volatile alkaline compounds such as hydrazine and the amines will influence titrimetric results, whilst residual chlorine which can react with ammonia will cause negative interference. Samples for ammonia-N test can be preserved by storing at  $4^\circ\text{C}$  or adding 0.8 ml conc.  $\text{H}_2\text{SO}_4$  per litre of sample. If acid preservation is used, sample must be neutralized with NaOH or KOH immediately before analysis.

## 16 Total Kjeldahl Nitrogen

16.1 This test measures the ammonia and organic nitrogen but not nitrite and nitrate-N. In the presence of acid and catalysts, organic-nitrogen is converted to ammonia-nitrogen which then can be determined by titration method.

## 16.2 Analytical Method

TKN is determined by Kjeldahl method. The sample is digested with acid (sulphuric acid) in the presence of potassium sulphate and mercuric sulphate as Catalysts, the amino nitrogen of many organic materials is then converted to ammonium sulphate. Sodium thio-sulphate decomposes the mercury ammonium complex in the digestate to liberate ammonia, which then is distilled from the alkaline medium and adsorbed in boric acid. The ammonia-nitrogen is determined by titration method as discussed previously.

Samples for TKN test can be preserved by storing at 4°C or addition of 0.8 ml conc.  $H_2SO_4$  per litre of sample.

$$TKN \text{ (mg/l)} = \frac{(\text{Vol of } H_2SO_4 \text{ used for sample} - \text{Vol of } H_2SO_4 \text{ for blank}) \times N}{\text{Vol of sample used}}$$

$$\text{Where } N \text{ of } H_2SO_4 = 0.02N$$

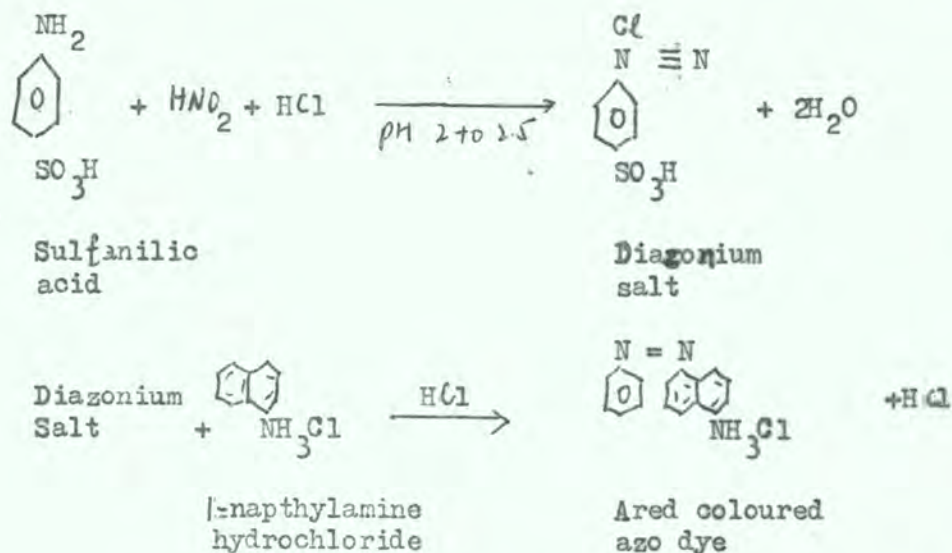
## 17 Nitrite-Nitrogen

17.1 Nitrite is an intermediate oxidation state of nitrogen between  $NH_3-N$  and  $NO_3^- - N$ . It is transitory and readily amendable to both bacterial oxidation to  $NO_3^-$  and reduction to  $N_2$  depending upon environmental factors eg DO and microbial condition.

### 17.2 Analytical Method

It is determined by diazotization method by using colorimetric measurement. Under acid condition at pH 2.0 to 2.5, nitrite ion as nitrous acid reacts with amino group of sulphanilic acid to form a diazonium salt which then combines with 1-naphthylamine hydrochloride to form a bright-coloured pinkish-red azo dye. The colour produced is directly proportional to the amount of nitrite-N present in the sample





As 1-naphthylamine hydrochloride reagent is unstable, it deteriorates rather rapidly, it is therefore necessary to use freshly prepared reagent each time.

Interferences caused by turbidity can be removed by using aluminium hydroxide or zinc sulphate and caustic soda. Antimonous, arsenic, bismuth, ferric, lead, mercurous, silver chloroplatinate and metavanadate that cause precipitation of complex under the condition of the test should be absent. Apparently coloured ions should also be absent. Furthermore, the presence of  $\text{Cu}^{2+}$  that causes low results by catalyzing the decomposition of diazonium salt, should be removed. Free Chlorine and  $\text{NCl}_3$  residual should be absent as  $\text{NCl}_3$  impairs false red colour. It is also advisable that sample for such test be filtered before analysis as small amount of SS seriously affects  $\text{NO}_2^-$  results.

Samples for  $\text{NO}_2^-$  test can be preserved by storing at  $4^\circ\text{C}$  or by adding 40 mg of mercuric ion as  $\text{HgCl}_2$  per litre of sample. No acid should be added as preservative.

## 18 Nitrate-Nitrogen

18.1 Nitrate concentration is negligible in raw sewage since digestion is at an early stage. It increases rapidly in the effluents of the oxidizing type of treatment. Nitrate determination is important in determining whether ground-water supplies meet Public Health Service recommendation for the control of methemoglobinemia in infants.

### 18.2 Analytical Method

It is determined by Brucine Method - Brucine, a complex naturally occurring organic compound, reacts with nitrates under acid conditions and at elevated temperature to produce a yellow colour that can be measured by the spectrophotometer at 410nm.

This method has an advantage is that normal chloride concentration do not produce an interference. However, its limitation is that colour development does not obey Beer's law ie a curved rather than a straight calibration curve is obtained.

The determination of  $\text{NO}_3^-$  by this method can be interfered by the presence of strong oxidizing or reducing agents as well as high concentration of organic matters. Ferrous and ferric ions and quadrivalent manganese give positive interference. However, interferences caused by residual chlorine and chloride can be eliminated or masked by the addition of sodium arsenite and excess sodium chloride respectively. Whilst that caused by nitrite of concentration up to  $0.5 \text{ mg NO}_2^-/1$  can be eliminated by the use of sulfanilic acid :



The sample for  $\text{NO}_3^-$  test can be preserved by freezing at  $4^\circ\text{C}$  or by adding 0.8 ml of conc.  $\text{H}_2\text{SO}_4$  or 40 mg mercuric ions (as  $\text{HgCl}_2$ ) to each litre of sample. If acid preservation is employed, sample has to be neutralized to pH 7 immediately before analysis.

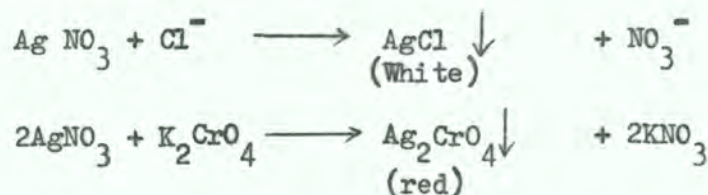
$$\text{NO}_3^- \text{-N(mg/l)} = \frac{\mu\text{g NO}_3^- \text{-N}}{\text{ml sample}} = \frac{\text{Absorbance} \times \tan \frac{\mu\text{g standard}}{\text{corresponding absorbance}}}{\text{ml sample}}$$

## 19 Chloride

### 19.1 Analytical Method

Chloride is determined by Argentometric method or Mohr method.

In a neutral or slightly alkaline solution potassium chromate can indicate the end point of the silver nitrate titration of chloride. Silver chloride is precipitated quantitatively before red silver chromate is formed.



$$\text{Cl}^-(\text{mg/l}) = \frac{(\text{ml titiant for sample} - \text{ml of titiant for blank})}{\text{ml of sample}} \times 35,450\text{N}$$

Where N = normality of  $\text{AgNO}_3$ .

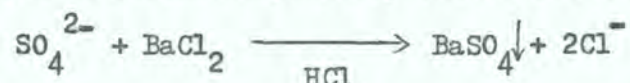
Positive interferences are generally caused by the presence of bromide, iodide and cyanide which register as equivalent chloride concentrations. Likewise orthophosphate in excess of 25 mg/l interfere by precipitation as silver phosphate and iron in excess eg 10 mg/l interferes by masking the end point. Sulphide, thiosulphate and sulphite ions also interfere, however such interferences can be removed by treatment of hydrogen peroxide.

20 Sulphate

20.1 Sulphates, under septic conditions, are reduced to sulphides which creates smell problems as well as toxic conditions.

20.2 Analytical Method

It is determined by gravimetric method with ignition of residue. In this method, sulphate is precipitated in a hydrochloric acid medium as barium sulphate by the addition of barium chloride.



Barium sulphate is precipitated at the temperature near the boiling point of the reacting mixture (ie the treated sample). The reacting mixture is then digested for more than 2 hours at 80° to 90° C. The precipitate is then filtered, wash until free of chlorides. It is then ignited and weighed as BaSO<sub>4</sub>.

$$\text{SO}_4^{2-} \text{ (mg/l)} = \frac{\text{mg BaSO}_4 \times 411.5}{\text{ml of sample}}$$

The sample can be treated with formaldehyde to prevent reduction of sulphate to sulphide. Oxidation of sulphite to sulphate can also be prevented by adjusting the pH of solution to below 8.

Apparently, the presence of suspended matter, silica, barium chloride precipitant, nitrate and sulphite in the sample will give higher result than the actual value. On the other hand, the precipitation of alkali sulphate and sulphate of some heavy metals, such as chromium and iron, will cause low results because such precipitation interferes with the complete precipitation of sulphate.



## 21 Sulphide

21.1 Sulphide is often present in ground water, it is commonly present in wastewater due to the decomposition of organic matters and bacterial reduction of sulphate.

### 21.2 Analytical Method

It is determined by Methylene Blue Method. The sulphide in the sample reacts with a strong acid solution of N,N-dimethyl-p-phenylene-diamine  $\left( \text{Me}_2\text{N} \begin{array}{c} \diagup \quad \diagdown \\ \text{O} \\ \diagdown \quad \diagup \end{array} \text{NMe}_2 \right)$  and ferric chloride to produce methylene blue which is then measured by spectrophotometer at 670 nm. Ammonium hydrogen phosphate is added after blue colour has developed to remove colour caused by ferric chloride.

$$\text{S}^{2-}(\text{mg/l}) = \frac{\text{Absorbance} \times \tan \left( \frac{\mu\text{g of standard S}^{2-}}{\text{corresponding Absorbance}} \right)}{\text{Vol of sample}}$$

Strong reducing agents and thiosulphate above 10 mg/l retard colour formation. Iodide diminishes colour formation when its concentration exceeds 2 mg/l. Whilst ferro-cyanide produces a blue colour which leads to high result. At high sulphide concentration eg. a few hundred mg/l, the reaction cannot take place.

However, interferences caused by sulphite, thiosulphite, iodide and many other soluble substances except ferrocyanide can be eliminated by precipitating the sulphide as zinc sulphide followed by replacing all the solution with distilled water.

## 22 Cyanide

22.1 Cyanide refers to all of the CN groups in cyanide compounds that can be determined as the cyanide ion,  $\text{CN}^-$ .

22.2 Analytical Method

Cyanide can be determined by the Titrametric method whereby the sample is just distilled in an alkaline medium as most interfering substances can be removed by distillation. The CN in the alkaline distillate is then titrated with a standard  $\text{AgNO}_3$  titrant to form the soluble cyanide complex,  $\text{Ag}(\text{CN}^-)_2$ . As soon as all the CN has been complexed and a small excess of  $\text{Ag}^+$  has been added, the excess  $\text{Ag}^+$  is detected by the silver sensitive indicator, paradimethylaminobenzalrhodarine, which immediately turns from a yellow colour to a salmon colour.

The samples must be analysed as soon as possible because most cyanides are very reactive and unstable. If the sample cannot be analyzed immediately, then it has to be preserved by adding NaOH pellets or strong sodium hydroxide solution to raise the pH to 12 or above, and store in a closed, dark bottle in a cool place. If oxidizing agents are present in the sample, then reducing procedure must be carried out before the sample is preserved. If the sample contains sulphide, it is removed by adding powdered cadmium nitrate to the sample.

Oxidising agents may interfere with the determination of cyanide by destroying most of the cyanide during storage and manipulation. They are eliminated by adding ascorbic acid to destroy them. Fatty acids also interfere by forming soaps under alkaline titration conditions, thus making the end-point almost impossible to detect.



Aldehydes convert cyanide to nitrite under the distillation conditions. Therefore, if they are present, only the direct titration without distillation can be used.

$$\text{CN (mg/l)} = \frac{\left( \begin{array}{l} \text{ml standard AgNO}_3 \text{ for sample} \\ - \text{ml standard AgNO}_3 \text{ for blank} \end{array} \right) 1000}{\text{ml of original sample}} \times \frac{250}{\text{ml of sample in distillate}}$$

## 23 Oil and Grease

23.1 The term oil and grease refers to a wide variety of organic substances, including hydrocarbons, fats, oils, waxes, and high molecular weight fatty acids, that can be extracted from aqueous solution or suspension by hexane.

### 23.2 Analytical Method

Oil and grease is determined by Soxhlet Extraction Method. A sample of wastewater is acidified with 50% of hydrochloric acid or sulphuric acid to hydrolyze the soluble metallic organic compounds. Solid and viscous grease and any oil present are separated from the liquid sample by filtration. The residue collected on the filter paper is dried in an oven at 103°C and then placed in an extraction thimble. Oil and grease is extracted with freon or n-hexane in a soxhlet apparatus at a rate of 20 cycles per hour for four hours. The residue remains after evaporation of the solvent is weighed to determine the oil and grease content.

$$\text{Oil \& grease (mg/l)} = \frac{\left( \begin{array}{l} \text{Wt of extraction Flask +} \\ \text{residue - Wt of Flask} \end{array} \right) \times 1000}{\text{ml of sample}}$$

Due to the varying solubilities of different greases, the rate and time of extraction in the Soxhlet apparatus must be exactly as directed. In addition the length of time required for drying and cooling the extracted material cannot be varied, otherwise there may be a gradual increase in weight presumably due to the absorption of oxygen or a gradual loss of weight due to volatilization.

The sample must be analysed not longer than 24 hours after collection. If the analysis cannot be done immediately, the sample can be preserved by, cooling to 4°C or acidifying the sample with 80% H<sub>2</sub>SO<sub>4</sub> to pH < 2.

## 24 Phenol

24.1 Phenols are the hydroxy derivatives of benzene and its condensed nuclei.

### 24.2 Analytical method

Phenol is determined by using the Chloroform Extraction Method. In this method, the sample is first acidified with H<sub>3</sub>PO<sub>4</sub> and CuSO<sub>4</sub> solution. This is to ensure the presence of copper ions which will eliminate any chemical changes resulting from the presence of strong alkaline solutions. The solution is then distilled and the distillable phenol collected is reacted with 4 - aminoantipyrine at a pH of 10.0 ± 0.2 in the presence of potassium ferricyanide to form a coloured antipyrine dye. This dye is then extracted with chloroform and dried. The dried extract is then measured for its absorbance at a wavelength of 460 nm.

$$\text{Phenol (}\mu\text{g/l)} = \frac{\mu\text{g Phenol} \times 1000}{\text{ml sample}}$$



It is preferable that samples are analysed within 4 hours after collection. If this is not possible, then the samples have to be preserved by just acidifying the samples with  $H_3PO_4$ , followed by the addition of 1.0 gm  $CuSO_4 \cdot 5H_2O$  per litre of sample to inhibit biodegradation of phenols. If  $H_2S$  or  $SO_2$  is present, then the samples have to be briefly aerated first. The samples are then kept at a temperature of  $5^{\circ}C$  to  $10^{\circ}C$  and analysed within 24 hours after collection.

Domestic and industrial wastewaters may contain such interferences as phenol - decomposing bacteria, oxidising and reducing substances, and alkaline pH values. Biological de-gradation, alkaline conditions and the presence of sulphur compounds interferences can be eliminated as described above. If oxidising substances are present, then they are eliminated by the addition of an excess of  $FeSO_4$  or  $NaAsO_2$  to remove them. Oils and tars contain phenols. These phenols are determined by performing an alkaline extraction before the addition of  $CuSO_4$ . This is done by adjusting the pH to 12.0 to 12.5 using NaOH pellets. The oils and tars are then extracted with chloroform and discarded. Any excess of chloroform in the aqueous solution is removed by warming on a water bath before the distillation step is proceeded.

## 25 Aluminium

25.1 Aluminium is the most abundant metal in the earth's crust (7.8%). It is exceeded in abundance only by 2 non-metals, oxygen and silicon. Aluminium does not occur free in nature. It forms oxide, hydrated oxides, fluoride and silicates.

25.2 Analytical Method

Aluminium is determined using the Eriochrome cyanine R method. Dilute aluminium solutions buffered to a pH of 6.0 produce with Eriochrome cyanine R dye a red to pink complex that exhibits maximum absorption at 535 nm. The intensity of the developed colour is influenced by the aluminium concentration, reaction time, temperature, pH, alkalinity, and the concentrations of the other ions in the sample. To compensate for colour and turbidity. The aluminium in one portion of sample is complexed with EDTA to provide a blank. The inference of iron and manganese, two elements often found in water, is eliminated by adding ascorbic acid.

Besides, iron and manganese, fluoride and polyphosphates may cause negative errors. When the fluoride concentration is constant, the percentage of error decreases with increasing amounts of aluminium. Orthophosphate in concentrations under 10 mg/l does not interfere. Sulphate does not interfere up to a concentration of 2,000 mg/l.

For accurate results, samples should be collected in clean acid rinsed bottles, preferably plastic, and they should be examined as soon as possible after collection. If only soluble aluminium is to be determined, then a portion of the sample should be filtered through a 0.45  $\mu$ m membrane filter. Filter paper, absorbent cotton or glass wool should not be used as filtering medium because they will remove most of the soluble aluminium.

$$\text{Al (mg/l)} = \frac{\text{Absorbance} \times \tan \frac{\mu\text{g Al standard}}{\text{corresponding Absorbance}}}{\text{ml of sample used.}}$$



26 Arsenic

26.1 Arsenic occurs free to small extent, but the important sources of it are sulphides, and oxides. It also occurs in most samples of iron pyrites and in ores of zinc and lead.

26.2 Analytical Method

Arsenic is determined by the Silver Diethyldithiocarbamate Method. In this method, inorganic arsenic is reduced to arsine  $AsH_3$ , by means of nascent hydrogen which is produced by zinc in acid solution in a Gutzert generator. The arsine so produced is then passed through a scrubber containing glass wool impregnated with lead acetate solution and then into an absorber tube containing silver diethyldithiocarbamate dissolved in pyridine. In the absorber, arsenic reacts with the silver salt to form a soluble red complex. This complex is then measured for its absorbance at a wavelength of 535 nm.

$$AS \text{ (mg/l)} = \frac{\text{Absorbance} \times \tan \frac{\mu\text{g As standard}}{\text{corresponding Absorbance}}}{\text{ml of sample}}$$

Antimony salts in the sample form stibine which may interfere with colour development by yielding a red colour with maximum absorbance at 510 nm.

27 Atomic Absorption Spectroscopy

27.1 Analyses of metals, which had proved difficult or extremely time consuming by other methods became routine, and today atomic absorption is often the method of first choice in elemental analysis, especially at low concentration.

27.2 Theory

Atomic absorption methods rely on the absorption of light by atoms. All atoms can absorb light but only at certain wavelength corresponding to the energy requirement of the particular atom. An atom after absorbing light at a specific wavelength, at which the right energy is given to transform such atom to another excited state which contains more energy than before. Generally, there are several possible excited states for each particular atom and each excited state has a particular energy. As such, each transition between difference electronic energy states is characterised by a different energy, and hence by a different wavelength of light. These wavelengths are sharply defined, and each defined wavelength shows a sharp intensity maximum (a spectroscopic line). Atomic spectra are distinguished by these characteristic lines. Apparently, the atomic spectrum characteristic of each element comprises a number of discrete lines, some arise from excited states and some from the ground states only those from the ground state are useful for the atomic absorption analysis, as most atoms in a practical atomiser are found in the ground state.

Furthermore, the absorption of light energy (ie absorbance) is proportional to the concentration of the atomic species at a given wavelength and for a given absorption path length.

The atomic absorption instrument is a system to allow measurement of this absorbance and to relate the measured absorbance to the required analytical concentration. The simplest way to use atomic absorption method is to measure the absorbance for standard solutions where the concentrations are known and then to compare the absorbance of the unknown solution.

With the atomic absorption, by employing the specific exciting sources, all the metals can be analysed.



### 27.3 Analytical Technique

Atomic absorption analysis may be performed by aspiration into a flame, or in the carbon rod atomiser or by cold vapour method. For a particular analysis, each method may be applicable each has its particular virtues and requirements and no single atomization technique is inherently better than other.

#### 27.3.1 Flame analysis

Most atomic absorption determinations are made using a flame atomiser system. In flame method, the sample in liquid form is aspirated continuously through a pneumatic nebulizer into the flame gas mixture. The light from the flame enters a monochromator to isolate the desired region of the spectrum. A photocell and some type of meter or electric amplifier measures the intensity of the isolate radiation when the atom population in the flame reaches a dynamic equilibrium. After carefully calibrating the photometer with solution of known composition and concentration, it is possible to correlate the intensity of a given spectral line of the unknown with the amount of an element present which emits the particular radiation.

For the analysis in the flame, the sample must be :

- 1) liquid or dissolved;
- 2) less than 5% total dissolved solids;
- 3) Chemically suitable for easy thermal decomposition;
- 4) in the appropriate concentration range;
- 5) available in at least 1 ml quantity;
- 6) adequately chemically matched with standards.

If the sample is uncomplicated, eg tap water or clear effluent samples, analyses can be carried out directly in such samples.

For a complex samples like sewage samples and particulated effluents, pretreatment of samples is required. Samples are to be digested with concentrated nitric acid on a water bath for 2 hours and filtered.

Phosphoric acid should not be used for digestions if calcium is to be determined in the air acetylene flame, because phosphates depress the absorption signal for calcium in this flame.

There are several types of interferences that might occur in the analysis, the most troublesome type is called chemical interference, which results from the lack of absorption of atoms bound in molecular combination in the flame. This can occur when the flame is not hot enough to dissociate the molecules or when the dissociated atom is oxidized immediately to a compound that will not dissociate further at the temperature of the flame. Interferences of this kind are extremely severe for magnesium, calcium, strontium and barium because in the presence of aluminium, silicon and phosphorus, the formation of refractory aluminates, silicates and phosphates will severely interfere with atom production. However such compound formation interferences can be overcome by (a) using high temperature flame such as nitrous oxide-acetylene, to decompose the compound concerned (b) adding a buffer element to compete with the analyte element for attachment to the interfering group.

Samples are generally acidified with Conc  $\text{HNO}_3$  to pH2 at the time of collection to minimize the adsorption of metals to the container wall.



### 27.3.2 Non Flame Analysis

To overcome low sensitivity and other limitations, non-flame method is used for generating the required population of free atoms. This method is generally used for determination at low concentration.

There are two types of non-flame analytical methods that are commonly used. (a) Carbon Rod Atomizer (b) Cold Vapour Method.

#### A Carbon Rod Atomizer

In this method, a high temperature programmed furnace is used for generating a population of free atoms so that atomic absorption can be measured.

A small sample is placed in the atomizer and a three-stage temperature program is used to separate the sample into fractions according to the boiling point and thermal stability of the chemical compounds involved. The dry stage involves gentle heating to remove solvent at a low temperature (usually below 100°C). In the ash stage, molecular organic and inorganic compounds are pyrolyzed and evaporated off the atomizer at a higher temperature (up to 1500°C), leaving a residue of stable inorganic compounds and free metal atoms. Finally, in the atomizer stage, the atomizer is heated more strongly (up to 3000°C) to decompose the remaining compounds

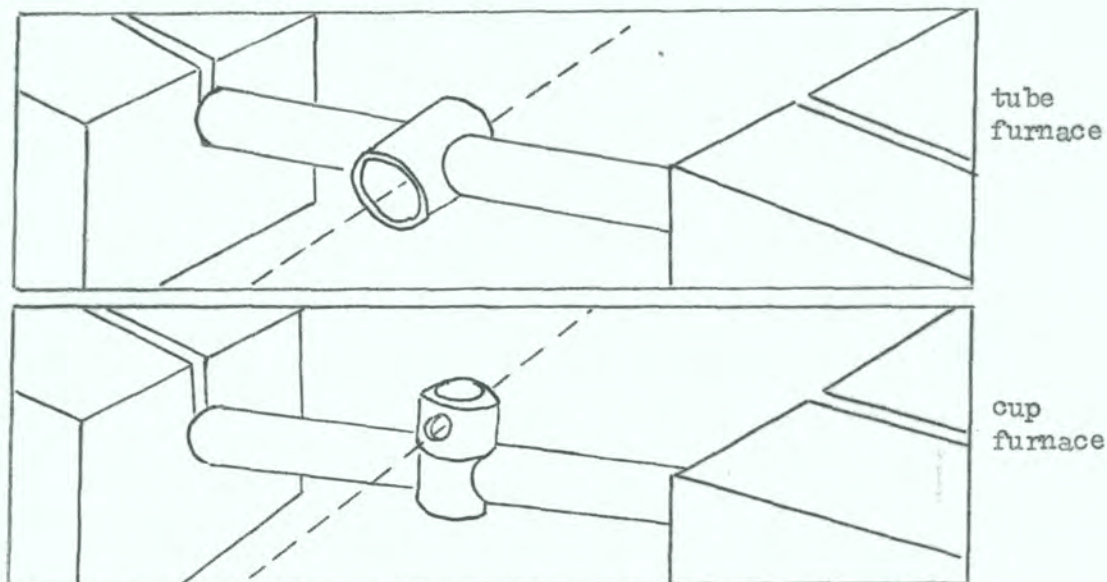
and **drive** free atoms into the light path for measurement of the atomic absorption signal. The absorption signal produced in the atomization stage is a sharp peak, and the height of the peak can be related to the amount of analyte element present in the sample. The height of the absorption peak can be found by means of a chart recorder. In each stage of the thermal program the temperature and time may be selected according to the nature of sample and analyte element.

In this process, the carbon rod atomizer is held between two electrodes. When a voltage is applied to the electrodes the temperature of the atomizer is raised because of the heating effect of the contact resistance between the atomizer and electrodes. By simply varying the voltage across the electrodes the temperature of the atomizer can be varied as required. While the atomizer is being heated it is 'sheathed' in a stream of inert gas (usually nitrogen) which prevents oxidation of the atomizer and also removes the vapour as it diffuses from the furnace.

For analysis in the carbon rod atomizer, the sample must be (a) solid, liquid or dissolved, but preferably homogeneous (b) chemically suitable for complete thermal separation of matrix and analyte. (c) in the appropriate concentration range (d) chemically comparable with convenient standards.



## Carbon Rod Atomizer



As the metallic ions to be determined are present at low concentration, metallic ions are therefore to be concentrated by chelation and solvent extraction before analysis. Many elements may be extracted easily from a large volume of solution into a much smaller volume of an organic solvent (preferably methyl isobutylketone MIBK) after reaction with a general chelating organic reagent such as ammonium pyrrolidine dithiocarbamate (APDC) standard solutions are extracted similarly such pre-concentration procedure increase the absorbance signal and improves precision and accuracy of the final method.

For samples that contain high solid, nitric acid is added to digest the sample before concentrating of samples for analysis.

Interferences caused by compound decomposition and formation is also observed. Spectral interference caused by molecular absorption and light scattering are considerably less severe in this method as the ashing of the sample is used to diminish the spectral interference.

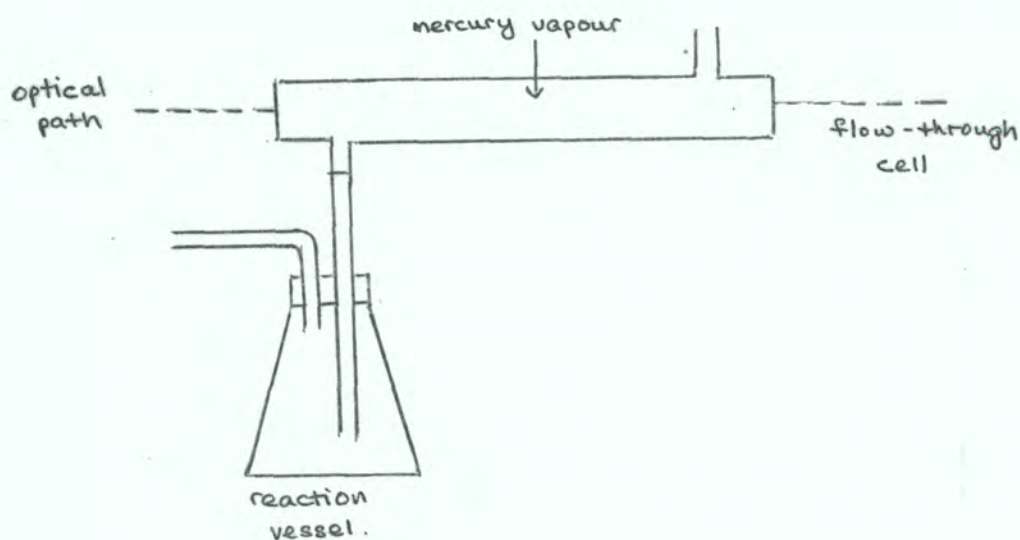
B Cold Vapour Method

Mercury determinations often involve very low concentrations, although the sensitivity in the flame for this element is comparable with others, the significant analytical level is often below the detectable limit, it therefore employs the cold vapour method for determination.

The sample must first be (a) digested with concentrated sulphuric acid, nitric acid and potassium permanganate and potassium persulphate. Excess permanganate is destroyed before analysis. (b) free from chemical interferences (c) in the appropriate concentration range.

Mercury compounds in acid solution are reduced to free element with stannous chloride, the mercury vapour is swept into a flow-through quartz cell placed in the light path of an atomic absorption instrument. The signal is recorded as a peak.





Mercury is much more conveniently analysed by vapour generation because of the volatility of mercury. With the carbon rod, the mercury absorption signal usually cannot be separated from matrix effects, but with cold vapour method, this separation is simple.

## 28 Automatic Analyser Unit

28.1 Besides using the analytical methods as described previously; COD, sulphate, anionic surfactants, ammonia, chloride, phosphorus, nitrite and nitrate are to be determined by use of the automatic analyser unit in the Water Pollution Control Laboratory.

28.2 The basic Auto Analyser consists of six separate units called modules - interconnected by plastic tubing, glass mixing coils, fittings and attendant pieces. The six modules of the system are (1) Sampler, (2) Proportioning Pump and Manifold (3) Dialyser (4) Heating Bath (5) Colorimeter and (6) Recorder.

### 28.3 General Principles

By preselected programming, sample fluids, reagents and standards are introduced into the system by the sampler module. This is done as follows :-

- 1) The sampler probe dips into the sample cups (40 cups can be held on a sample plate and the sample cup can be of various sizes).
- 2) Aspirates sample or standard or reagent into the system.
- 3) Withdraws from the sample cup.
- 4) Dips into wash bath and
- 5) Aspirates wash into the system.

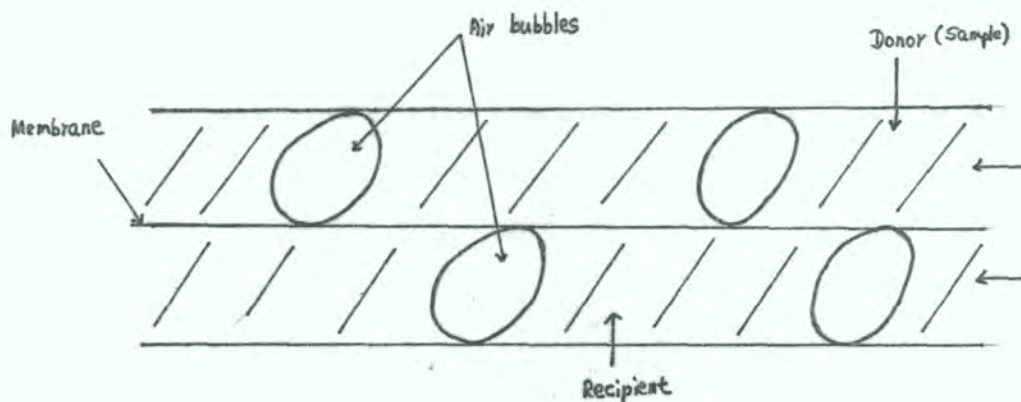
The movement of the probe from cup to cup is controlled by a cam. The cam controls the frequency of sampling and the sample-to-wash ratio.

The proportion of samples and reagents to be introduced into the system is controlled by the proportioning pump and manifold. At this Module, a number of pump tubes are selected : one having a delivery rate to pump the sample and the others having different delivery rates to pump the different reagents.

The sample may contain particulate matter or other interfering substances which would invalidate the colorimetry. The removal of such substances



are handled in the AutoAnalyser by making use of the principle of dialysis. The Dialyser Module consists of a matched pair of plastic plates having semi-circular grooves. A stream carrying the sample (the donor) flows through one of these semi-circular grooves while another stream (the recipient) flows on the other side of the membrane. Dialysable materials contained in the sample will dialyse through the membrane and be picked up by the recipient stream.



Upon leaving the Dialyser, the donor stream usually goes directly to waste, while the recipient stream flows to the colorimeter, after being first subjected to further treatment as may be demanded by the analysis.

Chemical reactions do not always take place instantaneously. Often, an appreciable amount of time is needed for a reaction to reach completion. If this is the case, the recipient stream from the Dialyser is then pumped to the "Time Delay Coil" while the liquid is held for a longer period for the colour to develop.

Often, heat is also required to develop a sufficient reaction. When heat is necessary the time delay coil is placed into a hot oil bath where the oil is held therm-ostatically at a closed controlled temperature and is continuously stirred. (Note : The time the liquid remains in the coil depends on the volume of the coil and the pumping rate).

Once the fluid has passed through the heating bath or time delay coil, the colour which is sufficiently developed is to be measured. Before going to the colorimeter, the stream is passed through the "debubbler" where the air bubbles are removed. The solution, free of air, is then pumped to the colorimeter flow cell. In the colorimeter module, one light beam from the colorimeter lamp is collimated through a lens system, reduced to a single band by an interference filter, and converted to electrical energy by the reference



photocell. Another beam passes through a mirror system, an interference filter, and the flowcell to the sample photocell. The electrical outputs from the photocells are applied to the recorder.

The recorder will then display on a graph the variation of the electrical output ratio between the sample and reference photocells. The peaks drawn by the recorder pen represent the relative optical density values of the sample, wash and standard solutions as they pass through the flowcell. Each peak represents a complete, single aspiration from a sample cup. Peak identification, therefore, is quite easy and foolproof.

#### 28.4 Analytical Method

##### 28.4.1 (I) Semi-automated COD in water and wastewater

(Range : 6-300 mg/l, 20-1000 mg/l)

This semi-automated procedure for the determination of COD combines a modified manual digestion as used in standard methods as described before, with an automated procedure based on the spectro-photometric measurement of  $\text{Cr}^{3+}$ . The sample is combined with an acid potassium dichromate, mercuric sulphate and an acid silver sulphate solution in a specially capped culture tube. It is then digested in a  $150^{\circ}\text{C}$  oven for two hours and the concentration of the  $\text{Cr}^{3+}$  ion is measured at 600nm in a 50mm flowcell.

(II) Total inorganic phosphate in wastewater

(Range : 0-10 mg/l)

Total inorganic phosphates in water are measured in this automated procedure by first converting the condensed phosphates present to ortho-phosphate by means of hydrolysis with sulphuric acid. The phosphates concentration is then determined by the reduction of phosphomolybdic acid with ascorbic acid.

Arsenic, vanadium, titanium, zirconium, germanium, sulphide, tannin, lignin and hexavalent chromium interfere. Soluble silicates do not interfere even at levels as high as 100 mg/l.

(III) Anionic Surfactants in Wastewater

(Range : 0-1.5 ppm, 0-20 ppm)

This method is an automatic version of the methylene blue procedure for alkyl benzenesulphonates, updated from the method of Sodengren. Chloride, sulphide and sulphate show no interference.

Emulsification which causes considerable error in the manual method, is completely avoided using this method. The colour developed is measured at 650nm.

(IV) Sulphate in Wastewater

(Range : 0-300 mg/l)

In this automated procedure for sulphate, the sample is first passed through a cation-exchange column to remove interferences. The sample containing sulphate is then reacted with barium chloride at pH of 2.5 - 3.0 to form barium sulphate. Excess barium



reacts with methylthymol blue to form a blue coloured chelate at a pH of 12.6 to 13.0. The uncomplexed methylthymol blue colour is grey, if it is all chelated with barium, the colour is blue. Initially, the barium chloride and methylthymol blue are equimolar and equivalent to the highest concentration of sulphate ion expected; thus the amount of uncomplexed methylthymol blue, measured at 460 nm is equal to the sulphate present.

(V) Nitrate and nitrite in wastewater

(Range : 0-1 mg N/l)

The automated procedure for the determination of nitrate and nitrite utilises the procedure whereby nitrate is reduced to nitrite by a copper-cadmium reductor column. The nitrite ion then reacts with sulphanilamide under acidic conditions to form a diazo compound. This compound then couples with N-1 naphthyl-ethylene-diamine dihydrochloride to form a reddish purple azo dye which is measured at 520 nm.

In surface waters normally encountered, the concentration of oxidizing or reducing agents and potentially interfering metal ions are well below the limits causing interferences. When present in sufficient concentration metal ions may produce a positive error ie. divalent mercury and divalent

copper may form coloured complex ions having absorption bands in the region of colour measurement.

#### 28.4.2 Multitest Cartridge for water

28.4.2.1	Ammonia	1 - 50 mg/l
	Ammonia	0.2- 10 mg/l
	Ammonia	0.02- 1.0mg/l
	Chloride	1 - 50 mg/l
	Phosphorus	1 - 50 mg/l
	Phosphorus	0.01- 0.5mg/l
	Silica	0.2 - 10 mg/l
	Total Oxidised Nitrogen	1 - 50 mg/l
	Total Oxidised Nitrogen	0.1 - 5 mg/l
	Nitrite	0.1 - 5 mg/l
	Nitrite	0.002 - 0.1mg/l

The abovementioned pollutants at its concentration ranges as indicated are determined by the use of multitest Analytical Cartridge developed by Technician, Basingstoke, U.K. : Modifications and additions were made to the method to suit local conditions and improve some chemistries.

#### 28.4.2.2 Ammonia

The emerald green colour formed by the reaction of ammonia, sodium salicylate, sodium nitroprusside and chlorine in a buffered alkaline medium is measured at 660 nm.



#### 28.4.2.3 Chloride

Chloride is reacted with mercuric thiocyanate releasing a proportional amount of thiocyanate ions. These react with ferric ions forming the red complex ferric thiocyanate, whose absorbance is measured at 480 nm. This reaction is non-linear.

#### 28.4.2.4 Phosphorus

A blue colour is formed by the reaction of orthophosphate, molybdate ion and bismuth ion, followed by reduction with ascorbic acid in acid solution. The absorbance is measured at 660 nm. The high acidity prevents interference from silicates.

#### 28.4.2.5 Silica

A blue colour is formed by the reaction of silicate and molybdate ion, followed by reduction with ascorbic acid in a low acidity solutions, oxalic acid is added to prevent phosphate interference.

#### 28.4.2.6 Nitrite/TON

Nitrite forms a diazo compound with sulph-anilamide, which is then coupled with N-naphthylethylenediamine dihydrochloride to form a purple azo dye measured at 520 nm. Nitrate plus nitrite (Total oxidised Nitrogen) is measured by the prior reduction of the nitrate to nitrite by a hydrazine solution containing copper and zinc ions.

ANNEX 9

ANALYTICAL QUALITY CONTROL AND ASSESSMENT  
OF LIMITS FOR ANALYTICAL DATA



ANALYTICAL QUALITY CONTROL AND  
ASSESSMENT OF LIMITS FOR ANALYTICAL  
DATA

ABSTRACT

Data from the laboratory can be of value only if they accurately describe the characteristics and concentrations of constituents in the water samples.

To achieve reliable and accurate data, the laboratory must be staffed with trained personnel who can perform the required tests. Furthermore, the physical facilities and equipment must be adequate.

The basic elements of quality control relating to laboratory services, instrumentation, glasswares, reagents, solvents and gases have been superficially dealt with as it is expected that trained staff have had these basic variables under control.

Once that approved methods have been used, the next step in quality control is to obtain valid precision and accuracy data initially, for each method and analyst. Once these have been generated and found to be satisfactory indicates that the analyst is capable of analysing the water samples, ie he is capable of generating valid data and has the method under control.

The assessment of limits for analytical data is best determined from the precision and accuracy quality control charts. The development of these charts is indicated in the paper and forms a crucial part of the comprehensive quality control assurance programme.

It must be mentioned that since the quality control of analytical data starts with sample collection a section on this has been included.

Introduction

1.1 The main function of the analytical laboratory is to provide qualitative and quantitative data which will be used for decision making.

1.2 Some examples in the use of such data are :-

- i) Quantitative and qualitative assessment of most organic, inorganic substances and micro-organisms can establish whether the water is suitable for consumption.
- ii) Data on wastewater analysis can monitor the characteristics of treatment plant influent, the final load imposed on water sources and the effectiveness of steps in the treatment processes.
- iii) Data can also be used to determine the extent of compliance of the polluting industry and can be used in computing trade waste tariffs.

1.3 These data can be of value only if they accurately describe the characteristics and concentration of constituents in the samples.

1.4 In order to achieve reliable and accurate data the laboratory must satisfy the following :-

- i) Have laboratory personnel that are adequately qualified and trained to perform the necessary tests.
- ii) Have the necessary physical facilities and adequate equipment.



- iii) Have analytical methods and records that are acceptable.
- iv) Have a measure of success in analysing appropriate evaluation samples and
- v) Have an existing quality assurance programme which will occupy about 10% of staff time.

## 2.0 Laboratory Personnel

2.1 The Laboratory should be headed by an analyst who should be responsible for providing :-

- i) Reliable laboratory description of samples.
- ii) Professional competence.
- iii) Validity of procedures.

2.2 The supporting laboratory personnel should be adequately qualified and trained to perform the tests. These personnel should be aware of the errors that can be associated with the analytical determinations . The following are some examples of likely errors :-

- i) Loss of materials in various steps of analysis i.e. underwashing/overwashing of precipitates.
- ii) Insufficient cooling of crucibles before weighing.
- iii) Allowing the use of reagents containing impurities.

## 3.0 Laboratory equipment and physical facilities

3.1 Laboratory equipment must be adequate for the type of analyses to be carried out. The errors associated with equipment can be reduced by the following operations :-

- i) Calibrate all apparatus and apply corrections e.g. balances should be checked and adjusted periodically with standardised weights.
- ii) Flasks, burettes and pipettes should be calibrated and appropriate corrections applied to original calibrations.
- iii) pH meters should be calibrated with standard buffer solutions periodically.
- iv) Spectrometers must be checked for wave length alignment as considerable loss of sensitivity will occur if the wave length is misaligned.

### 3.2 Atomic Absorption Spectrometer

The wave length must be periodically aligned and the standard solutions used must be from a reputable chemical firm. Quality deionised water must be used for diluting solutions.

## 4 Methodology

4.1 For a group of laboratories using a common data bank, a uniform methodology must be adopted in order to do away with this variable. The lack of uniformity will raise doubts on the validity of reported results. While acceptable methods are available in such publications as "Standard Methods for the Examination of Water and Wastewater", there is no assurance that laboratories using these methods are using them accurately.



5 Quality Assurance Programme

5.1 In California, some 600 water laboratories are approved by the Department of Health to analyse the inorganic, organic and microbiological parameters for drinking water.

5.2 One of the criteria for approval is that the laboratory successfully analyses appropriate performance evaluation samples and have a formalised quality assurance programme which will occupy no less than 10% of staff time.

5.3 This is necessary as it will assure that all laboratories in water analysis are producing meaningful assessments of water quality.

5.4 Most laboratories practise some form of quality control on analytical data e.g. standardization of titrant, calibration of instrument, the use of analytical grade chemicals and performance of duplicates but, however, very few laboratories have a comprehensive qualitative assurance programme.

5.5 Laboratories are urged to develop a comprehensive quality assurance programme to ensure reliability of water and wastewater data.

6 Quality Control for analytical performance

6.1 The basic elements of quality control (Qc) relating to laboratory services, instrumentation, glasswares, reagents, solvents and gases have been mentioned earlier. Assuming that these basic variables are under Qc, that approved methods are being used, the next step would be to obtain valid precision and accuracy data for each method and analyst.

6.2 In order that valid data continue to be produced, systematic daily checks must show that the test results remain reproducible.

6.3 Precision may be defined as the reproducibility of a series of measurements of the same quantity. Precision should be determined not on reference standards but on actual water samples. The samples chosen should cover a range of concentrations and interfering substances normally present in substances. Data for precision studies should not be collected until the analyst is thoroughly familiar with the method.

6.4 The spread of values during precision determination can be defined by the standard deviation S.

$$S = \sqrt{\frac{\sum_{i=1}^n X_i^2 - \frac{\left(\sum_{i=1}^n X_i\right)^2}{n}}{n-1}}$$

Where n = number of replicates

$X_i$  = concentration determined

The example for determining the precision data for detergent is in ANNEX 1.

6.5 In the determination of precision;

- i) at least four concentration ranges covering the normal range routinely encountered should be carried out.
- ii) At least seven replicate determinations should be made at each of the concentrations tested.



6.6 Accuracy. Accuracy expresses the correctness of a measurement. Precision accompanies accuracy, but a high degree of precision does not imply accuracy.

6.7 Accuracy data should be obtained from actual water samples routinely analysed and should be the same as that used for precision measurements.

6.8 In the determination, known amounts of the particular constituents should be added to the samples at concentrations where the precision of the method is satisfactory. Sufficient amounts must be added to double the concentrations.

6.9 For Accuracy determinations, at least seven replicates at each concentration should be carried out. The accuracy data should then be reported as percent recovery at the final concentration of the spiked sample. Percent recovery at each concentration should be the mean of the seven replicates.

6.10 An example for obtaining accuracy data for the detergent determination is given in ANNEX 2.

6.11 Once collected and documented, the precision and accuracy data will clearly show that the analyst is capable of analysing the water samples for that particular sample and is capable of generating valid data.

6.12 The data generated can be used in the preparation of quality control charts.

7 Applying Quality Control Charts in Environmental Laboratories

7.1 The variables in the laboratory ie. parameter, instrument and the analyst can be compared to the product, machine and the operator in the industrial applications. However, the variable, true concentration of the parameter under investigation, varies among samples.

7.2 Statistics that work well for industrial applications are sensitive to the variability in true concentrations e.g. the classic  $\bar{X}$  and R statistical values increase substantially as the concentration increases. The solution is to apply statistics that is not sensitive to this variation.

8 Quality Control Charts for Accuracy

8.1 The Classic Shewhart technique to evaluate the percent recovery instead of  $\bar{X}$  should be used. For standards, the % recovery is calculated

$$\text{as } P = 100 \frac{\text{observed}}{\text{unknown}}$$

or from the recovery of spikes in routine sample.

$$P = 100 \frac{\text{observed} - \text{background}}{\text{spike}}$$

$$\text{Average \% recovery } \bar{P} = \frac{\sum_{i=1}^n P_i}{n} \quad n = \text{No of samples.}$$

The Standard Deviation for % recovery

$$Sp = \sqrt{\frac{\sum_{i=1}^n P_i^2 - \left[ \frac{\sum_{i=1}^n P_i}{n} \right]^2}{n-1}}$$



8.2 The example for obtaining the control chart for percent recovery is given in ANNEX 3.

8.3 When applying the control chart, either of the following conditions would indicate an out-of-control situation :-

- i) Any point beyond control limits.
- ii) Seven successive points on the same side of the value  $\bar{P}$  of the central line.

8.4 When this happens, stop the analysis until the problem has been identified and resolved. The problem and its solution must be documented and all analyses since the last in-control-point must be discarded.

8.5 It may be necessary to develop separate percent recovery or Shewhart  $\bar{X}$  chart for low concentration level sample.

## 9 Precision Control Charts

9.1 These charts are developed by collecting data from many samples, a minimum of 15 to 20 in duplicate under assumed controlled conditions. Once these data have been generated over an extended period of time, the control charts are derived from the following steps :-

- (a) List the range (R) for each set of sample. This is the difference between each set of duplicate.
- (b) Calculate the range ( $\bar{R}$ ) by summing the list of R values and dividing by the number of sets of duplicates.

$$\bar{R} = \frac{\sum R}{n} \quad n = \text{No. of duplicates.}$$

- (c) Calculate the Upper Control Limit (UCL) or range according to

$$UCL_R = D_4 \bar{R} \quad D_4 = \text{Constant}$$

- (d) Calculate the Upper Warning Limit (L) or the range according to

$$UWL_R = 2/3 (D_4 \bar{R} - \bar{R}) + \bar{R}$$

Which for duplicates, becomes

$$UWL_R = 2.51 \bar{R}$$

An example for deriving the control chart is shown in ANNEX 4.

- (e) After obtaining the UCL value, the  $R_c$  value is established by rounding to the nearest whole number at higher concentration levels and to the nearest half unit for the lowest concentration.

9.2 The establishment of  $R_c$  (critical range) values at different concentrations levels is recommended to control precision. If any difference between duplicate analyses exceeds the critical range value for the appropriate concentration level, then analyses must be stopped until the problem is identified and resolved. The frequency should be increased for the next few precision checks. After resolving the problem, the solution should be documented and all analyses since the last in-control check must be repeated or discarded.



9.3 An example for the use of critical range  $R_c$  is given in ANNEX 5.

## 10 Field Personnel

10.1 As already mentioned earlier, quality control begins with sample collection. A comprehensive quality assurance programme should include the following steps for each parameter in the monitoring study :

- (a) Take independent samples A and B at the same sampling point. Depending on the parameter, side-by-side grab or for composite samplers, these be mounted in parallel.
- (b) Split sample A into  $A_1$  and  $A_2$ .
- (c) Split sample B into equal volume and add a spike T to one of them, this then becomes  $B_{SF}$ . The Spike T added should approximately double the actual concentration level.
- (d) Add the same spike T to a distilled water sample. This becomes  $D_F$ .

10.2 These Q.C. samples must be treated in the same way as the routine samples.

10.3 Samples  $A_1$  and  $A_2$  should be analysed and the absolute difference between the results should not exceed the critical value for precision to be in control.

10.4 Samples  $B_1$ ,  $D_F$  and  $B_{SF}$  should be analysed and the percent recovery of the spike determined for  $D_F$  and  $B_{SF}$ .

10.5 If the absolute difference between  $A_1$  and B are unsatisfactory, then the field sampling procedure did not provide representative sample.

11 Conclusion :

11.1 The adoption of a quality control programme as outlined in the paper would ensure valid and reliable analytical data.



ANNEX 1

Precision Data on water Samples  
for detergent (MBAS as LAS)

<u>Sample</u>	<u>Concentration</u> <u>mg/l Detergent</u>	<u>X<sub>1</sub><sup>2</sup></u>
1	3.2	10.24
2	3.1	9.61
3	3.2	10.24
4	3.1	9.61
5	2.9	8.41
6	2.9	8.41
7	2.9	8.41
<u>Average</u>	<u>3.0</u>	<u>Σ64.93</u>

$$(\sum X_1)^2 = (21.3)^2 = 453.7$$

$$\frac{(\sum X_1)^2}{n} = \frac{453.7}{7} = 64.81$$

$$s = \sqrt{\frac{64.93 - 64.81}{7-1}} = \sqrt{\frac{0.12}{6}} = 0.14$$

The standard deviation for a concentration of 3.0 mg/l  
detergent (MBAS as LAS) is ± 0.14.

EXAMPLE 2

ANNEX 2

Accuracy Data on water samples  
for detergent (MBAS as LAS)

<u>Sample</u>	<u>Conc. mg/l</u> (Sample spiked with 3.0 mg/l LAS)
1	5.9
2	5.8
3	5.9
4	5.9
5	5.7
6	5.8
7	5.8
Average	<u>5.83</u>

$$\text{Therefore \% Recovery} = \left[ \frac{5.83}{3.0+3.0} \right] \times 100 = 97$$



ANNEX 3

EXAMPLE 3

TABLE 1

Analysis of Total Phosphate-phosphorous Standards  
in mg/l Total PO<sub>4</sub> -P

1 Data from EPA Handbook for Analytical Quality Control

Sample No	Known	Found	Difference di	di <sup>2</sup>	Percent Recovery Pi	Pi <sup>2</sup>
1	0.34	0.33	0.01	0.0001	97	9,409
2	0.34	0.34	0.00	0.0000	100	10,000
3	0.40	0.40	0.00	0.0000	100	10,000
4	0.49	0.49	0.00	0.0000	100	10,000
5	0.49	0.49	0.00	0.0000	100	10,000
6	0.49	0.63	-0.14	0.0196	129	16,641
7	0.50	0.47	0.03	0.0009	94	8,836
8	0.50	0.53	-0.03	0.0009	106	11,236
9	0.50	0.56	-0.06	0.0036	112	12,544
10	0.52	0.59	-0.07	0.0049	113	12,769
11	0.66	0.70	-0.04	0.0016	106	11,236
12	0.66	0.60	0.06	0.0036	91	8,281
13	0.67	0.65	0.02	0.0004	97	9,409
14	0.68	0.65	0.03	0.0009	96	9,216
15	0.83	0.80	0.03	0.0009	96	9,216
16	0.98	0.75	0.23	0.0529	77	5,929
17	1.3	1.2	0.10	0.0100	92	8,464
18	1.3	1.3	0.00	0.0000	100	10,000
19	1.6	1.7	-0.10	0.0100	106	11,236
20	2.3	2.3	0.00	0.0000	100	10,000
21	2.3	2.4	-0.10	0.0100	104	10,816
22	3.3	3.3	0.00	0.0000	100	10,000
23	4.9	4.6	0.30	0.0900	94	8,836
	Total				<u>2,310</u>	<u>234,074</u>

ANNEX 3

EXAMPLE 3

$$\text{Average percent recovery } \bar{P} = \sum_{i=1}^{23} P_i = \frac{2310}{23} = 100.4$$

$$\text{S.D. for \% recovery } S_p = \sqrt{\frac{\sum_{i=1}^{23} P_i^2 - \left(\frac{\sum_{i=1}^{23} P_i}{23}\right)^2}{23 - 1}}$$

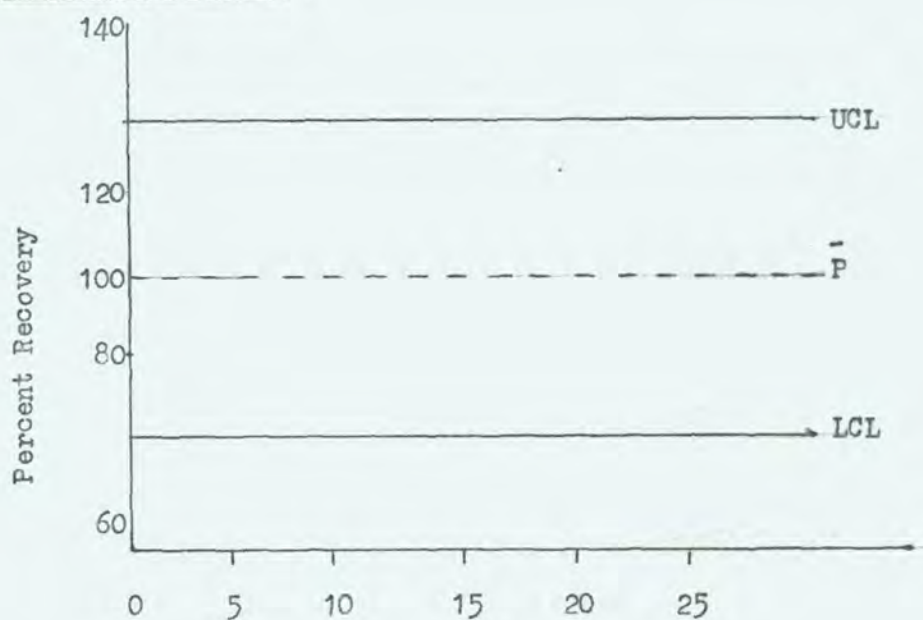
$$S_p = \sqrt{\frac{234,074 - \frac{(2,310)^2}{23}}{22}}$$

$$= \sqrt{94.075} = 9.7$$

$$\begin{aligned} \text{Upper Control Limit, } UCL &= \bar{P} + 3S_p \\ &= 100.4 + 3(9.7) = 129.5 \end{aligned}$$

$$\text{Lower Control Limit } LCL = 100.4 - 29.1 = 71.3$$

The completed chart :





ANNEX 4

Factors For Computing Control

Chart Lines

<u>Observations in Subgroup (<math>\eta</math>)</u>	<u>Factor A<sub>2</sub></u>	<u>Factor D<sub>4</sub></u>
2	1.88	3.27
3	1.02	2.58
4	0.73	2.28
5	0.58	2.12
6	0.48	2.00
7	0.42	1.92
8	0.37	1.86

Example Determination of  $UCL_R$  for COD determination for range 50 to 500 (mg/l).

(i) No of sets of duplicates  $\eta = 63$

(ii) Average range =  $\bar{R} = \frac{\sum R}{n} = \frac{393}{63} = 6.22$

(iii)  $UCL_R = D_4 \bar{R}$   $D_4 = 3.27$  for duplicates

$$UCL_R = 3.27 \times 6.22 = 20.3$$

(iv)  $UWL_R = 2/3 (D_4 \bar{R} - \bar{R}) + \bar{R}$

For duplicates reduces to

$$UWL_R = 2.51 \bar{R}$$

$$UWL_R = 15.6$$

ANNEX 4

Data for COD determination (50 to 500 mg/l)

Duplicate Results		Range R	Duplicate Results		Range R
78	74	4	200	196	4
321	325	4	332	332	0
86	86	0	60	52	8
100	96	4	106	86	20
237	241	4	266	266	0
109	101	8	114	118	4
55	59	4	254	250	4
150	150	0	235	216	19
114	118	4	501	497	4
200	208	8	102	94	8
87	87	0	121	114	7
222	226	4	51	51	0
139	139	0	484	492	8
251	255	4	241	257	16
89	81	8	218	233	15
342	342	0	315	315	0
66	62	4	59	55	4
186	190	4	64	66	2
62	58	4	100	108	8
84	80	4	62	77	15
196	196	0	77	69	8
208	204	4	349	352	3
174	200	26	60	52	8
284	292	8	304	320	16
485	485	0	356	367	11
85	89	4	427	419	8
248	246	2	167	172	3
66	70	4	102	114	12
80	76	4	316	316	0
170	152	18	229	224	8
274	266	8	214	206	8
452	441	11			

No of sets of duplicates  $n = 63$

Average range  $\bar{R} = \frac{\sum R}{n} = \frac{392}{63} = 6.22$



ANNEX 5

Quality Control Charts for Precision - Rc charts

Shewhart Upper Control Limits (UCL) and Critical Range Rc values for the differences between duplicate analyses within specific concentration ranges for three parameters.

<u>Parameter</u>	<u>Concentration Range</u>	<u>UCL</u>	<u>Rc</u>
BOD <sub>5</sub> (mg/l)	1 to <10	3.40	3.5
	10 to < 50	6.34	6
	25 to < 50	10.9	11
	50 to 150	21.3	21
	150 to 300	36.3	36
	300 to <1000	39.6	40
	1,000 above	579	579
Chromium (µg/l)	5 to < 10	1.05	1
	10 to < 25	1.86	2
	25 to < 50	3.66	4
	50 to <150	12.4	12
	150 to <500	17.2	17
	500 above	249	249

<u>Parameter</u>	<u>Concentration Range</u>	<u>UCL</u>	<u>Rc</u>
Copper ( $\mu\text{g}/\text{l}$ )	5 to < 15	3.04	3
	15 to < 25	4.41	4
	25 to < 50	3.73	5
	50 to < 100	7.62	8
	100 to < 200	9.19	9
	200 up	14.9	15

The Rc value is the UCL value rounded to the nearest whole unit at the higher concentration levels and to the nearest half-unit for the lower concentration level.

For Copper, the UCL value at 25 to 50  $\mu\text{g}/\text{l}$  is inconsistent with the UCL values for adjacent concentration levels and the Rc value has been adjusted to resolve this inconsistency. With the use of such tables, inconsistencies could be easily detected.

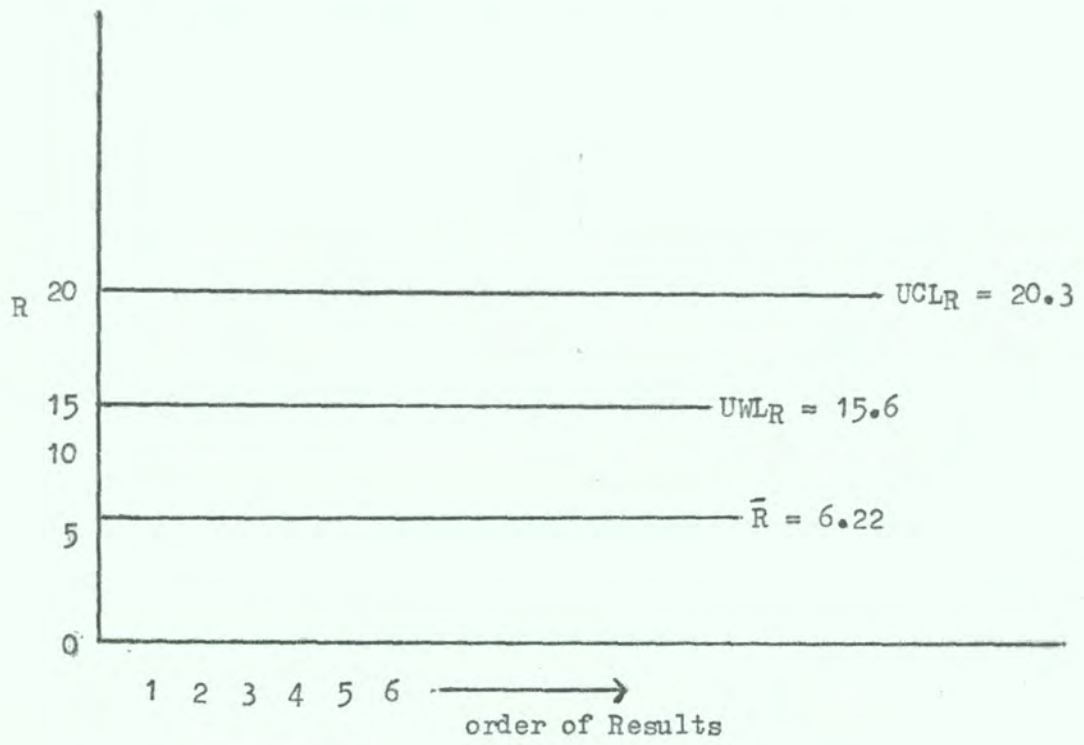
The table below illustrates the use of Rc values :

Critical Range Values for varying Concentration Levels

Parameter	Duplicates	R	Rc	$R \leq$	Condition of System
BOD ( $\text{mg}/\text{l}$ )	20 and 24	4	6	YES	Normal
Chromium ( $\mu\text{g}/\text{l}$ )	60 and 75	15	12	NO	Out-of-Control
Copper ( $\mu\text{g}/\text{l}$ )	46 and 51	5	5	YES	Normal



A completed R chart would look like this :-



ANNEX 10

SELECTION OF MONITORING STATIONS  
AND FREQUENCY OF SAMPLING



SELECTION OF MONITORING STATIONS  
AND FREQUENCY OF SAMPLING

---

SYNOPSIS

The development of water resources in Singapore requires careful planning, backed up with comprehensive measurements of water quality in various parts of the Island and the surrounding coastal waters. In any water quality monitoring programme however, there are always limitations on the number of samples which may be collected and analysed. The choice of sampling stations and frequency must therefore be carefully made to achieve the aims of the monitoring programme.

For rivers, streams and canals, sampling points must be carefully chosen to ensure that the water quality of the whole river catchment is closely represented. Other practical constraints such as accessibility, safety and permanency have also to be taken into account. Reservoir samples are chosen to show clear quality gradients and the sampling stations in the coastal waters are chosen near major pollutive or potentially pollutive sources such as sewage outfalls, refineries, river mouths, etc.

The sampling frequency of all these points are determined based on three considerations. Firstly, the frequency will largely be dependent on the reasons for carrying out the monitoring programme. Secondly, the type of data and parameters required must be established. Finally, the quantity of data required for making statistical evaluations must be established.

Based on these considerations, 130 inland monitoring stations and 46 sea sampling stations were chosen in and around the Island. Samples are collected weekly from 44 of the inland stations and for the rest of the stations, samples are collected on a monthly basis. All the samples are at present collected manually; but with the availability of reliable automatic sampling equipment, it is expected that the sampling programme will be automated in the future.



## 1 Introduction

The development of water resources takes high priority in Singapore. It requires careful planning, backed up with comprehensive measurements of water quality in various parts of the Island and the surrounding coastal waters. A water quality monitoring programme jointly carried out by the Ministry of the Environment and the Public Utilities Board was therefore set up in 1974 and has been periodically reviewed and modified since then. A map showing the locations of the sampling stations is in the Annex.

In this paper, some of the experience which has been gained through the designing and organising of this programme will be presented. As the subject of water quality monitoring is very broad, we will restrict ourselves only to the discussion of surface water monitoring. Effluent discharge monitoring and the monitoring of ground water supplies will not be touched on.

## 2 Objectives of Monitoring Programme

Before a water quality monitoring programme may be designed, the following must first be established :

- (a) a national water management plan and water use policy
- (b) water quality objectives and targets; and
- (c) objectives for monitoring programme.

In Singapore, certain rivers were first identified as having a potential of being converted into reservoirs through the construction of dams across their river mouths. Others had the possibility of having raw water extracted for public water supply. For such streams and rivers, the water quality target was set at a high standard. It was also decided that a water quality sufficient to encourage fish life in the rivers and canals flowing through

the city was desirable. A 10 year programme was therefore launched to clean up these rivers. For the remaining rivers and streams, it was necessary to ensure that the water quality did not deteriorate through pollution. Through such a management plan, the following objectives for the water quality monitoring programme were established :-

- (a) to monitor the suitability of potential raw water supplies;
- (b) to detect trends in the improvements in water quality as a result of implementation of water pollution control measures;
- (c) to detect the discharge of pollutants into rivers and streams;
- (d) to establish the pollution loads being discharged into reservoirs;
- (e) to monitor any deterioration of water quality due to sewage outfalls and farm activities;
- (f) to ensure the safety of beaches for swimming and bathing; and
- (g) to provide baseline data of water quality before potentially pollutive industries are set up

The above objectives had to be established first as they would determine the structure of the water quality monitoring programme especially with regards to the selection of monitoring stations and frequency of sampling.



### 3 Constraints in Sampling Programme

Once the objectives of the monitoring programme has been established, certain limitations and constraints must be considered. Some of these constraints are the availability of vehicles and boats, the availability of manpower, and the capacity of laboratory staff and equipment. With such constraints, there is a limit to the number of samples that can be collected. The number of monitoring stations becomes more or less inversely proportional to the frequency of sampling.

In monitoring the inland and coastal waters, we have generally preferred to choose a large number of sampling points and a moderate sampling frequency. For this reason there were initially 155 river monitoring stations and 46 sea sampling stations. Subsequently, it was felt that some points were unnecessary and the number of inland monitoring stations has been reduced to 130.

### 4 Choice of Sampling Points

The choice of sampling points is not an exact science. With the tremendous variations in the conditions of each river and stream, it is often difficult to choose sampling points which are completely representative. Many of the factors in the consideration of sampling points is based on common sense and experience. In this section, the factors governing the choice of river, reservoir and sea samples will be discussed separately.

#### 4.1 River/Canal Sampling Points

##### (a) Representative

A sampling point must **above all else** be representative of the water quality of the catchment or sub-catchment under study. Inland monitoring stations are often chosen downstream of major pollutive or potentially pollutive sources such as villages, pig farms, industries, etc. Sometimes another point upstream of such sources is also chosen to provide a comparison of water quality.

Generally, points should be chosen such that clear quality gradients may be observed. The information value of points with a low gradient is very limited. This must also be the basis of determining sampling points on broad rivers where there is a large variation in water quality at any cross-section. To ensure that sampling points are representative, it is often helpful to carry out temporary programmes with a relatively dense arrangement of sampling points. Points of low quality gradients may then be removed and the sampling restricted to some characteristic points from which the quality **profile of** the whole cross section of the river may be inferred.

##### (b) Accessible

Sampling points close to bridges and roads facilitate sampling. Also the time taken to reach the sampling station is reduced if the vehicle is able to get close to the station. Swampy areas are sometimes difficult to reach and must therefore be approachable by boat. Places prone to flooding is another problem. Care must be taken in the choice of such stations to ensure that they are accessible even during floods.



(c) Suitable

The station selected should have a moderate flowrate for practical purposes. A narrow stretch may not be suitable as the flow may be too fast for sampling to be safely carried out. On the other hand, too broad a section may cause the flow to be sluggish making flow measurements difficult.

(d) Stable

The cross sectional profile of the stream must be stable to simplify the computation of runoff calculations. Banks which have a tendency to collapse and river beds where silt may be easily deposited should be avoided.

(e) Permanent

Stations should, as far as possible, not dry up during dry periods. Only through permanent stations can the stream flow records be kept unbroken for a long period of time.

In the case of rivers affected by tide, the sampling point should preferably be 20-30m upstream of the point whose river bed RL is 101.7m.

(f) Others

The point chosen for sampling should be an approximately straight stretch of about 20m. This would not only give more accurate flow measurements but also ensure a representative quality not affected by turbulence.

#### 4.2 Reservoir Sampling Points

Reservoir sampling points, like river sampling points, should show any detectable quality gradient. Hence, points should be chosen at inlet to the reservoir, near the water works intake point, outlets, deepest points and at places representative of segments of the reservoir.

#### 4.3 Sea Sampling Stations

Sea sampling stations, like inland monitoring stations, are very much dependent on the objectives of the monitoring programme. For this reason, the monitoring station around the Island have been chosen near

- (a) sewage effluent outfalls;
- (b) power stations;
- (c) major potentially pollutive discharges e.g. the refineries;
- (d) major proposed installations e.g. the petrochemical complex;
- (e) swimming and recreational beaches, and
- (f) major rivers.

The general objective of the programme is to monitor land based pollution. Hence sampling points have been chosen relatively close to the shore. Most sampling points are approximately only 500-1000m away from the shore.



## 5 Frequency of Sampling

The data obtained from a monitoring programme may be thought of as painting a dynamic picture of the water quality. The higher the sampling frequency, the higher the degree of resolution and the easier will the details be discerned. It is, however, not always necessary to see the 'details'. Sampling should therefore not be carried out more often than necessary. Common frequencies range from yearly, monthly, weekly, daily to continuous monitoring. The necessary frequency will depend very much on

- (a) the desired degree of statistical confidence;
- (b) the objectives of the sampling programme;
- (c) the type of parameters measured.

### 5.1 Statistical Confidence

Theoretically, only very few samples are required to provide a picture of any trend in the changes of water quality. In practice however a much higher frequency is necessary to afford statistical evaluations to be made. Through such evaluations, it would be possible to separate the random occurrences and errors from the real trend. Also, such information as maximum, minimum, standard deviation, degree of confidence would also be obtained.

Such information is very useful specially at the initial stages of the programme when the water quality criteria is being established. The tendency is therefore to start with a higher sampling frequency than really necessary to provide the initial pool of data. An example of this is in the sampling of sea water around the Island. Although it has not been possible so far to observe any annual variation of the sea water quality, the programme has been carried out on a monthly basis in order to confirm this.

## 5.2 Frequency Based on Objectives

Like the determination of sampling points, the choice of sampling frequency largely depends upon the reasons why the programme is being carried out. For example, the variation of the water quality in the reservoirs have been found to be consistently very low. Yet the sampling frequency has not been reduced from the present monthly intervals as this is considered necessary to detect any indiscriminate discharge of toxic substances into the reservoirs. As a further illustration of this, the sampling of the waters in existing and proposed reservoir catchments has been carried out on a weekly rather than a monthly cycle to provide an indication of the effectiveness of the intense pollution control measures taken in such catchment areas.

Samples may have to be taken daily from a river flowing through an industrial zone to ascertain whether the water quality improves on weekends. A continuous monitoring is occasionally carried out for the purpose of gauging the effect of tides and stormwater flows.

## 5.3 Parameters Measured

The type of parameters measured must also be considered in order to determine the sampling frequency. This is because the speed of variation of the parameters measured will influence the reliability and usefulness of the data collected. In the monitoring of the total dissolved solids (T.D.S.) or chloride content of the



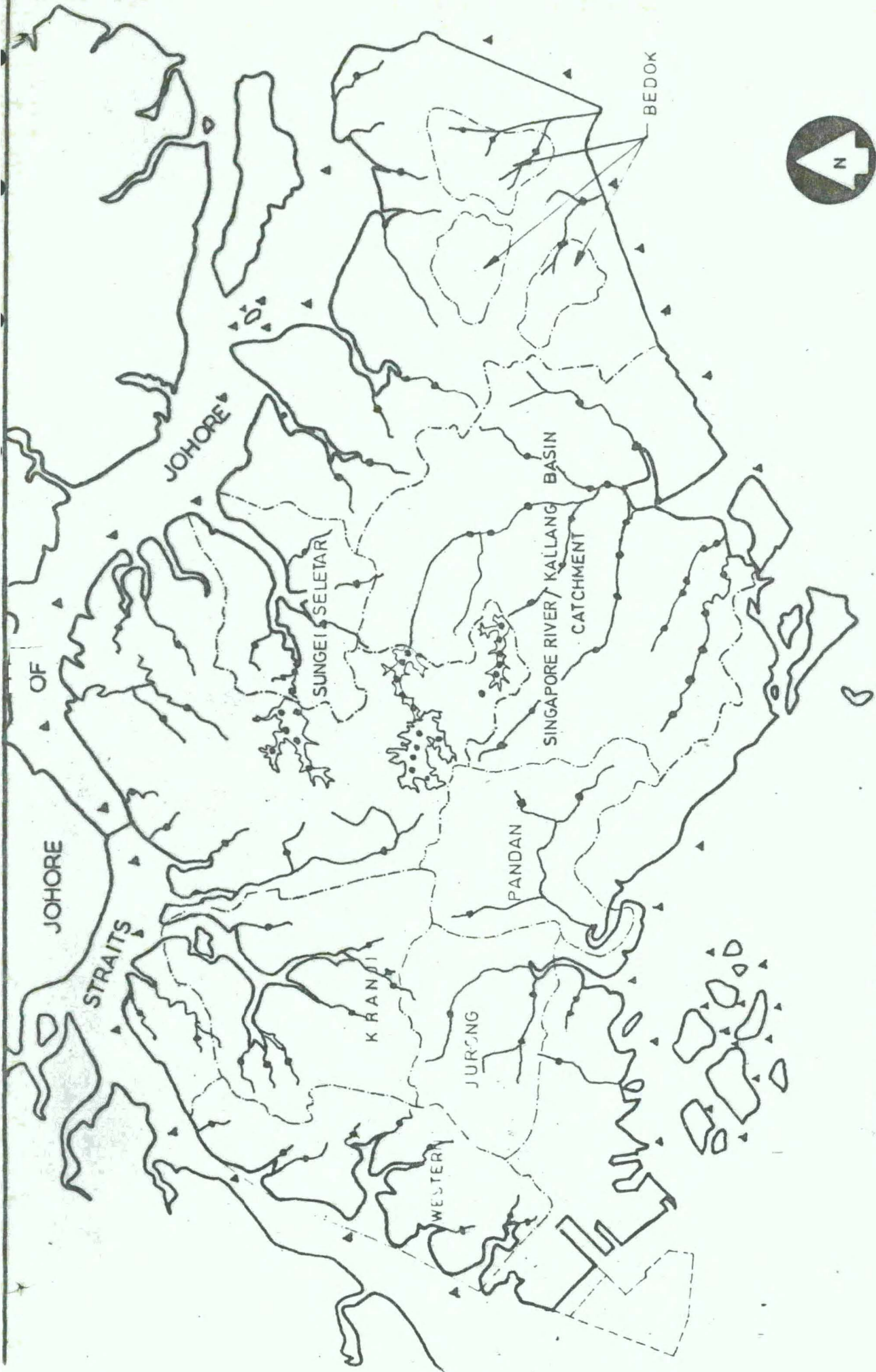
water in reservoirs, for example, the sampling frequency required may only be 2 or 3 times a year as the chloride level is expected to **change** very slowly. In contrast, the dissolved oxygen (D.O.) in a stream may be required to be monitored continuously to detect the diurnal variation due to the production of oxygen by algae during the daytime.

Another example is the monitoring of BOD. BOD being based on a biological process is expected to vary less rapidly in a stream as compared to say conductivity in the event of sudden chemical pollution. A continuous monitoring of conductivity may therefore be carried out with BOD samples being collected on a weekly or fortnightly basis.

## 6 Conclusion

After having discussed the factors affecting the choice of sampling stations and sampling frequency, it must be stressed that in order for a sampling programme to be successful, it must above all else be flexible. Because of the ever changing water quality and pollution control objectives, the programme itself must be frequently modified. In the design of any programme it becomes necessary to fix a date by which a review of the programme is due.

With the availability of better and more reliable automatic samplers, analysers and recorders, the monitoring the water quality itself becomes an ever changing art. The trend will continually be towards the greater use of automatic equipment and the increase of automatic monitoring stations.



SAMPLING STATIONS





ANNEX 11

BRIEF DESCRIPTION OF WASTEWATER TREATMENT  
PLANTS VISITED DURING THE FIELD VISITS

Matsushita Refrigeration Industries (S) Pte Ltd  
1 Bedok South Road, Singapore 1646

- 1 Products :  
Refrigerator compressors & compressor accessories.
  
- 2 Raw materials :  
Cast iron, steel sheets, plastics, aluminium, etc.
  
- 3 Manufacturing Process :  
Machining, punching, tumbling, phosphating, etc.
  
- 4 Sources of Trade Effluent :
  - 4.1 Tumbling area
  - 4.2 Machine shop area
  - 4.3 Shell fabrication line
  - 4.4 Boiler room
  
- 5 Trade Effluent Flowrates :  
Total average flowrate =  $134 \text{ m}^3/\text{day}$ .
  
- 6 Wastewater Treatment :
  - 6.1 The wastewater is first collected in the Wastewater Influent Tank. The floating oil is pumped into a Reaction Tank whilst the water flows into the General Tank.
  - 6.2 The wastewater is then pumped into the outside chambers of the Aero separator where it is mixed with Ferrous Sulphate, Lime, Activated Carbon, polymer coagulant, and air from an air blower. The air oxidises the soluble ferrous hydroxide in the wastewater into insoluble ferric hydroxide.
  - 6.3 The aerated wastewater then flows into the central chamber of the Aeroseparator which is in effect a clarifier. The settled sludge is pumped to any one of ten sand beds whilst the clarified supernatant is neutralised with sulphuric acid and discharged into the sewer.
  
- 7 Plant Details :
  - 7.1 General Tank  
 $11.2 \text{ m} \times 7.2 \text{ m} \times 2.8 \text{ m (Depth)} = 226 \text{ m}^3$
  - 7.2 Wastewater Influent Tank  
 $7.4 \text{ m} \times 2 \text{ m} \times 2.8 \text{ m (Depth)} = 37 \text{ m}^3$
  - 7.3 Reaction Tank  
 $2 \text{ m} \times 2 \text{ m} \times 2.5 \text{ m (Depth)} = 10 \text{ m}^3$
  - 7.4 Sand Beds (10 Nos)  
 $2 \text{ m} \times 4 \text{ m} \times 1.5 \text{ m (Depth)}$



- 7.5 Neutralisation Tank  
1.6 m x 1.6 m x 1.5 m (Depth)
- 7.6 Oil Filter Tanks (2 Nos)  
1.2 m  $\phi$  x 2 m (Height)
- 7.7 Aeroseparator  
4.8 m  $\phi$  x 4 m

8 Capital Cost

The total cost of the wastewater treatment plant is \$316,000. This is 0.34% of the total capital investment of the factory.

9 Manpower Required :

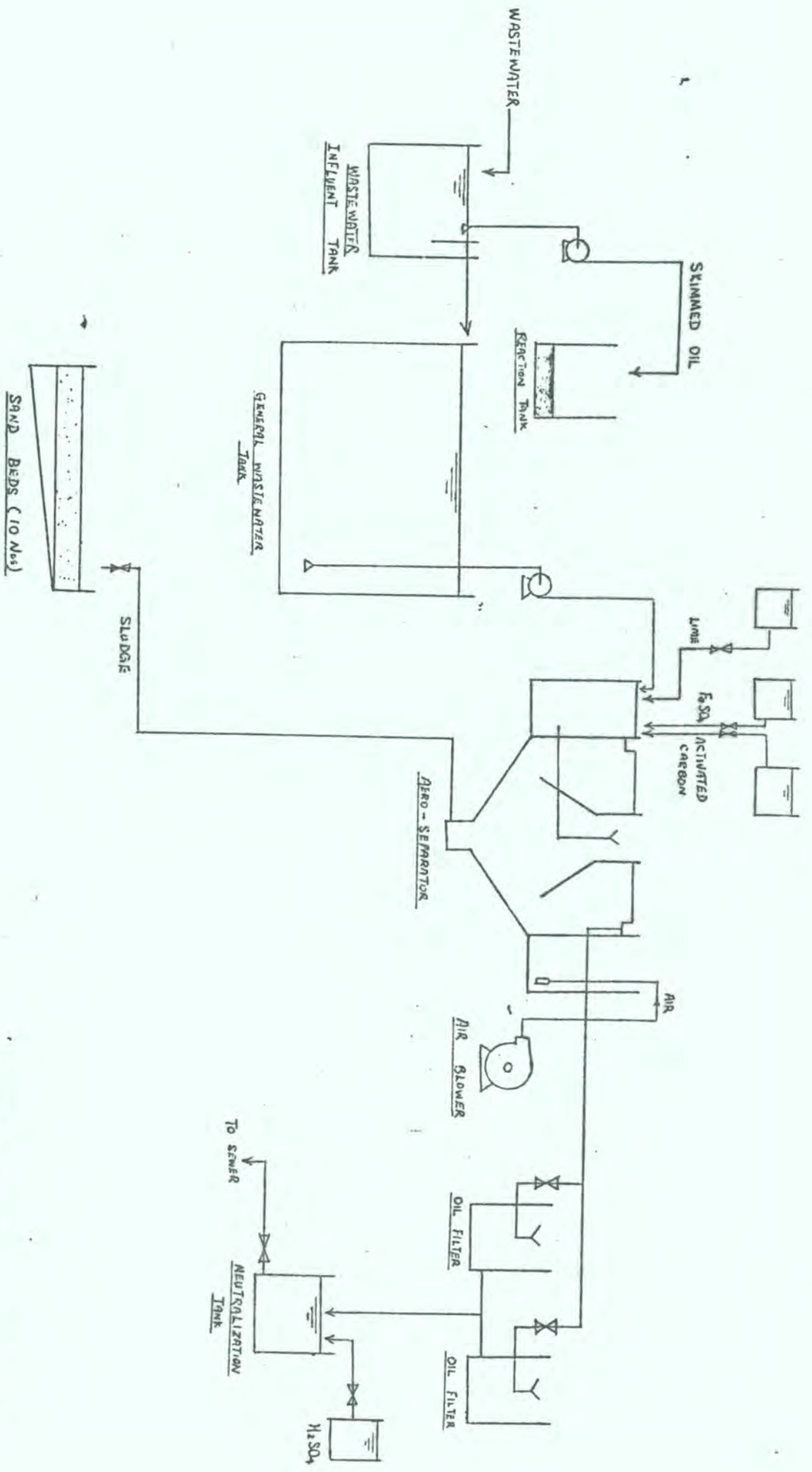
One full time worker on normal shift.

10 Operational Cost :

Chemicals	\$1,000/month
Electricity	\$ 600/month
Total	<u>\$1,600/month</u>

11 Effluent Quality :

<u>Parameter</u>	<u>Untreated Wastewater</u>	<u>Treated Effluent</u>	<u>Allowable Discharge Limit</u>
pH value	7.6	7.9	6-9
BOD <sub>5</sub>	2295 mg/l	50 mg/l	400 mg/l
COD	3550 mg/l	150 mg/l	600 mg/l
Oil & Grease	86 mg/l	6 mg/l	60 mg/l
Suspended Solids	50 mg/l	15 mg/l	400 mg/l
Dissolved Solids	645 mg/l	675 mg/l	3000 mg/l



MATSUSHITA REFRIGERATION SPACE (PTE) LTD  
 WASTEWATER TREATMENT FLOW DIAGRAM



Bedok Wastewater Treatment Plant  
Koh Sek Lim Road, Singapore 1649

1 Sources of Wastewater :

Changi, Bedok, Tampines and Siglap areas.

2 Wastewater Flowrates :

2.1 Design flowrates through on-site Raw Sewage Pumping Station.

Average rate	16,000 m <sup>3</sup> /d
Peak rate	39,000 m <sup>3</sup> /d

2.2 Design flowrates from Bedok New Town Pumping Station.

Average rate	42,000 m <sup>3</sup> /d
Peak rate	99,000 m <sup>3</sup> /d

2.3 Present average daily flow 29,000 m<sup>3</sup>/d

2.4 Present population equivalent served 160,000 persons

3 Consultants :

Camp, Dresser and McKee.

4 Wastewater Treatment :

4.1 Wastewater from Bedok New Town enters the Plant from Bedok Pumping Stations. Wastewater from the rest of the catchment gravitates to the Plant's Influent Pumping Station. The wastewater is then treated by conventional high rate activated sludge process with primary clarification, aeration and final sedimentation. This process has the advantage of small land requirement and being able produce a high quality effluent.

Surface aerators are used in preference over diffuser domes mainly because of easier maintenance. There is some flexibility in the operation of the aerations tanks and the settled sewage may be introduced as plug flow or step flow.

This is the only sewage treatment works in Singapore using the vacuum filter for sludge dewatering. A centrifuge, because of its high speed requires critical maintenance and high power consumption. Hence it was not used. Although the filter presses have approximately the same operating cost as the vacuum filter, the latter was chosen in Bedok Waste Water Treatment Plant as the continuous production of sludge was considered as being compatible with the possibility of installing a sludge incinerator which requires a continuous feed. The sludge is conditioned by lime, ferric chloride or organic polymers before dewatering. After dewatering the sludge is used as soil conditions for horticultural purposes. Excess sludge is used as landfill

5 Treatment Plant Details :

5.1	Primary Settling Tanks (2)	
	Dimensions (m)	12.15 x 61.0 x 3.02
	Overflow Rate ( $m^3/d/m^2$ )	
	@ Average Flow	39.13
	@ Peak Flow	92.42
5.2	Aeration Basins (2)	
	Total Volume ( $m^3$ )	17,295
	Aerators (8)	
	Size, ea. (kW)	75
	Oxygen Transfer Rate (kg/kW/hr)	1.67
5.3	Flocculator-Clarifiers (3)	
	Dimensions (m)	36.6 Dia x 4.45 SWD
	Overflow Rate	
	@ Average Flow ( $m^3/d/m^2$ )	22.24
5.4	Return Activated Sludge Pumps (4)	
	Capacity, ea. (l/s)	225
5.5	Effluent Ponds (3)	
	Total Surface Area (ha)	2.53
	Average Depth (m)	2.36
	Detention Time (days)	1.0
5.6	Gravity Thicknes (2)	
	Dimensions (m)	9.2 Dia x 3.0 SWD
	Solids Loading ( $kg/m^2/d$ )	83.5
5.7	Air Flotation Thickeners (2)	
	Dimensions (m)	5.6 x 16.6 x 3.0 SWD
	Solids Loading ( $kg/m^2/d$ )	52.4
5.8	Primary Digester (1)	
	Dimensions (m)	26.0 Dia x 10.85 SWD
	Detention Time (days)	13.25
	Volume ( $m^3$ )	57.61
5.9	Secondary Digester (1)	
	Dimensions (m)	26.0 Dia x 10.48 SWD
	Volume ( $m^3$ )	55.64
5.10	Vacuum Filters <sub>2</sub> (2)	
	Size, ea. ( $m^2$ )	33.5
	Design Loading ( $kg/hr/m^2$ )	19.5

6 Design Criteria :

		<u>Phase 1</u>	<u>Expanded Plant</u>
6.1	Population Equivalent	319,200	580,000
6.2	Per Capita Flow, lpcd (gpcd)	180 (40)	200 (44)
6.3	Flows $10^3$ cu m/day (mgd)		
	Average	58 (12.8)	116 (25.6)
	Peak	137 (30.1)	274 (60.2)
	Minimum	29 (6.4)	58 (12.8)



6.4	Loadings, kg/day (lb/day)		
	Per Capita BOD <sub>5</sub>	0.0570 (0.125)	0.0628 (0.138)
	Total BOD <sub>5</sub>	18,200 (40,000)	36,400 (80,000)
	Per Capita SS	0.0573 (0.126)	0.0628 (0.138)
	Total SS	18,300 (40,300)	36,400 (80,000)
6.5	BOD <sub>5</sub> Concentration, mg/l	313	313
6.6	BOD <sub>5</sub> removal at Primary Sedimentation Tanks (PST)	30%	
6.7	BOD <sub>5</sub> loadings on Aeration Tanks	0.0399 kg/cap/d 2,330, 160 kg/yr	
6.8	Sludge production	0.0541 kg/cap/d 3,160,024 kg/yr	

7 Manpower Required :

65 fulltime staff and workers.

8 Capital Cost :

\$46M (1977)

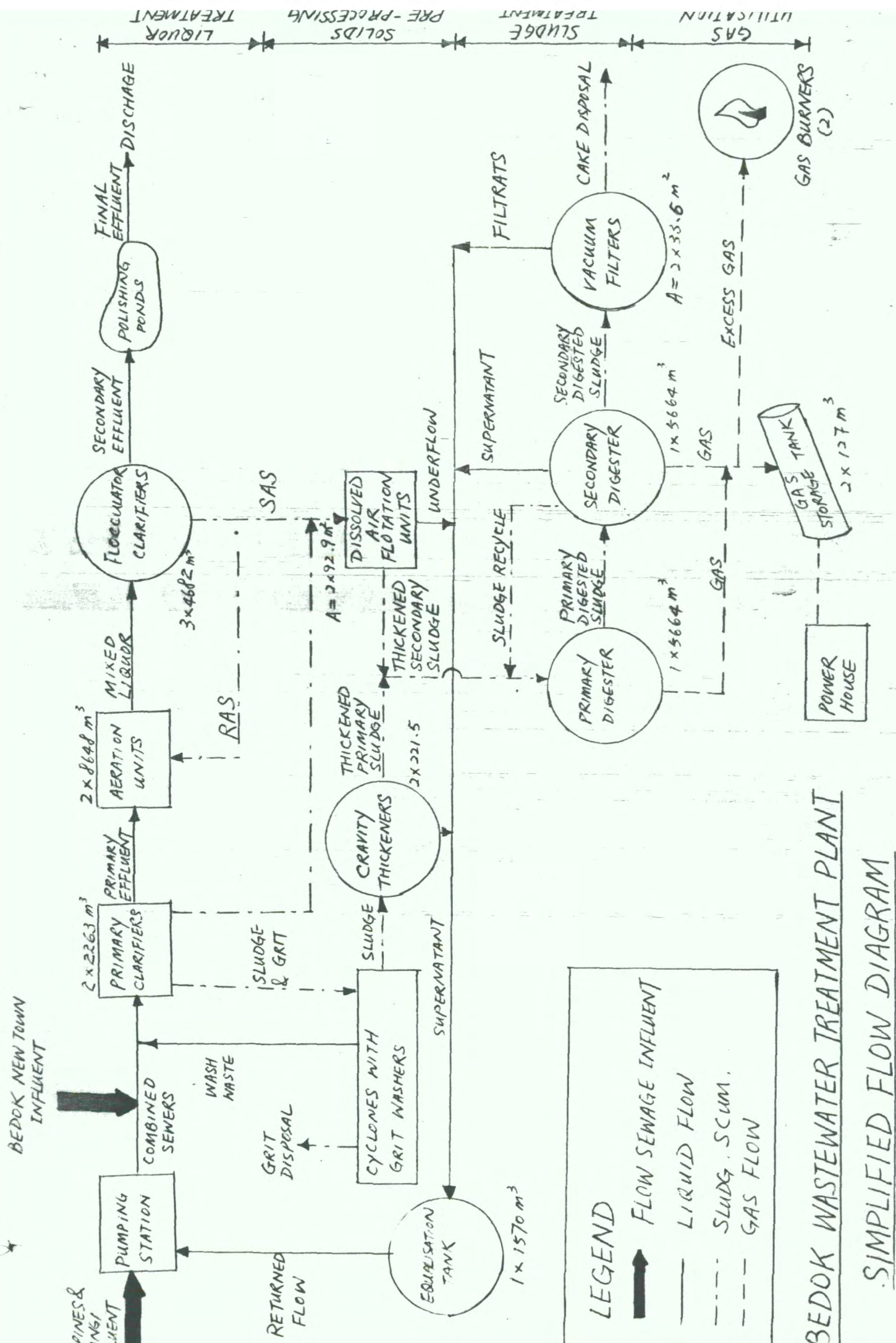
9 Operating Cost :

Manpower	\$42,300/month
Electricity	\$32,900/month
Chemicals	\$ 7,000/month
Others	\$11,900/month
	<hr/>
	\$94,100/month
Unit Cost	11¢/m <sup>3</sup> of sewage.

10 Effluent Quality

<u>Parameter</u>	<u>Combined Sewage</u>	<u>Bedok Influent</u>	<u>Secondary Effluent</u>
BOD <sub>5</sub>	394 mg/l	307 mg/l	13 mg/l
COD	837 mg/l	603 mg/l	70 mg/l
Suspended Solids	378 mg/l	272 mg/l	18 mg/l
Dissolved Solids	540 mg/l	454 mg/l	342 mg/l
Detergent	5.4 mg/l	5.5 mg/l	0.3 mg/l





**LEGEND**

- FLOW SEWAGE INFLUENT
- LIQUID FLOW
- SLUDGE, SCUM,
- GAS FLOW

BEDOK WASTEWATER TREATMENT PLANT  
SIMPLIFIED FLOW DIAGRAM

Beecham Pharmaceuticals Pte Ltd  
Quality Road, Singapore 2261

- 1 Product :  
Semi-synthetic penicillins.
  
- 2 Raw Materials Used :  
Acids, alkalis, salts, etc, and the following solvents : Methyl Iso-butyl Ketone (MIBK), Acetone, Iso-propyl Alcohol, Ethyl Acetate.
  
- 3 Manufacturing Process :  
Confidential.
  
- 4 Sources of Wastewater :
  - 4.1 Process plant
  - 4.2 Solvent recovery plant
  - 4.3 Pharmaceutical building
  - 4.4 Drum store and tank farm
  
- 5 Wastewater Flowrates :

Weak wastes	136 m <sup>3</sup> /day
Strong wastes	<u>106 m<sup>3</sup>/day</u>
Total	<u>242 m<sup>3</sup>/day</u>
  
- 6 Consultants :  
Watson ( S E Asia).
  
- 7 Wastewater Treatment :
  - 7.1 The biological treatment system chosen for this factory is a 3-stage biological filter with interstage sludge removal together with an activated sludge process for effluent polishing.
  - 7.2 The biological filter uses synthetic plastic media and can accept strong wastes with considerable shock loading.
  - 7.3 The aeration tank of the activated sludge process uses diffused air domes in preference over surface aerators. Considerable cost savings was thus achieved as there was an existing air supply from the factory.



Diffused air domes require periodic cleaning but this can be minimised by improved air filtration systems. The high shearing forces inherent in mechanical aeration tend to result in high SVI's. Assurance of better sludge settling can therefore be obtained from diffused air systems. Furthermore, when tanks must be emptied for maintenance, aeration can be maintained with diffused air. Mechanical aerators also tend to create mists which can be a source of smell problems. Power requirements for aeration efficiency and reliability of both systems are approximately the same.

- 7.4 The sludge from both the biological filters and aeration tank is thickened by a Dissolved Air Flootation Unit (DAFU). Although a DAFU requires more space than a centrifuge, the labour and maintenance of a centrifuge could cost approximate four times that of a DAFU because of the precision equipment involved in the centrifuge.

## 8 Treatment Plant Details :

- 8.1 Balancing Tanks (3 Nos)  
 Total capacity 300 m<sup>3</sup>  
 Retention time 24 hours  
 With recirculating pumps
- 8.2 pH Adjustment Tank  
 Nominal capacity 3 m<sup>3</sup>  
 Retention time 15 mins  
 Agitator 0.5 kW  
 Automatic acid dosing  
 Pre-set nutrient dosing
- 8.3 Biological Filters
- |                    | <u>Stage 1</u>     | <u>Stage 2</u>     | <u>Stage 3</u>     |
|--------------------|--------------------|--------------------|--------------------|
| Length             | 16.8m              | 7.2m               | 6.6m               |
| Breadth            | 7.2m               | 7.2m               | 7.2m               |
| Height             | 6.0m               | 6.0m               | 6.0m               |
| Volume             | 726 m <sup>3</sup> | 311 m <sup>3</sup> | 285 m <sup>3</sup> |
| Recirculation rate | 84 l/s             | 36 l/s             | 36 l/s             |

8.4	<u>Humus Tanks (3 Nos)</u>	
	Nominal capacity	12.5m <sup>3</sup>
	Dimensions	2.5mx2.5mx1.3m (side wall)
	Retention time	1 hour
	Hopper bottom	60°
	Continuous sludge drawoff	5700 l/hr (tank 1) 2400 l/hr (tank 2) 850 l/hr (tank 3)
8.5	<u>Aeration Tank (2 channels)</u>	
	Nominal capacity	200m <sup>3</sup>
	Retention time	16 hours
	Dimensions (each channel)	1.9mx15mx3.5m (Depth)
	No. of diffuser domes	120
	Air supply	14Nm <sup>3</sup> /min
8.6	<u>Final Settling Tank</u>	
	Nominal capacity	25m <sup>3</sup>
	Retention time	2 hours
	Dimensions	3.6mx3.6mx1m (side wall)
	Hopper bottom	60°
	Return activated sludge	235m <sup>3</sup> /d
8.7	<u>Sludge Holding Tank</u>	
	Nominal capacity	45m <sup>3</sup>
	Retention capacity	1.5 days

## 9 Design Criteria :

9.1	<u>Influent</u>	
	Flowrate	300m <sup>3</sup> /d
	BOD <sub>5</sub>	13,000 mg/l
	COD	20,000 mg/l
	Solvent content	0.56%
9.2	<u>Nutrient Additions</u>	
	Phosphorus	28 kg/d (104 kg/d H <sub>3</sub> PO <sub>4</sub> )
	Nitrogen	176 kg/d (380 kg/d of Urea)
9.3	<u>Biological Filtration</u>	
	BOD <sub>5</sub> removal	58% (Stage 1) 58% (Stage 2) 44% (Stage 3)
	Irrigation rate	2.5m <sup>3</sup> /m <sup>2</sup> -hr
9.4	<u>Aeration Tank</u>	
	Air requirement	125Nm <sup>3</sup> /kg BOD removal
	Loading	1.2 kg BOD/kg MLSS
	MLSS	1,600-2,000 mg/l
	BOD removal	80%



9.5 Sludge Production

Humus sludge	0.3kg/kg BOD removed 220m <sup>3</sup> /d
Surplus activated sludge	0.7% dry solids 0.6kg/kg BOD removed 30m <sup>3</sup> /d
Thickened sludge	3-4% solids

9.6 Humus Sludge Settling

Upward flow velocity 2m/hr

9.7 Final Sludge Settling

Upward flow velocity 1m/hr

10 Capital Cost :

S\$1.9 M (1976)

11 Manpower Required :

2 workers (full-time)

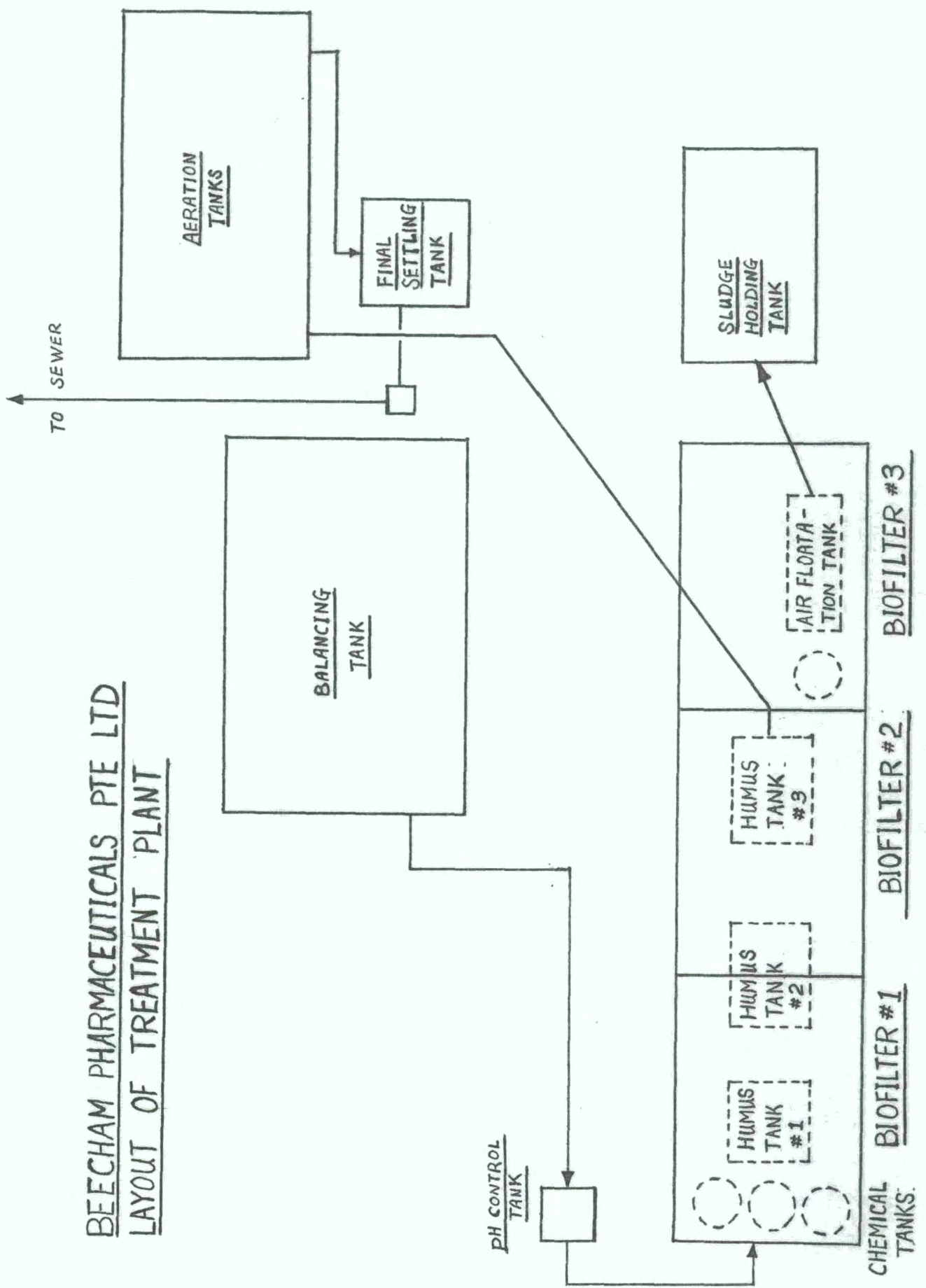
12 Operating Costs :

Chemicals	\$ 9,100/month
Electricity	\$ 1,700/month
Manpower	\$ 1,700/month
Sludge disposal	\$ 6,700/month
Total	<u>\$19,200/month</u>

13 Effluent Quality :

<u>Parameter</u>	<u>Effluent Quality</u>
pH	7.7
BOD	88 mg/l
COD	889 mg/l
Solvent	0.023%
Suspended Solids	250 mg/l
Dissolved Solids	2983 mg/l
Chloride	606 mg/l
Sulphate	263 mg/l

BEECHAM PHARMACEUTICALS PTE LTD  
LAYOUT OF TREATMENT PLANT





1     Products :

Metal and plastic components used in the assembly of electronic and household equipment.

2     Raw Materials :

ABS plastics, zinc.

3     Manufacturing Process :

Die casting, machining, injection moulding, chemical nickel plating, copper plating, nickel plating, chromium plating, drying, assembling.

4     Sources of Wastewater :

4.1   Cyanide Wastewater

4.1.1	Continuous effluent	2000 l/hr (including *)
	pH	9-10
	Cyanide (CN <sup>-</sup> )	50-100 mg/l
	Copper	30-50 mg/l

4.1.2 Spent plating solution

	pH	12-13
	Cyanide (CN <sup>-</sup> )	50 g/l
	Copper	20 g/l

4.1.3 \*Air exhaust water scrubber effluent (alkaline)

	pH	9-10
	Cyanide (CN <sup>-</sup> )	0.1 mg/l

4.2   Chromate Wastewater

4.2.1	Continuous effluent	3500 l/hr (including **)
	pH	2-3
	Chromium (Cr <sup>6+</sup> )	50-100 mg/l

4.2.2 Spent plating solution

	pH	0
	Chromic acid (CrO <sub>3</sub> )	400 g/l
	Sulfuric acid (H <sub>2</sub> SO <sub>4</sub> )	400 g/l

4.2.3 \*\*Air exhaust water scrubber effluent (acidic)

	pH	2-3
	Chromium (Cr <sup>6+</sup> )	0.2 mg/l

4.3   Chemical Nickel Wastewater

4.3.1	Continuous Wastewater	200 l/hr
	pH	8-9
	Nickel	30-50 mg/l

4.3.2 Spent Plating Solution

	pH	8-9
	Nickel	10 g/l

4.4	<u>Barrel Grinding Wastewater</u>	
4.4.1	Continuous effluent	3000 l/day (including ***)
	pH	7-8
	Zinc	3- mg/l
	Detergent	200-300 mg/l
4.4.2	***Air exhaust water scrubber effluent (NOX)	170 l/day
	pH	12.5-13
	Sulphide	15 g/l
4.5	<u>Acid/Alkali Wastewater</u>	
4.5.1	Continuous effluent	14000 l/hr
	pH	3-4
	Nickel	10-20 mg/l
	Copper	10-20 mg/l
4.5.2	Spent Acid	2400 l/week
	pH	0
	HCl	60 g/l
	H <sub>2</sub> SO <sub>4</sub>	50 g/l
	Nickel	5 g/l
	Copper	5 g/l
4.5.3	Spent Alkali	880 l/week
	pH	13-14
	Caustic Soda	20 g/l
4.6	<u>Pure Water Supply</u>	
4.6.1	Continuous flowrate	3000 l/hr
	pH	6-7
	Total metals	1-2 mg/l
	Dissolved salts	20-30 mg/l

## 5

Wastewater Treatment :5.1 Cyanide Wastewater

- 5.1.1 Spent plating solution is collected in an evacuation tank and slowly bled into the continuous effluent.
- 5.1.2 The cyanide is destroyed in a 2-stage process.
- 5.1.3 In the 1st stage cyanide is oxidised to cyanate by NaClO with NaOH at pH 10 and ORP + 300 mV.
- 5.1.4 In the 2nd stage the cyanate is completely oxidised to CO<sub>2</sub> and N<sub>2</sub> by NaClO at pH 8-9 and ORP + 650 mV.
- 5.1.5 The effluent is then sent to the acid/alkali mixing tank.



## 5.2 Chromate Wastewater

- 5.2.1 Spent chrome plating solution is slowly bled into continuous effluent stream.
- 5.2.2 The Chromium (6+) is reduced to Chromium (3+) by  $\text{NaHSO}_3$  and  $\text{H}_2\text{SO}_4$  at pH3 and ORP - 300 mV.
- 5.2.3 The effluent is then sent to the acid/alkali mixing tank.

## 5.3 Nickel Wastewater

- 5.3.1 Spent plating solution is slowly bled into the continuous effluent stream.
- 5.3.2 Nickel Pyrophosphite,  $\text{Ni}(\text{H}_2\text{PO}_2)_2$  is decomposed to  $\text{Ni}(\text{OH})_2$  by  $\text{NaClO}$  and  $\text{Ca}(\text{OH})_2$  at 12-13.
- 5.3.3  $\text{Ni}(\text{OH})_2$  is precipitated in another tank at pH11 with organic coagulant.
- 5.3.4 The sludge is removed in a thickener and is dewatered in a filter press.
- 5.3.5 The supernatant from the thickener combines with the treated barrel grinding wastewater and passes through an activated carbon column.
- 5.3.6 The effluent from the carbon column is then sent to the acid/alkali mixing tank.

## 5.4 Barrel Grinding Wastewater

- 5.4.1 The pH is raised to 9-10 by  $\text{NaOH}$ .
- 5.4.2  $\text{NaClO}$  is then added to oxidise  $\text{Na}_2\text{S}$  to  $\text{Na}_2\text{SO}_4$  by slowly decreasing the pH.
- 5.4.3  $\text{FeCl}_3$  and  $\text{Ca}(\text{OH})_2$  are added quantitatively to precipitate zinc, iron, etc as their hydroxides.
- 5.4.4 Organic coagulant is added to aid solid-liquid separation.
- 5.4.5 The sludge is dewatered whilst the supernatant is mixed with the treated nickel wastewater as described above.

## 5.5 Acid/Alkaline Wastewater

- 5.5.1 The wastewater is first pumped to the mixing tank.
- 5.5.2  $\text{Ca}(\text{OH})_2$  is added. Insoluble hydroxides of Cr, Zn, Fe and Cu are precipitated at pH 9-9.5.
- 5.5.3 Organic coagulant is added to aid floc formation.
- 5.5.4 The sludge is settled in a tilted plate clarifier.
- 5.5.5 The supernatant is pumped through sand filters for complete removal of metal hydroxides.
- 5.5.6 The filtrate is automatically neutralised and discharged into the sewers.
- 5.5.7 The sludge is dewatered in a filter press.

11 Treated Effluent :

Parameter	Effluent Quality	Allowable Discharge Limit
pH	7.4	6-9
COD	200 mg/l	600 mg/l
Suspended Solids	20 mg/l	400 mg/l
Dissolved Solids	2500 mg/l	3000 mg/l
Oil & Grease	20 mg/l	60 mg/l
Cyanide	1 mg/l	2 mg/l
Nickel	5 mg/l	10 mg/l
Chromium	1 mg/l	5 mg/l
Copper	1 mg/l	5 mg/l
Zinc	3 mg/l	10 mg/l



1 Products :

- 1.1 Liquified Petroleum Gas (LPG)
- 1.2 Gasolines
- 1.3 Kerosenes
- 1.4 Jet Fuels
- 1.5 Diesel Fuels
- 1.6 Residual Fuels
- 1.7 Solvents
- 1.8 Sulfur

2 Raw Materials :

Crude Oil, Tetra Methyl Lead, Dyes, Ethyl Mercaptans, etc.

3 Manufacturing Process :

3.1 Crude Distillation

Crude oil is converted into useful products by the Distillation Process which separates the crude oil into various fractions on the basis of volatility. The existing refinery can distill 175,000 bbls of crude a day.

3.2 Distillate Desulfurization

Distillates (gas oil & kerosene) are treated in a Catalytic Hydrodesulfurization or CHD process to remove contaminants such as sulfur, nitrogen, metal and color. CHD is a hydrogen treating process. Cobalt molybdenum oxides on alumina-supported catalyst are being used in the process and the average reactor temperature is in the range of 600-700°F.

3.3 Catalytic Reforming

Catalytic Reforming is a process wherein hydrocarbon (Naphtha) molecules are rearranged or reformed in the presence of a platinum containing catalyst with a hydrogen recycle stream.

The molecular rearrangement results in an increase in octane rating of the feed stock. This process is capable of economically making a gasoline component having clear research octane ratings as high as or higher than 100.

### 3.4 Kerosene Merox Process

This Kerosene Merox Process, chemically converts mercaptans present in the straight run kerosene from the Crude Distillation Unit to disulfides. This conversion is based on the ability of a catalyst composed of cobalt chelates in an alkaline environment (sodium hydroxide) to promote the oxidation of mercaptans to disulfides using air as the source of oxygen.

### 3.5 Vacuum and Visbreaker Units

The Vacuum Distillation Unit coupled with the Visbreaker Unit is an integral part of the Resid Upgrading Process. The Vacuum Distillation Unit is designed to process atmospheric residual crude from the crude unit into distillate products (LVGO, MVGO & HVGO) and a vacuum residual for Visbreaker Unit feed. The LVGO will be used as a distillate fuel blending components while the HVGO would be used as residual fuel viscosity cutter stock. HVGO together with vacuum bottom is charged to the Visbreaker for Residual fuel production.

The Visbreaker is the principal unit of the Resid Upgrading Process. The HVGO & Vacuum Resid is charged to the heaters where the feed components undergo a reduction in viscosity under specified conditions of residence time and temperature. The visbroken product, will supplement cutter stock for viscosity control is rundown to residual fuel blending tankage.

### 3.6 Sulfur Recovery

The sulfur plants (3) employing the Claus Process are to recover the elementary sulfur from the Amine Acid gas. Each unit consists of a thermal stage and three catalytic stage. The conversion of Hydrogen Sulfide ( $H_2S$ ) from the Amine Plant to elementary sulfur is based on a controlled combustion with oxygen in air. The sulfur produced in the Reactor Furnance is condensed in a condenser & flows to a sulfur pit.

### 3.7 Steam Generation

Steam is generated from boilers and furnace waste heat boilers for use in the various processes, tank and line heating, oil burner atomizing and turbine driving.

A simplified Refinery flow diagram is attached for your reference.



4 Sources of Wastewater :

- 4.1 Crude Distillation
- 4.2 Distillate Desulfurization process
- 4.3 Vacuum Distillation & Visbreaking
- 4.4 Merox Plant
- 4.5 Blow-down from boilers and water cooling system
- 4.6 Dewatering from storage tanks
- 4.7 Ballast water from vessels

5 Wastewater Flowrate :

167 m<sup>3</sup>/hr (normal rate).

6 Wastewater Treatment :

The wastewater in the refinery constitutes mainly oily water from the various sources as mentioned in item 4 above. These streams of wastewater flow through the underground sewer lines into the treatment plant by gravity. This wastewater is first treated in the API Separator where the surface oil is being physically removed before it is pumped into the Air Flotation Unit for removing suspended solids and emulsified oil. Treated water from the flotation unit is then sent to the biological oxidation lagoon to reduce BOD with the aid of mechanical aerators. Further reduction in BOD to meet effluent standards is achieved in the final effluent retention pond.

During this retention period, the settling of suspended solids in the effluent will also be enhanced before it is discharged into the sea.

7 Details :

7.1 API Separator

The API Separator has three (3) channels and is sized to handle a total volume of 925 m<sup>3</sup>/hr of wastewater. In each channel, there is a flight scraper to move surface oil towards the effluent end. A rotatable skimmer will then drain the surface oil to an oil collecting sump where it is then pumped to the recovery oil tank.

7.2 Air Flotation Unit

This unit has two channels each capable of handling 50% of the 925m<sup>3</sup>/h water rate. The unit is equipped with a water recycle and dissolved air injection system. The scrapers drain the froth into a collecting sump and the oily froth is then transferred by a pump to the oil recovery tanks for retention and dewatering.

### 7.3 Biological Oxidation Lagoon

There are five sets of floating mechanical aerators in the Biological Oxidation lagoon. These aerators are used to promote biological oxidation. The lagoon is designed for a wastewater retention time of 56 hours at normal flow of 102 m<sup>3</sup>/h and 6 hours at 925 m<sup>3</sup>/h (maximum rate).

### 7.4 Effluent Retention Pond

This Retention Pond will further reduce BOD & TSS content by allowing a longer settling time for the effluent before it is discharged into the sea.

## 8 Design Criteria

The wastewater treatment plant in Mobil Jurong refinery is designed to handle a normal flow rate of 167 m<sup>3</sup>/h up to a maximum rate of 925 m<sup>3</sup>/h during rainy or fire fighting condition and to meet the following allowable effluent quality :

### 9 Treated Effluent :

<u>Parameters</u>	<u>Effluent Quality</u>	<u>Allowable Limits</u>
BOD	39 mg/l	50 mg/l
TSS	50 mg/l	50 mg/l
Oil/Grease	10 mg/l	15 mg/l
Sulfide	0.2 mg/l	1 mg/l
Phenol	0.1 mg/l	1 mg/l

### 10 Capital Cost :

Some S\$24 million, about 4% of the total capital investment, was invested for the construction and installation of the wastewater treatment facilities.

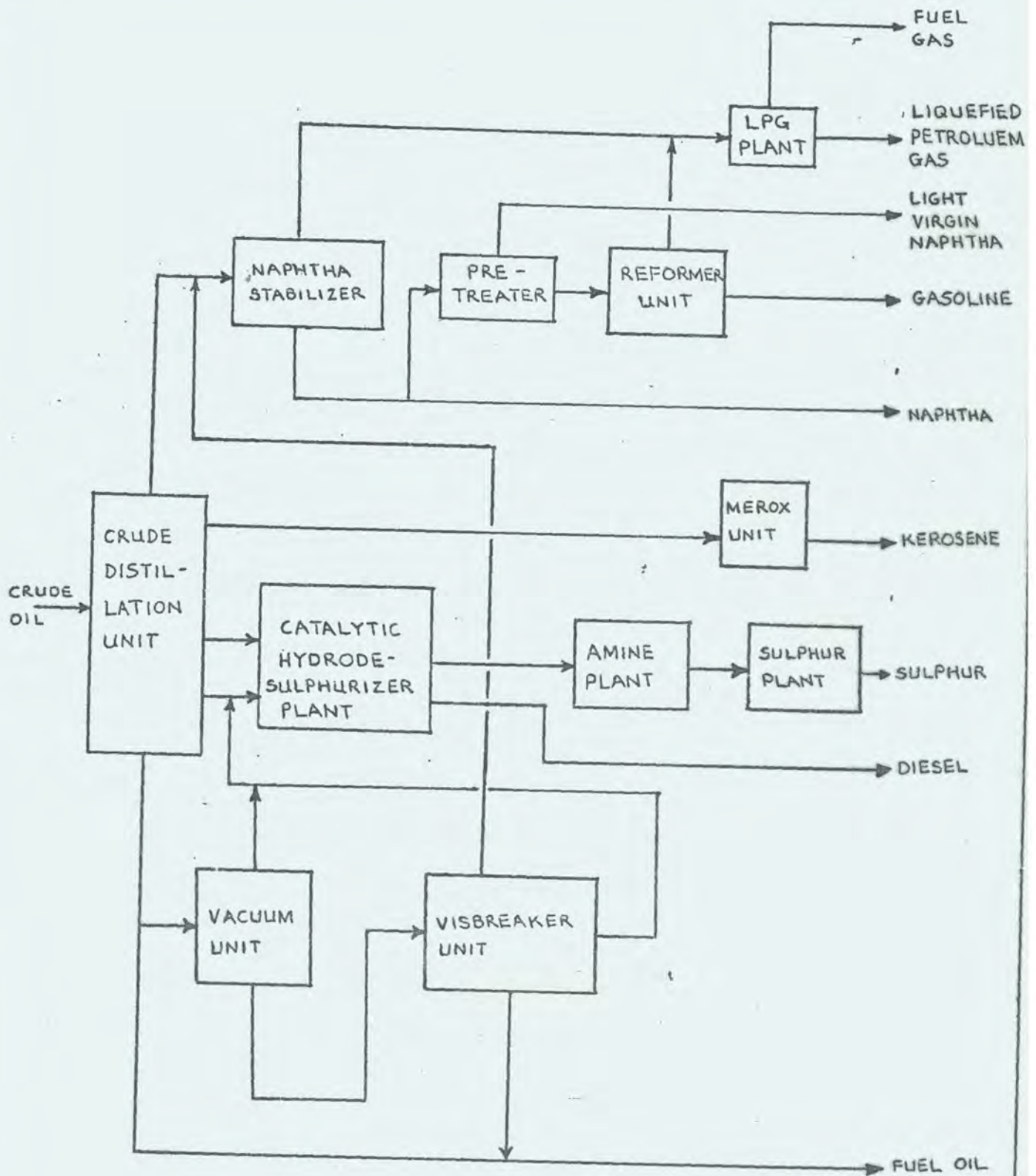
### 11 Manpower Required :

- 11.1 Four Technicians working full-time (24 hours 3 shift-cycle per day).
- 11.2 Two Senior staff on part-time.
- 11.3 Training is normally provided during the commissioning of the facilities.

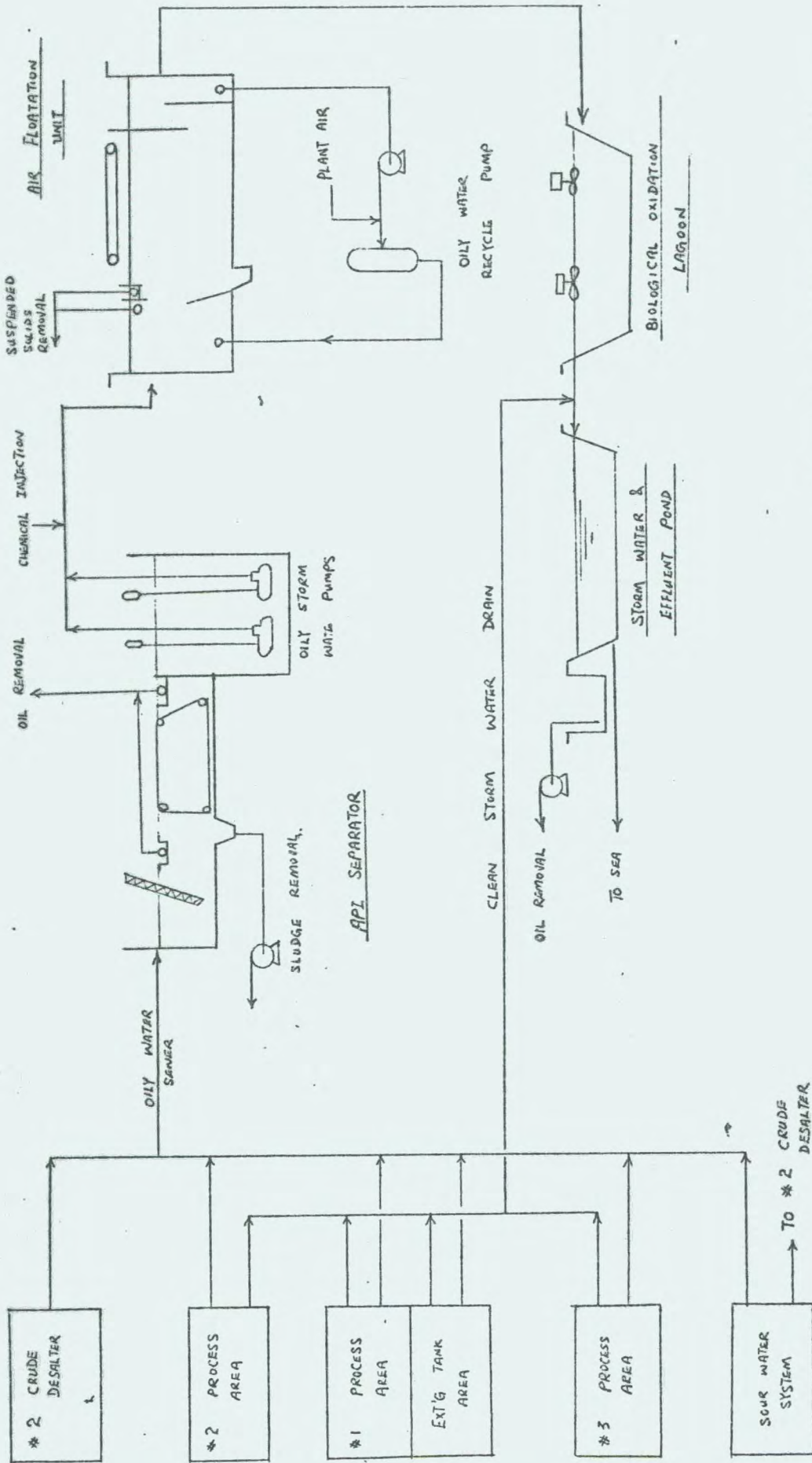
### 12 Operating Cost :

Manpower cost : \$60,000 per year.  
 Power cost : \$47,000 per year.  
 Total cost : \$107,000 per year.





MOBIL OIL SINGAPORE PTE LTD  
REFINERY FLOW DIAGRAM



MOBIL OIL SINGAPORE PTE LTD  
EFFLUENT TREATMENT FLOW DIAGRAM



Amoy Canning Corporation (S) Ltd  
13 Km, Bukit Timah Road  
Singapore 2158

1 Products :

- 1.1 Canned Food
- 1.2 Soya Sauce
- 1.3 Soft drinks
- 1.4 Reconstituted milk

2 Manufacturing Process :

- 2.1 Canned Foods : washing, cutting, cooking, filling, seaming, sterilizing, etc.
- 2.2 Soya Sauce : cooking, mould growing, fermenting, concentrating, filtering, sterilizing, bottling, etc.
- 2.3 Soft Drinks : mixing, sterilising, bottling, etc.
- 2.4 Milk : mixing, boiling, homogenising, bottling, etc.

3 Wastewater Flowrates :

	Source	Flowrate (l/hr)
(a)	Canned food	568 - 1420
(b)	Soya Sauce	284 - 682
(c)	Soft drinks	4545 - 8712
(d)	Milk	1326 - 3030

4 Consultants :

Singapore Institute of Standards & Industrial Research.

## 5 Wastewater Treatment :

The treatment plant used in this factory is a high rate biological filter using synthetic plastic media. The liquid waste is distributed over the surface of two towers in series packed with plastic ('Flocor') medium. The medium provides a large surface area upon which biological growths build up and form a gelatinous film. The waste gravitates down through the medium and is intimately contacted with the biological film which feeds on the organic impurities in the waste and oxidises them to harmless inorganics compounds. The excess humus solids generated by the biological activity are carried down through the medium by the waste and are removed in settlement tanks.

Conventional biological filtration media (eg. stone, gravel or clinker) are limited by the hydraulic and organic loading rates they can accept. Plastic media operate at much higher loading rates thereby reducing the size of the filters. Plastic media have higher specific surface area and voidage fraction which allow higher suspended solids levels to be accepted than with conventional media. For these reasons, filters using synthetic media were chosen for treating the strong organic waste which is readily biodegradable.

Although the operation of the filter in two stages in series requires additional pumping which increases running cost, the two stage arrangement has the advantage of greater filter efficiency. The overall economics, therefore, is in favour of this arrangement.

## 6 Plant Details :

- 6.1 Trickling Filter (2 Nos) :  
3.3 m x 4.2 m x 7.5 m (Height)
- 6.2 Filter Media (each stage)  
3 m x 3.6 m x 6.6 m (Height)
- 6.3 Clarifier  
5.4 m  $\phi$  x 4.8 m (Depth)

## 7 Design Criteria :

- 70% BOD reduction in 1st stage
- 85% BOD reduction in 2nd stage.

## 8 Capital Cost :

S\$400,000 (1975 cost).



9 Manpower Requirement :

1 general worker (full-time)  
 1 supervisor (part-time)  
 1 mechanic (part-time)

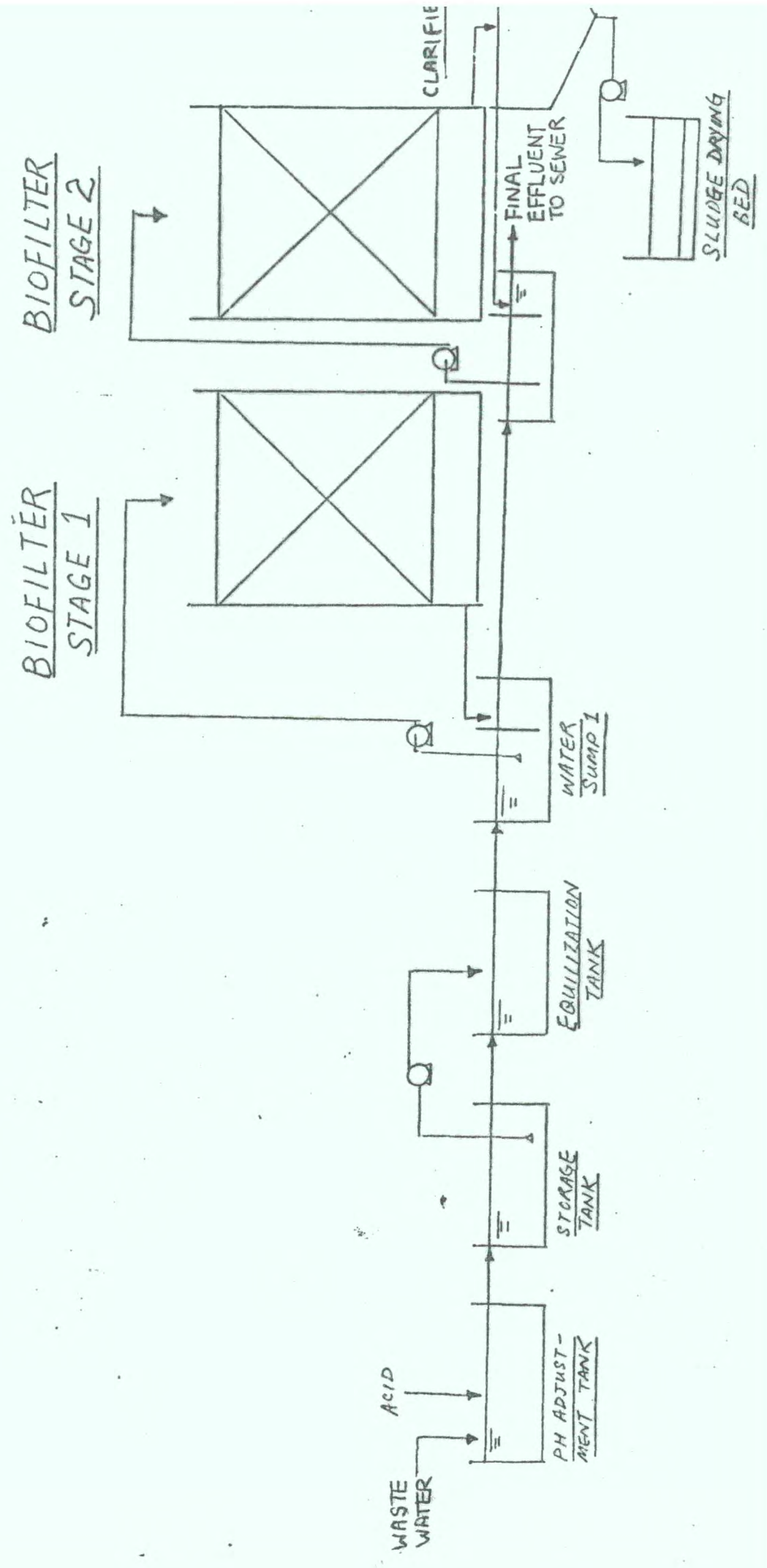
10 Operating Costs :

Manpower : S\$1,000 per month  
 Electricity : S\$ 300 per month  
 Maintenance/repairs : S\$ 400 per month  
 Total : S\$1,700 per month

11 Effluent Quality :

<u>Parameter</u>	<u>Effluent Quality</u>	<u>Allowable Limit</u>
BOD	20 mg/l	400 mg/l
COD	82 mg/l	600 mg/l
Suspended Solids	15 mg/l	400 mg/l
Dissolved Solids	613 mg/l	3000 mg/l
Chloride	98 mg/l	1000 mg/l
Detergent	0.1 mg/l	30 mg/l

# EFFLUENT TREATMENT FLOW DIAGRAM





- 1 Products :  
Canned food and beverages.
  
- 2 Raw Materials :  
Meat, vegetable, eggs, curry powder, soya beams, cane sugar, herbs, chrysanthemum, sugar canes and fruit juice.
  
- 3 Manufacturing Process :
  - 3.1 Canned Food : Chopping, cooking, filling, seaming, sterilising, packing etc.
  - 3.2 Beverages : Syrup blending, mixing, filling, sterilising etc.
  
- 4 Sources of Wastewater :
  - 4.1 Washing and cleaning of raw materials, bottle washing, general cleaning and washing, cooling water and discharge from sterilizers.
  - 4.2 The rate of wastewater discharge is about 580 m<sup>3</sup>/day. The quality of the wastewater is given below :-

BOD <sub>5</sub>	1,500 - 3,000 mg/l
COD	3,000 - 5,000 mg/l
TSS	200 - 660 mg/l
  
- 5 Wastewater Treatment :
  - 5.1 An activated sludge treatment plant is provided to treat the wastewater.
  - 5.2 The wastewater is collected in a pump sump and then pumped into a balancing/holding tank which is aerated with compressed air to prevent odour nuisance.
  - 5.3 From the balancing tank, the wastewater flows at a controlled rate into the aeration tank. Two floating mechanical aerators are provided to supply the oxygen required. The mixed liquor suspended solids in the aeration tank is maintained at 4,000 - 6,000 mg/l.
  - 5.4 The mixed liquor is then allowed to settle in a final clarifier. The supernatant is discharged as the final effluent.
  - 5.5 The sludge accumulated in the clarifier is continuously withdrawn at a rate of 100% influent wastewater flow by two RAS pumps and returned to the aeration tank. The two RAS pumps are also used to discharge surplus sludge into tankers for disposal at sewage treatment works.

6 Details of Treatment Units

	<u>Unit</u>	<u>Capacity</u>	<u>Retention time</u>
(a)	Balancing Tank	100 m <sup>3</sup>	4 hrs
(b)	Aeration Tank	850 m <sup>3</sup>	1.5 days
(c)	Final Clarifier	50 m <sup>3</sup>	2 hrs

7 Capital Cost

S\$500,000

8 Manpower Required

1 full-time trained Operator.

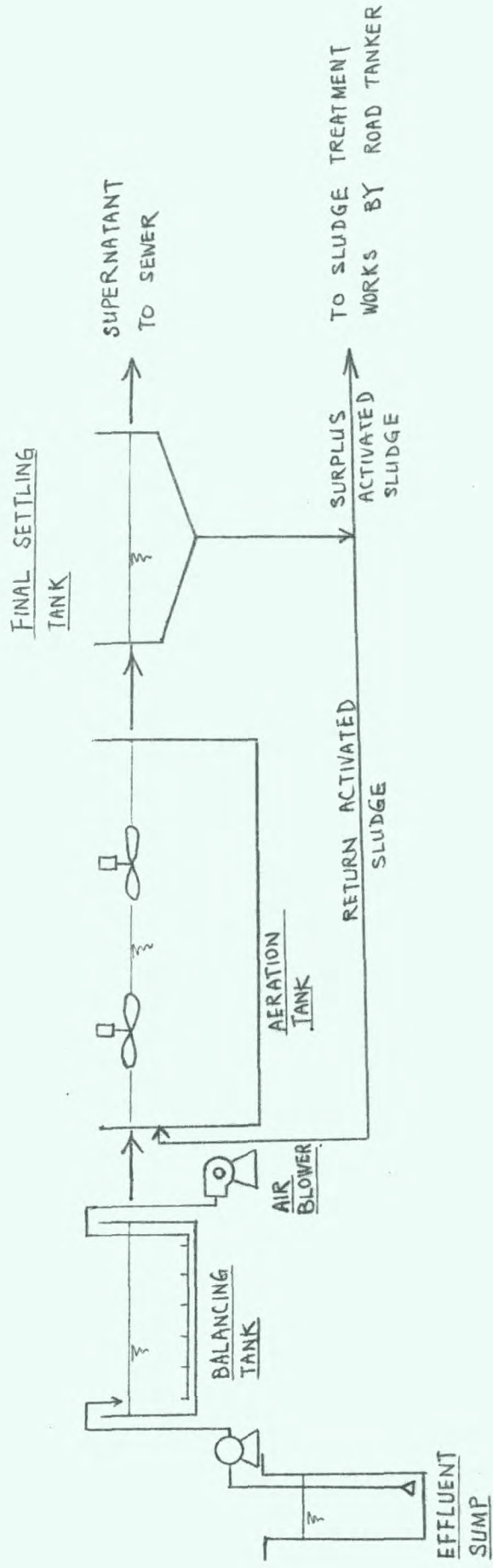
9 Operating Cost

Electricity	\$2,400 /mth
Tariff for sludge disposal	\$ 760 /mth
Transport cost for sludge	\$1,750 /mth
Materials	\$ 500 /mth
Manpower	\$1,200 /mth

Total :	\$6,610 /mth
---------	--------------

10 Land RequiredApprox. 360 m<sup>2</sup>





YEO HIAP SENG LTD

EFFLUENT TREATMENT FLOW DIAGRAM

Singapore Zoological Gardens  
80 Mandai Lake Road,  
Singapore 2572

1 Size of Zoo :

1100 animals (114 species)

2 Source of Wastewater :

- 3.1 Domestic sewage from staff and public toilets.
- 3.2 Wastewater from cafeteria and tea kiosks.
- 3.3 Animal waste and cage washings.
- 3.4 Wastewater from moats and animal bathing pools.

3 Wastewater Flowrates :

Average flowrate : 75 m<sup>3</sup>/day

4 Consultants :

Watson (S E Asia)

5 Wastewater Treatment :

The wastewater treatment plant is based on the activated sludge process. This is a biological wastewater treatment technique in which a mixture of wastewater and biological sludge (micro-organisms) is agitated and aerated. The biological solids are subsequently separated from the treated wastewater and returned to the aeration process as needed.

The system used by the zoo is a modification of the conventional aeration process and is called a Pasveer Ditch. A surface type aerator is used that provides aeration and circulates the wastewater through the ditch which is shaped like a racing track. This type of plant has no primary settlement of sludge and the wastewater is aerated for a 24 hour period rather than the 6-8 hours used in conventional plants. This long aeration period called extended aeration, allows the activated sludge formed to be partially digested within the aeration tank so that it can be dewatered and disposed of without the need for large sludge digestion capacity.

The final sedimentation tank is incorporated into the ditch by providing two parallel channels along one straight stretch of the ditch. Whenever the flow is directed through one channel, the other channel is being used to allow the sludge to settle. The sludge is drawn off and the supernatant discharged always from the quiescent channel.



Because of the simplicity of the design, no trained personal is required to operate the plant. The operation may also be easily automated as in this plant. The capital cost is also much lower compared with other conventional forms of treatment.

6 Treatment Plant Details :

6.1	Oxidation Ditch	
	Area	34.4m x 11.3m
	Channel	1.2m (Depth) 1.2m (Width at bottom) 3.7m (Width at top)
6.2	Sludge Drying Bed (12 Nos)	
	Dimensions	6m x 3m x 0.8m (Depth)
6.3	Aerator	
	Length	1.3m

7 Design Criteria :

Population equivalent	700 persons
Cage washing	54.5m <sup>3</sup> /d
BOD loading	38 kg/day
Effluent standards	20 mg/l BOD 30 mg/l SS

8 Capital Cost :

S\$86,000 (1971)

9 Manpower Required :

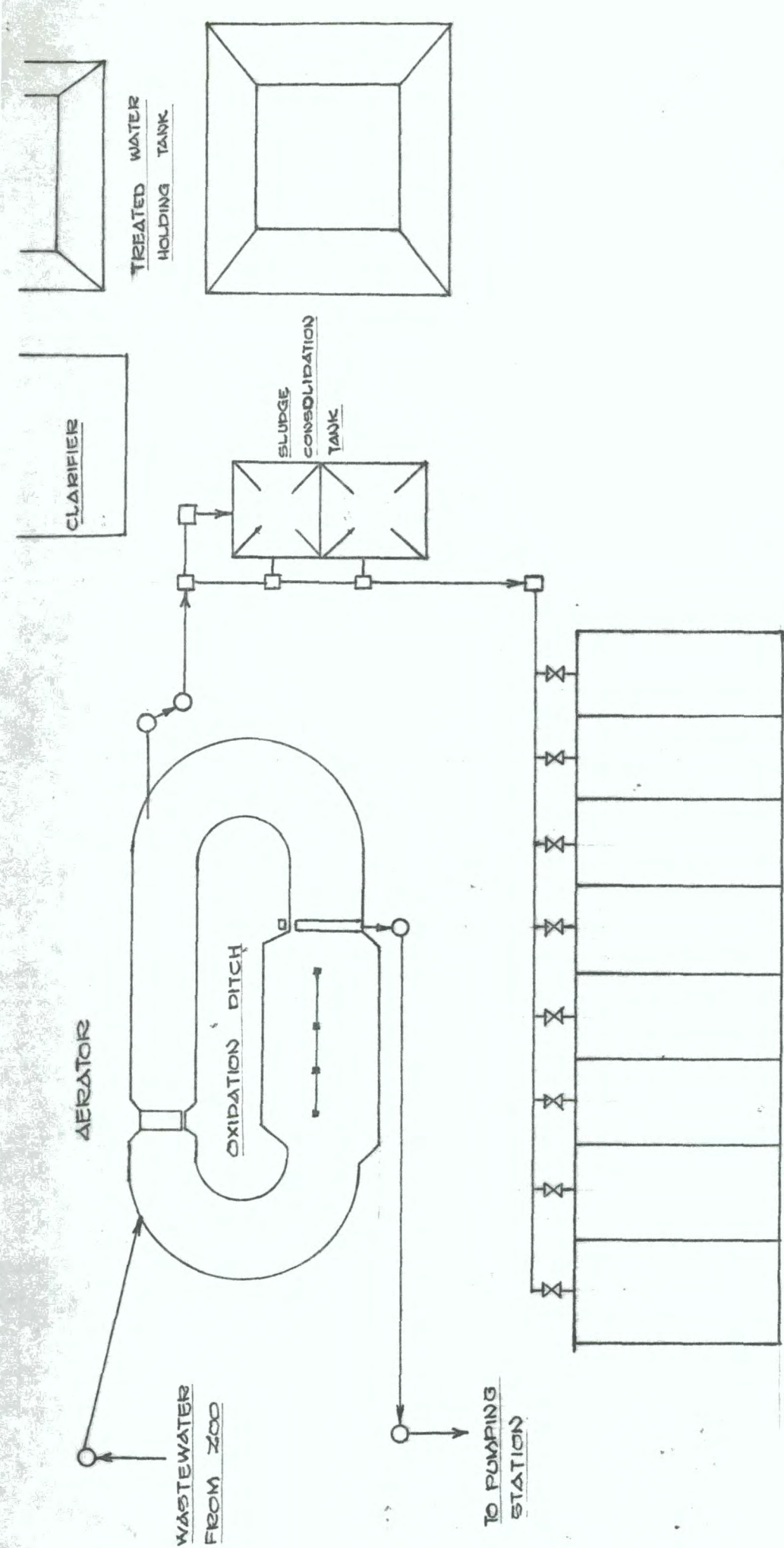
2 persons (part-time)

10 Operational Costs :

Manpower	\$ 600/month
Electricity	<u>\$2,000/month</u>
Total	<u>\$2,600/month</u>

11 Effluent Quality :

<u>Parameter</u>	<u>Effluent</u>
BOD <sub>5</sub>	14 mg/l
COD	49 mg/l
Suspended Solids	23 mg/l
Dissolved Solids	236 mg/l
Ammoniacal N	8.7 mg/l



SINGAPORE ZOOLOGICAL GARDENS  
LAYOUT OF TREATMENT PLANT



ANNEX 12

APPLICATION FORM FOR PERMISSION TO DISCHARGE  
TRADE EFFLUENT INTO A PUBLIC SEWER/WATER-  
COURSE/CONTROLLED WATERCOURSE

**GOVERNMENT OF THE REPUBLIC OF SINGAPORE**  
**The Trade Effluent Regulations, 1976 (Regulation 4)**

To: Assistant Director  
 Water Pollution Control and Drainage  
 Sewerage Department

**Application Form for Permission to Discharge Trade Effluent  
 into the Public Sewer/Watercourse/Controlled Watercourse**

*Particulars of Applicant*

1. Full Name of Applicant .....
2. Position in Firm/Company .....
3. Name of Firm/Company .....
4. Location of Plant/Factory .....
5. Relevant Building Plan No. ....

*Particulars of Trade, Process and Waste*

6. Type of Trade/Business/Industry .....
7. Manufacturing Process (from raw materials to finished products—flow sheet to be attached):  
 .....
8. Layout of various units and plants in the factory and flow direction of trade effluent (Plan to be attached):—  
 .....
9. Approximate quantity of water consumption for the premises in cubic metres/month  
 .....
10. Approximate quantity of trade effluent to be discharged in cubic metres/month and daily peak flow  
 .....
11. Raw materials and chemicals used in the process  
 .....
12. Nature of trade effluent to be discharged (please submit analysis report as shown in Appendix 1 — Page ii)  
 .....
13. I propose to incorporate the following form of treatment of trade effluent before it is discharged (Drawings and details of design to be attached)  
 .....
14. Name of consultant(s), if any .....
15. Any other relevant information (to be attached herewith)
16. I intend to discharge the above stated trade effluents into the public sewer\*/watercourse/controlled watercourse\* at the point(s) shown on the attached plan No. ....  
 (\*delete as necessary).
17. I declare that the particulars in this application form are true in every respect and that I undertake to inform the Sewerage Department, Ministry of the Environment, within fourteen days of any change of the particulars stated in this application occurring at any time after the date of this application.

Date: .....

Signature

 Name of Applicant  
 (in BLOCK LETTERS)



GOVERNMENT OF THE REPUBLIC OF SINGAPORE  
THE WATER POLLUTION CONTROL AND DRAINAGE ACT, 1975  
THE TRADE EFFLUENT REGULATIONS 1976

(to be submitted together with application form)

- A. Source(s) of trade effluent: .....
- B. Observation: (a) Temperature .....
- (b) pH Value .....
- (c) Appearance .....
- C. Results of analysis expressed in milligrams/litre\*
  - 1. BOD.
  - 2. COD
  - 3. Suspended Solids
  - 4. Dissolved Solids
  - 5. Chloride
  - 6. Sulphate
  - 7. Oil & Grease (n-hexane extract)
  - 8. Detergent
  - 9. Cyanide
  - 10. Sulphide
  - 11. Phenolic Compounds
  - 12. Others (where applicable)
  - .....
  - .....

Signature of Chemist: ..... Signature of Applicant: .....

Laboratory: .....

Date: ..... Date: .....

\*Analysis to be carried out in accordance with the latest edition of 'Standard Methods for the Examination of Water and Wastewater' published jointly by the American Public Health Association, the American Water Works Association and the Water Pollution Control Federation.

ANNEX 13

GUIDELINES FOR THE SUBMISSION OF  
TRADE EFFLUENT REPORTS



# GUIDELINES FOR THE SUBMISSION OF TRADE EFFLUENT REPORTS

## MINISTRY OF THE ENVIRONMENT

### 1 PRELIMINARY SURVEY

#### 1.1 Site Investigation

- (a) A detail study of all the manufacturing processes in the factory where water is used and discharged and the pollution potential on each of the processes.
- (b) All sources of trade effluent produced and their respective contribution to the pollution load.
- (c) An inventory of water users and their respective consumptions.
- (d) Variations in the mode of operations and discharges.
- (e) Availability of existing discharge and disposal facilities e.g. public sewers or treatment plants.
- (f) Availability of site for the pretreatment plant required.
- (g) A detached site layout plan showing the location where trade effluent is to be discharged.
- (h) Flow chart, schematic sketches and other relevant drawings have to be submitted also.

#### 1.2 Trade Effluent Sampling

- (a) Samples should be collected as many as possible at all locations where trade effluent is being discharged noting their respective rates of flow.
- (b) Variation in quality during various modes of operation should also be noted. Possibility of balancing flow discharges for the determination of composite samples should be studied.

#### 1.3 Analysis and Suitability Study of Samples

- (a) Complete analysis of samples in accordance with the requirements.
- (b) Analysis of toxic materials and heavy metals should be included if they are present.
- (c) Simple physical and chemical treatment tests e.g. sedimentation and flocculation under different conditions, simple neutralisation test should be carried out.
- (d) Simple biochemical treatment experiments should be carried out if necessary.
- (e) Simple laboratory model study may be made.
- (f) Submission of complete report on the significance and suitability of treatment of the trade effluent.



1.4 Evaluation Study

- (a) Interpretations and evaluation of the analytical results.
- (b) Possibility of reusing the waste water with or without further treatment within the same process or in another system.
- (c) Possibility of altering or modifying existing processes or changes or raw materials and chemical used in the total elimination or reduction of the use of water.
- (d) Feasibility of segregating various waste discharges for separate treatment or re-use.
- (e) Preliminary design of treatment plants and disposal facilities after careful review of different methods of treatment applicable to the effluent under study.
- (f) Evaluation of the effectiveness of the proposed treatment plant.
- (g) Economic study on the various types of treatment units respective of capital and operation cost.

1.5 Submission of Report to Controlling Authority

- (a) Final copy of report to be submitted to the Management and the controlling authority
- (b) Submission of report to the controlling authority after clearance with management.
- (c) Final acceptance of the report or alternative proposals by the Management.
- (d) Date of instruction to consultants to proceed with design work.

2 DETAILED ENGINEERING DESIGN AND CONSTRUCTION

- (a) Type of treatment process accepted by the management and approved by the controlling authority.
- (b) Flow diagram of the process used in the final design.
- (c) Site plan for the location of the proposed treatment plant.
- (d) Engineering design of the whole plant.
- (e) Preparation of specifications and contract documents
- (f) Calling of tenders and acceptance of contractors and ordering of equipment.
- (g) Supervision of construction and testing of equipment.
- (h) Advising on operation procedures of the plant.

3 COMPLETION TIME

- (a) A time schedule of the various stages of the work must be included in any of the reports submitted for consideration.
- (b) Reports on various phases may be submitted one at a time.



