GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. 6

WATER QUALITY

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GOVERNMENT OF MALAYSIA

NATIONAL WATER RESOURCES STUDY, MALAYSIA

SECTORAL REPORT

VOL. 6

WATER QUALITY

OCTOBER 1982

JAPAN INTERNATIONAL COOPERATION AGENCY

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COMPOSITION OF THIS VOLUME

This Volume consists of two parts: Part 1 deals with the subject matters of Peninsular Malaysia and Part 2 is devoted to the States of Sabah and Sarawak.

ABBREVIATIONS

(1) Plan

FMP	:	First Malaysia Plan
SMP	:	Second Malaysia Plan
TMP	:	Third Malaysia Plan
4MP	:	Fourth Malaysia Plan
5MP	:	Fifth Malaysia Plan
6MP	:	Sixth Malaysia Plan
7MP	:	Seventh Malaysia Plan
NEP	:	New Economic Policy
OPP	:	Outline Perspective Plan
RESP	:	Rural Environmental Sanitation Program

(2) Domestic Organization

DID (JPT)	:	Drainage and Irrigation Department
DOA	:	Department of Agriculture
DOE	:	Division of Environment
DOF	:	Department of Forestry
DOFS	:	Department of Fishery
DOM	:	Department of Mines
DOS	:	Department of Statistics
EPU	:	Economic Planning Unit
FAMA	:	Federal Agricultural Marketing Authority
FELCRA	:	Federal Land Consolidation and Rehabilitation Authority
FELDA	:	Federal Land Development Authority
ICU	:	Implementation and Coordination Unit
MARDI	:	Malaysian Agricultural Research and Development Institute
MIDA	:	Malaysian Industrial Development Authority
MLRD	:	Ministry of Land and Regional Development
MMS	:	Malaysian Meteorological Service
MOA	:	Ministry of Agriculture
MOF	:	Ministry of Finance

MOH	:	Ministry of Health
MOPI	:	Ministry of Primary Industries
MRRDB	:	Malaysia Rubber Research and Development Board
NDPC	:	National Development Planning Committee
NEB (LLN)	:	National Electricity Board
PORIM	:	Palm Oil Research Institute of Malaysia
PWD (JKR)	:	Public Works Department
RDA	:	Regional Development Authority
RISDA	:	Rubber Industry Small-holders Development Authority
RRIM	:	Rubber Research Institute of Malaysia
SEB	:	Sabah Electricity Board
SEBC	:	State Economic Development Corporation
S(E)PU	:	State (Economic) Planning Unit
SESCO	:	Sarawak Electricity Supply Corporation
UDA	:	Urban Development Authority

(3) International or Foreign Organization

ADAA	:	Australian Development Assistance Agency
ADB	:	Asian Development Bank
ASCE	:	American Society of Civil Engineers
FAO	:	Food and Agriculture Organization of the United Nations
IBRD	:	International Bank for Reconstruction and Development
ILO	:	International Labour Organization
IMF	:	International Monetary Fund
IRRI	:	International Rice Research Institute
JICA	:	Japan International Cooperation Agency
JSCE	:	Japan Society of Civil Engineers
MOC	:	Ministry of Construction, Japan
OECD	:	Organization for Economic Cooperation and Development
OECF	:	Overseas Economic Cooperation Fund, Japan
UK	:	United Kingdom
UNDP	:	United Nations Development Program

UNSF	:	United Nations Special Fund
US or USA:		United States of America
US/AID	:	United States Agency for International Development
USBR	:	United States Bureau of Reclamation
WHO	:	World Health Organization
WMO	:	World Meteorological Organization

(4) Others

B	:	Benefit
BOD	:	Biochemical Oxygen Demand
C	:	Cost
CIF	:	Cost, Insurance and Freight
COD	:	Chemical Oxygen Demand
D&I	:	Domestic and Industrial
dia	:	Diameter
EIRR	:	Economic Internal Rate of Return
El.	:	Elevation above mean sea level
Eq.	:	Equation
Fig.	:	Figure
FOB	:	Free on Board
FSL	:	Full Supply Level
GDP	:	Gross Domestic Product
GNP	:	Gross National Product
H	:	Height, or Water Head
HWL	:	Reservoir High Water Level
LWL	:	Reservoir Low Water Level
O&M	:	Operation and Maintenance
Q	:	Discharge
Ref.	:	Reference
SITC	:	Standard International Trade Classification
SS	:	Suspended Solid
V	:	Volume
W	:	Width

ABBREVIATIONS OF MEASUREMENT

Length

mm = millimeter
cm = centimeter
m = meter
km = kilometer
ft = foot
yd = yard

Area

cm^2 = square centimeter
m^2 = square meter
ha = hectare
km^2 = square kilometer

Volume

cm^3 = cubic centimeter
l = lit = liter
kl = kiloliter
m^3 = cubic meter
gal. = gallon

Weight

mg = milligram
g = gram
kg = kilogram
ton = metric ton
lb = pound

Time

s = second
min = minute
h = hour
d = day
y = year

Electrical Measures

V = Volt
A = Ampere
Hz = Hertz (cycle)
W = Watt
kW = Kilowatt
MW = Megawatt
GW = Gigawatt

Other Measures

% = percent
PS = horsepower
° = degree
' = minute
" = second
°C = degree in centigrade
10^3 = thousand
10^6 = million
10^9 = billion (milliard)

Derived Measures

m^3/s = cubic meter per second
cusec = cubic feet per second
mgd = million gallon per day
kWh = kilowatt hour
MWh = Megawatt hour
GWh = Gigawatt hour
kWh/y = kilowatt hour per year
kVA = kilovolt ampere
BTU = British thermal unit
psi = pound per square inch

Money

M$ = Malaysian ringgit
US$ = US dollar
¥ = Japanese Yen

CONVERSION FACTORS

	From Metric System	To Metric System
Length	1 cm = 0.394 inch 1 m = 3.28 ft = 1.094 yd 1 km = 0.621 mile	1 inch = 2.54 cm 1 ft = 30.48 cm 1 yd = 91.44 cm 1 mile = 1.609 km
Area	1 cm^2 = 0.155 sq.in 1 m^2 = 10.76 sq.ft 1 ha = 2.471 acres 1 km^2 = 0.386 sq.mile	1 sq.ft = 0.0929 m^2 1sq.yd = 0.835 m^2 1 acre = 0.4047 ha 1 sq.mile = 2.59 km^2
Volume	1 cm^3 = 0.0610 cu.in 1 lit = 0.220 gal.(imp.) 1 kl = 6.29 barrels 1 m^3 = 35.3 cu.ft 10^6 m^3 = 811 acre-ft	1 cu.ft = 28.32 lit 1 cu.yd = 0.765 m^3 1 gal.(imp.) = 4.55 lit 1 gal.(US) = 3.79 lit 1 acre-ft = 1,233.5 m^2
Weight	1 g = 0.0353 ounce 1 kg = 2.20 lb 1 ton = 0.984 long ton = 1.102 short ton	1 ounce = 28.35 g 1 lb = 0.4536 kg 1 long ton = 1.016 ton 1 short ton = 0.907 ton
Energy	1 kWh = 3,413 BTU	1 BTU = 0.293 Wh
Temperature	°C = (°F - 32)·5/9	°F = 1.8°C + 32
Derived Measures	1 m^3/s = 35.3 cusec 1 kg/cm^2 = 14.2 psi 1 ton/ha = 891 lb/acre 10^6 m^3 = 810.7 acre-ft 1 m^3/s = 19.0 mgd	1 cusec = 0.0283 m^3/s 1 psi = 0.703 kg/cm^2 1 lb/acre = 1.12 kg/ha 1 acre-ft = 1,233.5 m^3 1 mgd = 0.0526 m^3/s
Local Measures	1 lit = 0.220 gantang 1 kg = 1.65 kati 1 ton = 16.5 pikul	1 gantang = 4.55 lit 1 kati = 0.606 kg 1 pikul = 60.6 kg

Exchange Rate
(as average between July and December 1980)

$1 = M$2.22
¥100 = M$1.03

PART 1

PENINSULAR MALAYSIA

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1. INTRODUCTION

This Report presents the results of water quality study including the inventory of existing purification systems, present water quality in rivers, present monitoring systems of water quality, sewerage development plans, salinity river stretches, projection of water quality, water pollution abatement plan, planning materials, economic benefit and cost and manpower requirement, basing on the numerous data and studies available in 1980 in Malaysia.

The study on the present water quality in the rivers was carried out for 26 rivers which were selected based on the water quality in 1979 and 1980 and the water quality in 1990 and 2000 were projected for all basins except three basins, i.e. P. Langkawi, P. Pinang and Golok Basins. Water pollution abatement plans were drawn up for the basins where BOD concentration is higher than the target values. Public sewerage system in urban area and purification facilities in palm oil mills and rubber factories were proposed for water pollution abatement plans in the Study. To carry out the water pollution abatement plans will be expected to decrease the pollutant load into rivers and keep the water quality clean.

2. INVENTORY OF EXISTING FACILITIES FOR POLLUTION ABATEMENT

2.1 General Purification Systems

The effluent from industries, mines, households and livestock farms has already very much polluted river water in Peninsular Malaysia. Especially, rivers which flow through major or industrial cities are extremely polluted. Due to this pollution, these rivers do not keep their good water quality for water supply, fishery, industrial water, agricultural water and environmental conservation. In order to keep the good quality of river water, it is necessary to establish purification systems of wastewater from pollutant sources.

Generally, the kinds of purification systems existing in Peninsular Malaysia are categorized as physical, chemical and biological.

2.1.1 Physical purification methods

Physical purification methods are used in the pretreatment processes designed to eliminate large, floatable or very dense substances whose presence could upset the proper operation of the treatment installation.

(1) Screening

Screening is one of the most common pretreatment processes. The finesses of screening are determined not only by the dimension of the matter to be removed but also by the nature of the treatment envisaged in the future.

The most frequently used screens are curved bar screen, rack and pinion screen, and screen equipped with brushes, combs or rakes.

(2) Grit/sand removal

Grit/Sand removal is designed to remove from raw water all the gravel, sand and other large particles to avoid deposits in the channels and pipes, so as to protect pumps and other apparatus against abrasion, and also to avoid overloading the ulterior treatment process.

(3) Calrification

Clarification is designed to eliminate suspended solid from the liquid by gravity. Sludge recirculation clarifiers as well as sludge blanket units have been developed. These accelerated clarifiers can be utilized for all treatment processes involving the use of chemical.

(4) Floatation

There are two types of floatation: floation using air and electro-floatation.

2.1.2 Chemical purification methods

Chemical purification refers to the removal of pollutants from effluent by undergoing several chemical alterations. These processes include precipitation, flocculation, ion exchange, carbon absorption, oxidation and reduction.

(1) Chemical Precipitation

Chemical precipitation is one of the most common chemical purification processes. It is used to remove some of the inorganic matter from wastewater; for example, elevated pH aids in the removal of heavy metals by precipitation of the Hydroxides and carbonates. The addition of hydrated lime to hardwater also removes the bicarbonates.

(2) Flocculation

If flocculating agents are added to the effluent, it will result in the formation of flocs which would then be settled. Some of the flocculating agents are ferric chloride, aluminium sulphate and copper chloride.

(3) Ion Exchange

It is widely used to soften or demineralise water and to recover useful by-products from industrial effluent. Ion exchange is basically a process of exchanging certain undersirable cations and anions of the wastewater, such as sodium, hydrogen, etc. It is widely used in the removal of heavy metal ions from metal-plating wastewater.

2.1.3 Biological purification methods

Biological purification methods relay on the breakdown of organic matter in effluent by micro-organisms under controlled conditions. The main biological purification methods are aerobic digestion and anaerobic digestion. The aerobic bacteria in the presence of dissolved oxygen attack and break-down complex organic compounds into carbon dioxide and water. Anaerobic bacteria in the absence of dissolved oxygen attack and break-down complex organic compounds into methane, hydrogen sulphide, carbon dioxide and ammonia.

Some of more common biological purification methods used for purifying industrial effluent are trickling filtration, activated sludge process, oxidation ditch, anaerobic pond and aerobic pond.

(1) Trickling Filtration

The trickling filter consists essentially of a circular structure containing a packed bed of suitable depth of inert material such as rock, stone, slag, coal, coke and gravel. Waste is deposited over the bed by rotary distributors or fixed nozzles and trickles down through the bed to the underdraines which take away the purified waste. The process is continuous and requires adequate ventilation. The medium is covered with an active gelatinous film containing bacteria, protozoa and fungi which in the presence of oxygen brings about the biological purification and stabilization of the waste.

(2) Activated Sludge

Activated sludge is an aerobic system which consists of an aeration tank followed by a sedimentation tank. In the aeration tank, a mixture of settled effluent and bacteriologically active sludge is aerated, and after settlement in the sedimentation tank, the effluent is discharged. Part of the activated aludge settled in the sedimentation tank is returned to the aeration unit to assist oxidation of a further quantity of effluent. The aeration can be done by the use of diffused air or by a mechanical aeration system.

(3) Oxidation Ditch

It may be used where land is available for stabilization ponds or trickling filters. The effluent in the oxidation ditch is made to flow pass the aeration rotors at brief intervals during which it becomes aerated. The amount of flocs in the system is much more than that in the activated sludge plant. However, the process is not sensitive to sudden increase in the loading.

(4) Anaerobic Pond

Under the anaerobic conditions in the pond, organic matter is broken down with the emission of gasses like methane, ammonia and hydrogen sulphide. Anaerobic digestion is suitable for waste with a high concentration of organic matter. The effluent resulting from anaerobic purification is not suitable for discharge into any watercourse. It has to be further treated in an aerobic pond.

(5) Aerobic Pond

In properly designed aerobic ponds arranged in series, solids are retained and organic matter completely digested and stabilised. The organic matter is oxidised to carbon dioxide, ammonia and water. The oxygen required for oxidation is obtained from the air or the photosynthetic activity of algae in the pond. Oxygen may also be introduced by artificial aeration.

2.2 Sewerage System

The cities which operate the waterborne sewer system in Peninsular Malaysia are Kuala Lumpur (including Petaling Jaya and Shah Alam) and Georgetown (including Bandar Bayan Baru) in Pulau Pinang.

2.2.1 Sewerage system in Kuala Lumpur and its vicinity

Out of estimated population of 1,080,000 in 1974 in Kuala Lumpur and its vicinity, approximately 150,000 people are served by the waterborne sewer system. About 300,000 to 350,000 people are served by septic or Imhoff tanks, some having biological filters, and the remainder use less satisfactory systems, mainly night soil buckets, pit latrines or over-water course latrines.

The sewerage from Kuala Lumpur and its vicinity is mainly purified at the Pantai Sewage Treatment Works having primary settlement tanks and sludge digestion tanks before it is discharged into the Kelang river. There are other treatment works in Kuala Lumpur each dealing with flows from a specific community such as military establishment, leper settlement or package treatment plant. The sewarage and purification systems of the stated area are summarized in Table 1 (Ref.1).

2.2.2 Sewerage system in Georgetown and its vicinity

Out of estimated population of 482,000 in 1980 in Georgetown and its vicinity, approximately 222,000 people use the sewer system. In Georgetown 217,000 people use the sewer system and about 96,000 people rely on septic tanks whereas about 121,000 people use the conservancy system. However, about 48,000 people are without any from of sanitary waste disposal facilities other than the use of open pits, privies, drains and the sea. The wastewater collected from Georgetown is discharged through the Western Channel to the sea without purification.

In Bandar Bayan Baru, 5,000 people are served by the sewer system and 13,000 people rely on septic tanks, night soil collection service and pit latrines. The sewage from Bandar Bayan Baru is primarily purified in stabilization ponds and then discharged to the nearby Kluang river. The sewerage and purification systems in Georgetown and Bandar Bayan Baru are shown in Table 1 (Ref. 2).

2.3 Purification System for Rubber and Palm Oil Processing

2.3.1 Purification system for rubber processing

The effluent from natural rubber processing industries has been one of the important sources of water pollution in Malaysia. Three main types of rubber namely, Conventional Grade, Block (Standard Malaysian Rubber (SMR)) and Latex Concentrate have different characteristics of effluent. These characteristics of effluent from factories which process various types of products are shown in Table 2. Due to these various types of characteristics, it is necessary to choose the suitable purification system for the treatment. The Rubber Research Institute of Malaysia (RRIM) has shown the effectiveness of biological methods, incorporating anaerobic and facultative ponding system and oxidation ditch system in purifying wastewater from SMR block rubber factories. Since the effluent from conventional sheet and crepe factories is similar to those from SMR block rubber, the system is expected to apply equally well (Ref. 3).

In the case of latex concentrate effluent, technology is at a less advanced stage. To test the performance of the ponding system, pilot plant which consists of 1 anaerobic tank and 3 facultative tanks was established at a latex concentrate factory by the natural rubber industry with RRIM in Malaysia. The result shows that it is good for BOD removal but not so good for total nitrogen and ammoniacal nitrogen removal (Ref. 3).

The system which consists of 1 anaerobic pond and 2 facultative ponds in series has been established for a combined effluent from a latex concentrate plant and a SMR block rubber line by a commercial factory (Ref. 3).

In general, biological ponding system is established as a purification system for rubber processing effluent. The summary of effluent from rubber processing factories is shown in Table 3.

At present (1980), the investigation of rubber processing factories including characteristics of effluent, effluent volume and purification system is carried out by DOE. DOE divides Peninsular Malaysia into four regions, namely Northern Region, Central Region, Southern Region and Eastern Region. Based on this investigation, inventory of purification systems for rubber processing effluent by each region has been framed and is shown in Table 4 to 11. Next, Table 12 shows the summary of existing purification systems used in 206 rubber processing factories in Peninsular Malaysia. According to this Table, 121 factories have established some kind of purification systems and among them 113 factories use biological purification systems which are anaerobic, aerobic, facultative or their combination, and 9 factories use land disposal, 3 factories carry out complete recycle of effluent, 1 factory is going to construct purification system, 48 factories have no purification system, 11 factories have a construction plan of purification system and data is not available for 13 factories.

2.3.2 Purification system for palm oil processing

The effluent from palm oil processing can generally be described as a high viscous brown liquid, high in total solids and oil, having BOD_3 and COD values approaching 22,000 mg/lit and 61,000 mg/lit respectively. Table 13 shows the characteristics of effluent for palm oil mills (Ref. 4).

Popular purification system applied in palm oil mills is biological because of its simple facilities and the effectiveness of pollutant abutement similar as in rubber processing factories; however, physical and chemical purification systems are still being used.

The distinctive characters of effluent from palm oil mill are as follows. Biochemical analysis has shown that sludge contains significant quantities of protein and carbohydrates which can be used as animal feed (Ref. 5). Inorganic analysis of the effluent has also shown that the level of metals is low and does not represent any serious toxicological problem. Hence, the effluent can be applied on to land as fertilizer (Ref. 5).

At present, DOE is collaborating with the Asian Institute of Technology, Bankgkok, on crude palm oil waste disposal. Tables 14 to 20 show the inventory of purification system for palm oil processing based on this investigation and Table 21 summarizes the types of purification being applied or being implemented in various palm oil mills. The types of purification have been broadly categorized and several modifications exist, or combination of two types is being used. The main types of purification are biological system and oxidation ponding systems. There are 56 palm oil mills using such systems. Land disposal system for raw effluent or partially treated effluent is being used by 35 palm oil mills.

2.4 Purification System for Tin Mine Effluent

Most of the tin mines in Peninsular Malaysia are centred in the Kinta river basin, Kelang river basin and Langat river basin. Tin mining waste contains large amounts of inorganic SS that does not settle readily. The amount of silt allowed to be discharged into rivers during mining operation is controlled by legislation and supervised by DID and DOM. The permissible SS effluent value from any tin mine is 11,300 mg/lit (800 grains/gallon). This value is comparatively high for permissible SS value of rubber or oil palm processing effluent. According to the five year sedimentation data at the station of the Chenderiang river (a tributary of Kinta river) analysed by DID, the sediment concentration level distribution is 200 - 10,000 mg/lit. Another report shows that the product of the mine effluent is characterized by turbidity of the order of 5,000 - 10,000 mg/lit (Ref. 6). It means that large amount of SS passes down the river.

Useful purification system for tin mining effluent is a series of lagoons having long retention periods. After passing through those lagoons, purified water can be cyclically used for operation of water jet and is then discharged at low SS concentration.

2.5 Purification System for Industrial Effluent

Industrial effluent has various characteristics depending upon manufacturing processes. The various purification systems for industrial effluent have already been described in 2.1.1 & 2.1.2.

"Industrial Effluent Source Survey" was carried out by DOE in 1978 for 45 factories in Perai and Butterworth industrial estates. Tables 22 to 23 show inventory of industrial purification systems in the stated area. According to Tables 22 to 23, 26 factories have no purification facilities, 10 factories have some kind of pretreatment facilities using only waste traps, waste filters and sedimentation tanks and data is not available for 9 factories. In short, the existing industrial factories in the stated area have almost no purification facilities except pretreatments or simple physical purification facilities.

2.6 Purification System for Animal Husbandry Effluent

The pig population centred in particular areas, for example Pulau Pinang, Perak, Selangor and Negeri Sembilan, in Peninsular Malaysia is on the rise. As pig farms usually have no pond or space for pig waste treatment, piggery waste is becoming a source of water pollution in Peninsular Malaysia. The lack of lagoons or space hinders their implementations of purification of pig waste. Hence, waste from pig farms is usually discharged to rivers without being purified. However, in the suburbs of Kuala Lumpur and Ipoh, pig wastewater is usually discharged to former mining pools which are now used to cultivate fish of plankton feeder. In this way, the pig waste is used as a feed for fish. It is advisable that pig farmers should establish purification facilities so as not to pollute river water. Several types of biological purification systems will be using Aerobic-Algal Lagoons, Facultative Lagoons, Anaerobic Lagoons, Aerated Lagoons, Oxidation Ditch, Activated Sludge Method,Compositing and Anaerobic Digesters (Ref. 7).

3. PRESENT CONDITION OF WATER QUALITY BY RIVER

3.1 Water Quality

Since March, 1978, regular river water quality monitoring program has been carried out partly to assess the existing conditions of national waters by DOE.

The numbers of Water Quality Monitoring Station carried out by DOE were 371 in 1978 and 443 in 1979.

Based on the data obtained from DOE in 1978 and 1979, same water quality monitoring stations for 26 rivers in both years were selected for analytical comparison. Tables 24 to 26 and Tables 27 to 29 show the mean, maximum and minimum values of the five selected parameters namely, pH, BOD, COD, SS and ammoniacal nitrogen, in 1978 and 1979.

However, only pH, BOD, SS and ammoniacal nitrogen are used to indicate the degree of pollution by DOE.

3.1.1 BOD_5

BOD_5 is commonly used as a primary indicator of organic pollution. It is also useful to classify the stretches of a river with respect to its BOD range. An acceptable U.K. classification initiated by D. Balfour and Sons (Ref. 1) is based on the 5-day 20°C BOD as follows;

BOD_5	Classification
0 - 4 mg/lit	Clean
4 - 8 mg/lit	Mildly Polluted
8 - 12 mg/lit	Moderately Polluted
more than 12 mg/lit	Grossly Polluted

The BOD classification is applied for the 26 rivers based on the data in Tables 24 - 29 as shown in Table 30. The Table shows that some stretches in 5 rivers; the Kedah river, Merbok river, Juru river, Kelang river and Pahang river, were moderately or grossly polluted in 1978; 8 rivers; the Kedah river, Merbok river, Juru river, Buloh river, Kelang river, Langat river, Linggi river, and Endau river, were also moderately or grossly polluted in some stretches in 1979. There were 4 rivers; the Kedah river, Merbok river, Juru river and Kelang river,especially polluted. It also shows the number of moderately or grossly polluted rivers, increased. The distributions of the mean BOD level along the four especially polluted rivers, in 1978 and 1979, are shown in Fig. 1.

The nine moderately or grossly polluted rivers in 1978 and 1979 are selected for analysis:

(1) Kedah River

The mean BOD levels were in the range of 2.2 - 87.8 mg/lit at 7 WQMSs in 1978 and 1 - 15 mg/lit in 1979 at 12 WQMSs. The water became polluted throughout the year in 1979. Especially, WQMS No. 6206608 at 65.3 river km had recorded the highest level at the upstream in both 1978 and 1979 (see Fig. 1). It seems that it was the sugar factory nearby that had contributed to the high BOD level. The values in 1978 were generally higher than those in 1979.

(2) Merbok River

The mean BOD levels were in the 3 - 188 mg/lit range at 7 WQMSs in 1978 and in the nil - 248 mg/lit range in 1979 at 7 WQMSs. Lower levels of the mean BOD were recorded at the middle stretch of the river and the highest level was recorded at the upstream, in both 1978 and 1979. Generally, the mean BOD levels for 1979 is lower than that of 1978 at the respective point along the river (see Fig. 1). It is judged that several rubber processing factories and domestic households in the Petani River, a tributary near WQMS No. 5705606, were large pollutant sources.

(3) Juru River

Juru River is one of the most polluted rivers in Peninsular Malaysia. The mean BOD level was in the 4.3 - 158 mg/lit range at 9 WQMSs in 1978 and in the 2.8 - 107 mg/lit range at 9 WQMSs in 1979. The high BOD levels recorded at WQMS Nos. 5304605 and 5304607 (see Fig. 1) were most probably due to waste effluent received from rubber processing factories, a number of small mills and the largest piggery community in the area. Effluents from industrial estate located near the coastal area was also discharged.

(4) Buloh River

The mean BOD levels were in the 0.9 - 7.3 mg/lit range at 8 WQMSs in 1978 and in the 1.5 - 416 mg/lit range at 9 WQMSs in 1979. The mean BOD levels increased rapidly in 1979. It seems that the growing industry in the river basin had contributed to the increase in BOD level. Furthermore, rubber and palm oil factories were also main pollutant sources. There were three WQMS recorded grossly polluted levels in 1979.

(5) Kelang River

The mean BOD levels were in the 1.5 - 13.3 mg/lit range at 10 WQMSs in 1978 and in the 1.1 - 9.9 mg/lit range at 12 WQMSs in 1979. Due to the great population and industrial factories at the middlestream, higher levels of the mean BOD were observed within that stretch of river (see Fig. 1). This river was moderately or grossly polluted.

(6) Langat River

The mean BOD levels were in the 0.5 - 1.9 mg/lit range at 11 WQMSs in 1978 and in the 0.8 - 8.0 mg/lit range at 11 WQMSs in 1979. The Langat River was clean in 1978 but two WQMS recorded 4.7 and 8.0 mg/lit in 1979. There are several rubber factories which seemed the main pollutant sources in this river basin.

(7) Linggi River

The mean BOD levels were in the 1.0 - 8.0 mg/lit range at 12 WQMSs in 1978 and in the 0.9 - 19.9 mg/lit range at 12 WQMSs in 1979. In 1978 and 1979 this river was clean or mildly polluted except one WQMS in 1979 recorded 19.9 mg/lit which is classified as grossly polluted. This was due to the existence of pig farms, rubber factories and domestic households in Seremban.

(8) Endau River

There was only one WQMS in 1978 and the mean BOD level was 3.5 mg/lit; however, in 1979, the mean BOD levels were in the 0.7 - 9.6 mg/lit range at 5 WQMSs. This river was classified clean in 1978 and 1979 except one WQMS recorded 9.6 mg/lit which is classified as moderately polluted in 1979. Several palm oil mills and domestic households in Keluang seemed to be the main pollutant sources.

(9) Pahang River

The mean BOD levels were in the 0.6 - 55.8 mg/lit range at 12 WQMSs in 1978 and in the 0.5 - 8.0 mg/lit range at 12 WQMSs in 1979. The highest mean BOD levels were recorded at a WQMS which is located at the Mai bridge, the way to Jerantut, in both 1978 and 1979. It is most probably due to the waste effluent discharged from the surrounding palm oil mills.

(10) Other 17 Rivers

The mean BOD levels of other 17 rivers recorded were less than 8 mg/lit, and therefore are classified as clean or mildly polluted in both 1978 and 1979.

3.1.2 pH

The mean pH levels recorded in all 26 rivers were in the 3.4 to 8.0 range in 1978 and in the 3.6 - 8.0 range in 1979. Most of the WQMS with low mean pH levels were in the tidal zone. However, the mean pH levels of Batu Pahat river at almost all WQMS were less than 4.0. Since WHO must have recommended an optimum permissible pH range of 6.5 to 9.2 for drinking water (Ref. 8), therefore the water of all the rivers except the light rivers; the Kerian river, Tengi river, Langat river, Batu Pahat river, Melaka river, Benut river, Sekudai river and Johor river, may be considered safe for drinking purposes. The mean pH levels of these eight rivers recorded to be less than 6.5 in both the years; 1978 and 1979. Among them the distributions of mean pH levels of four rivers; the Kerian river, Tengi river, Langat river and Batu Pahat river, are shown in Fig. 2.

3.1.3 Suspended solids

Suspended Solids (SS) is one of the most important pollutants in Peninsular Malaysia because of the tin mining operation, the waste effluent consists chefly of inorganic SS that does not settle down readily. As mentioned in 2.4, most of the tin mines in Peninsular Malaysia are centred in the river basins of the Kinta, Kelang and Langat. These three rivers are classified in class D or E, according to the following SS concentration classification which has been used by D. Balfour & Sons (Ref. 1):

SS	Classification
Class A	0 - 50 mg/lit
Class B	50 - 250 mg/lit
Class C	250 - 500 mg/lit
Class D	500 - 1,000 mg/lit
Class E	more than 1,000 mg/lit

The SS Classification is applied for the 26 rivers as shown in Table 31 (also see Fig. 14).

According to this SS Classification, the Perai river, Melaka river, Kuantan river, Bernam river, Selangor river, Buloh river and Linggi river also detected more than 1,000 mg/lit of SS concentration at their downstream or estuaries in 1978 or 1979. The high SS concentration detected was mainly due to industrial factories and domestic households in towns located at the downstreams or coastal areas.

Fig. 3 shows the mean SS levels of four rivers with high mean SS levels in 1978 and 1979. These four rivers are the Kinta river, Kelang river, Langat river and Melaka river.

3.1.4 Ammoniacal nitrogen

Ammoniacal Nitrogen (NH_4-N), is as important as BOD in indicating the level of organic pollution. Taking 1 mg/lit as the maximum permissible limit of Ammoniacal Nitrogen concentration for fishery, the DOE data show that almost all along the rivers of Juru, Kelang and Linggi in 1978, and of Merbok, Juru, Buloh, Kelang, Linggi and Melaka in 1979, recorded more than 1 mg/lit of mean Ammoniacal Nitorgen. Hence, from 1978 to 1979, there was an increase of 3 rivers which were unsuitable for aquatic living. The highest level of Ammoniacal Nitrogen concentration of 65.6 mg/lit was recorded in Kelang river in 1978, and the highest level recorded in Merbok river in 1979 was 45.5 mg/lit. The level of NH_4-N is correlated with the level of BOD_5. For most of the rivers which were polluted or grossly polluted had recorded more than 1 mg/lit or NH_4-N. Fig. 4 shows the distribution of mean Ammoniacal Nitrogen levels of the Juru river, Kelang river, Linggi river and Melaka river.

3.2 Major Pollutants

Mean of mean levels, max. of max. levels and min. of min. levels of pH, BOD_5, SS and NH_4-N of Table 24 to Table 29 are shown in Table 32 and Table 33. pH, BOD_5, SS and NH_4-N are indicators of major pollutants.

The WQMS are generally polluted if they satisfy the following conditions derived from pollution classification:

(1) pH : more than 9.2 or less than 6.5

(2) BOD : more than 8 mg/lit

(3) SS : more than 500 mg/lit

(4) Ammoniacal Nitrogen : more than 1 mg/lit

The number of WQMS polluted by the major pollutants using Max. & Min. for pH and Max. for BOD, SS and NH_4-N of Table 32 to 33 for each river is shown in Table 34.

Using Table 32 and Table 33 mean BOD_5 and SS of 26 rivers in 1978 and 1979 are shown in Fig. 13 and Fig. 14.

3.3 Pollutant Sources and Their Locations

Major/industrial cities, rubber factories, palm oil mills, tin mines and pig farms are considered as chief pollutant sources of river water pollution in the Study.

In order to observe river water pollution by effluent from rubber factories,Peninsular Malaysia is divided into four regions by DOE. These are the Northern Region including Perlis, Kedah, Penang and Perak, the Central Region including Selangor, Negeri Sembilan and Melaka, the Southern Region including only Johor, and the Eastern Region including Pahang, Trengganu and Kelantan. There are 67 rubber factories in the Northern Region, 64 in the Central Region, 50 in the Southern Region and 25 in the Eastern Region. The production capacity of each of these 206 rubber factories is more than 5 t/d.

The number of existing palm oil mills in Peninsular Malaysia is 133. The states with more than 20 palm oil mills are Perak, Selangor, Johor and Pahang.

There are many tin mines in Peninsular Malaysia. Among them, 130 tin mines using river water for operation are selected in this Study. There are 90 tin mines in Perak, 22 in Kuala Lumpur, 6 in Johor, 8 in Pahang and 4 in Tregganu.

The increasing pig population recently has caused its environmental concern in Peninsular Malaysia. At present, the States having a pig population of more than 100,000 are Penang, Perak, Selangor, Negeri Sembilan and Johor.

These pollutant source locations are shown in Figs. 5 to 12. The inventory of pollutant sources by river basins is shown in Tables 35 to 37. These tables are useful for projection of water pollution in 1990 and 2000.

4. PRESENT MONITORING SYSTEM FOR WATER QUALITY

The importance of monitoring of water quality and quantity of surface water resources has always been convinced by various authorities. The water quality sampling and analysing program has been initiated by DOE and DID in last few years until now (Refs. 9 & 10).

4.1 National Water Quality Monitoring Program by DOE

The Malaysian Government realised the growing environmental problems in the country, passed the Environmental Quality Act and established the Division of Environment (DOE) under the Ministry of Science, Technology and Environment in 1974. The Act requires the inland water quality to be protected and enhanced for the purpose of multiple beneficial uses, conducive to public health, safety and welfare.

4.1.1 Establishment of river basin control regions

Water pollution control of inland waters, management and allocation of water resources, entail the establishment of water quality control regions in accordance with river basin drainage systems. A total of 49 river basin control regions have been established in Peninsular Malaysia. Fig. 15 shows these water quality regions (WQR) in Peninsular Malaysia.

4.1.2 Water quality monitoring and surveillance

In exercising regulatory functions, river monitoring and surveillance constitute the major activity in Water Quality Assessment Program. The needed water quality data enable the DOE to achieve the following realisations:

- to determine the conditions of the rivers;
- to assess the effectiveness of the instituted water pollution control measures (Refs. 11 to 14)

4.1.3 Program objectives

The primary objectives of the monitoring and surveillance program are as follows:

- The surveillance of domestic water supply, river fishing and agricultural irrigation against the presence of toxic substances.
- Gauging changes in water quality resulting from new sources of pollution, which enable remedial measures to be taken.

- Determine if established water quality objectives and water quality standards are achieved; thus, enable evaluation of adequacy and effectiveness of pollution control measures.

- Provide data based on current and future development activities on national water quality and aquatic environment.

4.1.4 Programming

The National Water Quality Monitoring Program (1978) requires the routine water quality monitoring and surveillance of important river basins. Prior to this, there was no systematic river water quality monitoring in the country except those carried out by DID which meant mainly for drainage and agricultural irrigation.

Before the program was commenced, a network of monitoring stations at critical locations was established for more important rivers with respect to sources of public water supplies, river fishery and agricultural irrigation. Each monitoring station is coded according to the system of DID. This enables information on water quality and other hydrological data to be interchangeable between DID and DOE.

The samples for analysis are distributed according to the following regions,

- Johor Bahru region
- Petaling Jaya region
- Penang/Ipoh region
- Kuala Trengganu region

The programming is based on the number of monitoring stations selected on river-priority basis, and matched with the number of sub-professional available. Water quality monitoring stations (WQMS) in Peninsular Malaysia are shown in Fig. 16.

The numbering system for WQMS used by DID and DOE is as follows, Station number has 7 spaces; 4 for North and East grid number, 1 for type and 2 for series within a grid square. And numberings are 12 - 67 for North grid,97 - 99 & 00 - 44 for East grid, 1 - 9 for type and 01 - 99 for series within a grid square.

(1) Type

1	:	Rainfall
2	:	Climate
3	:	Evaporation
4	:	River
5	:	Sediment
6	:	Water Quality
7	:	Ground Water
8	:	Soil Moisture
9	:	Not yet allocated

(2) Grid

The size of each grid square is six minutes of longitude by six minutes of latitude (11 km x 11 km).

(3) Example

A station defined by longitude 102°46'E and latitude 03°27'N would lie within grid number 3427 as explained in the following;

3 : from 03°, latitude is considered first

4 : 27' ÷ 6' = 4 (This indicates that 27' falls in the six minute interval between the fourth and fifth decimal parts of degree.)

2 : from 102°, longitude is considered second

7 : 46' ÷ 6' = 7 (This indicates that 46' lies between the seventh and eighth decimal part of a degree.)

(4) Number of stations per grid

There would be 100 stations of one type within one grid square of size 11 km x 11 km (approximately maximum 2 stations of one type per square mile).

4.1.5 Water quality parameters

The national waters are principally used for drinking, agricultural irrigation, fishery and industrial processing, particularly for processing agro-based products such as palm oil, rubber, tapioca, sago and pineapple. The basic parameters selected to represent the various qualitative aspects of the national waters are pH, Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Suspended Solids (SS) and Ammoniacal Nitrogen (NH_4-N). However, the kinds of pollutant sources found in a river basin will determine that additional parameters such as Chloride Concentration, Conductivity etc. be analysed. Analysis is carried out by the Department of Chemistry Laboratories in Petaling Jaya, Penang, Ipoh, Johor Bahru and Kuala Trengganu.

4.2 Water Quality Sampling System of DID

The collection of water quality data is an indispensable activity undertaken by the Drainage and Irrigation Division (DID) of the Ministry of Agriculture and Rural Development for the long-term water resources assessment of the country.

In the first publication of Hydrological Data Water Quality Records in 1974, data were collected from initial sampling network of 28 water quality stations established throughout Peninsular Malaysia.

The subsequent publications in 1975 and 1976 represent a more extended and revised water quality sampling network. Data were collected from 66 water quality stations in 1975 but only 62 water quality stations in 1976. Besides, water quality data were also collected from temporary river water quality stations and groundwater quality stations. Water quality sampling network expansion is shown in Table 38 and water quality stations in Peninsular Malaysia are shown in Fig. 16.

4.2.1 Water quality data collection

The type of data collected varies according to the water quality objectives of a particular area, namely:

- Experimental Basin Study
- Representative Basin Study
- Fisheries
- Irrigation
- Pollution
- Water Supply
- Baseline Study

The number of sampling stations in accordance with objectives is shown in Table 39.

4.2.2 Water quality sampling objectives

The data collected are intended for the provision of input data to agencies involved in water resources study and pollution control.

The sampling network has been designed in accordance with the following objectives:

(1) Determining the suitability of the source of water supply for a particular purpose and the establishment of the degree of treatment necessary;

(2) Evaluating the effect of waste effluent on receiving water and downstream users;

(3) Providing information on the present water quality which can be used to demonstrate its future changes;

(4) Conducting specific scientific investigations such as studies in representative basins, effects of land use on water quality, nutrient loss etc;

(5) Demonstrating to the public that an effort is being made to protect the natural environment by effective management of resources.

5. DEVELOPMENT PLANS

5.1 Exisitng Sewerage Development Plans

There are several cities having 4MP continuation projects or projects with master plan under the 4MP for their sewerage systems. The cities having 4MP continuation projects are Kuala Lumpur, Shah Alam Ipoh, Butterworth/Bukit Mertajam and Pulau Pinang including Georgetown, Bandar Bayan Baru and the Northern Coast. At present, Alor Setar has already finished the feasibility study of its sewerage system project. Sewerage development plans of these cities are shown in Tables 40 to 41 as inventory.

At present the sewerage development plan reports of Pulau Pinang, Butterworth/Bukit Mertajam, Ipoh, Kuala Lumpur and Alor Setar are available. However, the reports of the other cities are under study or not available. The sewerage development plans of the 5 cities will be described below:

5.1.1 Sewerage system projections for Pulau Pinang

The proposed plans of sewerage systems for Pulau Pinang including Georgetown, Bandar Bayan Baru and the Northern Coast are as follows (Ref. 2):

(1) The proposed improvents include extension throughout the Greater Georgetown Area of lateral and trunk sewers that convey flows to the disposal sites. The establishment of several new pumping stations, the improvement of existing pumping stations, the addition of mains and a new ocean outfall with preliminary purification facilities, should be included.

(2) The Bandar Bayan Baru system should remain a separate entity with all sewage conveyed to a purification treatment plant which provides secondary level of purification.

(3) The Northern Coast should be connected into the Greater Georgetown Sewer System.

(4) The duration of the Master Plan is divided into four stages, namely, 1981 - 1985, 1986 - 1990, 1991 - 1995, and 1996 - 2000. The designed population, Capital and operation and maintenance (O&M) costs at 1980 price level are as follows:

	Designed Population (10^3)	Costs at 1980 Price Level Capital (M\$$10^6$)	O&M (M\$$10^6$/y)
1980	197	18.6	0.99
1981 - 1985	-	41.2	1.57
1986 - 1990	348	47.1	2.02
1991 - 1995	-	44.9	2.43
1996 - 2000	589	17.9	2.80

5.1.2 Sewerage system projections for Butterworth/Bukit Mertajam metropolitan area

The proposed plans of sewerage system for Butterworth/Bukit Mertajam Metropolitan Area are as follows (Ref. 15):

(1) The sewerage system should be principally a separate system.

(2) The physical facilities recommended to be developed include (i) system of sanitary main, branch and lateral sewers, (ii) pumping stations, and (iii) sewage purification facilities in the form of stabilization ponds.

(3) Industrial wastewater should also be taken into account for sewerage planning. The joint purification of industrial wastewater with domestic waste using stabilization ponds should be implemented from the economic point of view.

(4) It is considered appropriate to divide the program into four construction stages, namely 1980 - 1985 (1st stage), 1986 - 1990 (2nd stage), 1991 - 1995 (3rd stage) and 1996 - 2000 (4th stage). Designed area and population by stage, construction cost and O&M cost by stage at 1977 price level are as follows:

	Designed Area (10^3 ha)	Designed Population (10^3)	Cost at 1977 Price Level Construction (M\$$10^6$)	O&M (M\$$10^6$/y)
1980 - 1985	1.00	84.0	37.7	2.58
1986 - 1990	-	458	-	5.56
1991 - 1995	-	545	-	-
1996 - 2000	-	648	-	-

(5) The First Stage program should comprise the main sewer with total length of about 55 km to convey sewage to the purification plant with four stabilization ponds, which will be then discharged into either the Perai river or the Juru river directly through nearby waterway.

5.1.3 Sewerage system projections for Ipoh

The proposed plans of sewerage system for Ipoh are as follows (Ref. 16):

(1) The physical facilities recommended to be developed include (i) system of sanitary main, branch and lateral sewers, (ii) pumping stations and (iii) sewage purification facilities in the form or oxidation ponds.

(2) Industrial wastewater should also be taken into account for sewage planning.

(3) The designed area, the designed population at the designed year of 2020, the construction cost and O&M cost at 1974 price level are as follows:

Designed Year	Designed Area	Designed Population	Cost at 1974 Price Level Construction ($M\$10^6$)	O&M ($M\$10^6/y$)
2020	830 ha for industrial area	840,000	96.0	0.686

5.1.4 Sewerage system projections for Kuala Lumpur

The proposed plans of sewerage system for Kuala Lumpur are as follows (Ref. 1):

(1) The Pantai sewer network should be extended as far as the capacity of the existing trunk sewer allows.

(2) The remainder of the conurbation area should be divided into an additional ten completely independent sewerage areas.

(3) Industrial wastewater should be also taken into account in the sewerage planning. The sewerage facilities will provide for present and future commercial and industrial developments. Facultative oxidation ponds should be used for purifiying wastewater, but in most areas these must be converted ultimately into aerated lagoons.

(4) To achieve the construction program objectives, it is necessary to divide the program into three periods, namely, 1976 - 1980, 1981 - 1985 and 1986 - 2005. The designed area, the designed population, the capital cost and O&M cost at 1974 price level are as follows:

	Designed Industrial Area (ha)	Designed Population (10^3)	Cost at May 1974 Price Level	
			Capital (M$$10^6$)	O&M (M$$10^6$)
1976 - 1980	118	411	103	5.41/4 y
1981 - 1985	309	668	127	11.8/5 y
1986 - 2005	1,767	1,670	459	104/20 y

5.1.5 Sewerage system projections for Alor Setar

The proposed plans of sewerage system for Alor Setar are as follows (Ref. 17):

(1) Wastewater from residential areas, commercial areas, institutional areas and schools should be purified at the proposed purification plant.

(2) The physical facilities recommended to be developed include (i) system of sanitary main, branch and lateral sewers, (ii) pumping stations, and (iii) sewage purification facilities in the form of stabilization ponds with facultative ponds and maturation ponds in series.

(3) To achieve the construction program objectives, the program is divided into several periods. The first 5 years are proposed as the first stage with the recommended items as follows:

- Proposed Sewerage Facilities:

. Sewer Facilities	21.9 km
. Pumping Stations	6 pumps
. Waste Stabilization Pond	Sedimentation Cell Facultative Pond Maturation Pond
. Cleaning Machine	1 set
. Laboratory	

- Total cost of Construction and O&M at 1979 price level (M$$10^3$)

	1981	1982	1983	1984	1985
Construction	4,350	4,910	5,740	5,050	2,770
O & M	217	258	493	602	713
Total	4,570	5,170	6,230	5,650	3,480

5.2 Innovations of Purification Technology

Most of the purification systems have already been described in 2.1 but not the innovation of the purification systems for rubber or palm oil effluent.

The existing purification technology is sufficiently useful for purifying the effluent from the tin mines or pig farms. For the effluent from tin mines, flocculation, coagulation and settling of chemical purification are useful, but in practice it should be ensured that before any effluent has been discharged from the site of a tin mine it should first pass through a series of holding lagoons having long retention periods.

The several types of biological purification systems for piggery wastewater have already been described in 2.6. And it is necessary to advise that pig farmers should establish purification systems so as not pollute river water.

The innovations of purification systems for rubber factory and palm oil mill effluent will be described below:

5.2.1 Innovations of purification technology for rubber factory effluent

The ponding system as a purification system is applicable to rural based rubber factories with land availability. However, for more urban sited rubber factories where land use is expensive, the Rubber Research Institute of Malaysia is studying the use of mechanical aeration for the purification of latex concentrate effluent. The advantages of this method are the increased oxygen transference and better control of purification operations. This technique is currently being applied in pilot plant (Ref. 3).

Other on-going research areas include the optimisation of ponding performance and the applicability of the anaerobic filter bed, rotating bio-disc and aerated lagoons for purification (Ref. 3).

5.2.2 Innovations of purification technology for palm oil mill effluent

The future purification of palm oil mill effluent appears to be bright as seen by the number of new processes being developed and made available (Ref. 18).

(1) Conversion

The conversion of palm oil mill effluent directly or indirectly into a useful by-product has received top priority. Direct by-product recovery by screening, filter pressing, vacuum spray drying, vacuum filtration or by simple evaporation can be used as animal feed. The disadvantage is the high capital cost and the uncertainty of the market.

(2) Chemical treatment

The chemical system involves the use of screens and flocculants to remove solids. Further treatment by aeration is said to lower the BOD level further.

(3) Methane production

It has been estimated that from 0.4 - 0.7 litre of methane gas per gram of COD added could be recovered by anaerobic tank fermentation process of the effluent. This treatment is worthwhile looking into further from the economic prospect point of view in the sale of methane gas as fuel.

(4) Process modification

Process modification is a method to tackle the problem at source by reducing the quantity of effluent discharged. Treatment problem need not arise if this process could result in no discharge or only result in an effluent which can be utilized directly as animal feed.

6. SALINITY RIVER STRETCH

When surface river water is used for water supply and agricultural irrigation at the downstream, it is necessary to investigate its salinity, because high salinity concentration injures crops and requires high treatment technology for drinking purposes. International Standards for Drinking Water have been promulgated by the WHO as a worldwide guide to the improvement of water quality and treatment. According to the standards, the chloride concentration prescribed is 200 mg/lit as the highest desirable level and 600 mg/lit as maximum permissible level (Ref. 19).

Intakes for water supply and agricultural irrigation should be at the upper stream from the salinity river stretch. Hence, it is important to estimate the salinity river stretch when establishing new intakes. However, salinity concentration sometimes is changeable at some points along a particular river, depending upon its tidal level, slope of river bed, discharge of surface flow and wind direction.

Chloride concentration data is available from DOE but not relating with the tidal level and discharge of surface flow, therefore, salinity river stretch was very roughly estimated by applying the 200 mg/lit standard chloride concentration and based on several reports and hearings of estimated distances of salinity water or tidal effects from estuary. Estimated salinity river stretches are summarized in Tables 42 to 43.

According to Tables 42 to 43, Kelang river and Muar river have the longest salinity stretch of about 60 km. The tidal effects of Muda river, Melaka river, Kesang river and Sekudai river are understandably stopped at their respective tidal gates.

7. PROJECTION OF WATER QUALITY

7.1 General

Pollutant load and water quality of rivers by Basin were projected based on projection of D&I water demand. Major pollution sources are composed of 19 cities, 48 districts, 27 palm oil mills, 10 rubber factories and animal husbandry in Sabah and Sarawak. These sources are grouped into nine categories; i.e., (1) Urban domestic sewerage, (2) Urban domestic non-sewerage, (3) Rural domestic, (4) Urban manufacturing sewerage, (5) Urban manufacturing non sewerage, (6) Rural manufacturing, (7) Palm oil processing, (8) Rubber processing and (9) Animal husbandry. Each category has different figures respectively for net unit pollutant load, discharge ratio, runoff ratio and infiltration ratio. Composition of the above pollution sources is illustrated in Fig. 17.

In order to know the degree of organic water pollution of river, BOD was sellected among fiver parameters for living environment such as BOD, SS, DO, pH and NH_4-N.

Projected pollutant load and water quality by Basin are shown in Tables 44 to 67. And projected maximum BOD concentration distributions in 1990 and 2000 for Case 1 and Case 2 are illustrated in Figs. 18 to 21.

7.2 Source of Pollution

As major pollution sources, 105 cities, 76 districts, 139 palm oil mills, 206 rubber factories and 48 pig farms are selected in the Study.

There are 133 palm oil mills in Peninsular Malaysia in 1980. Number of palm oil mill will increase to 138 in 1990 and 139 in 2000. Water demand of these palm oil mills is as shown in Tables 68 to 72.

There are 206 rubber factories in Peninsular Malaysia in 1980, 1990 and 2000. Water demand of these rubber factories is as shown in Tables 73 to 79.

There are numerous small-holder pig farms in Peninsular Malaysia. These numerous pig farms were grouped into 48 pig farms, being estimated production more than 1,000 heads of pigs in 2000. The pig production will grow rapidly with the annual average rate of 2.3% during the period from 1980 to 1990 and 1.7% from 1990 to 2000. Projected pig production of 48 pig farms is as shown in Tables 80 & 81.

7.3 Water Quality Projection

7.3.1 Methodology

Water quality of river was projected for all Basins in Sabah and Sarawak.

Water quality was calculated as the following order:

(1) Pollutant load from pollution source (PLS)
= Customer demand (C.D.) x Discharge ratio (D-ratio)
x Net unit pollutant load (NUPL)

(2) Pollutant load inflow to river (PLR)
= PLS x Runoff ratio (R-ratio) x (1 + Infiltration ratio (I-ratio))

(3) Pollutant load at balance point (PLBP)
= PLR x Residual purification ratio (RP-ratio)

(4) Water quality at balance point (WQBP)
= PLBP/Maintenance flow at balance point (MFBP)

(5) Water quality at some point (W.Q.)
= CD x D-ratio x NUPL x R-ratio x (1 + I-ratio)
x RP-ratio/Maintenance flow at some point

Water quality was calculated by outlet of polluted wastewater in a Basin.

Water quality projection flow-chart is given in Fig. 22.

Calculation of water quality was carried out on the following assumptions:

(1) Maintenance flow used for water quality projection is 97% probability Basin discharge and kept at every outlet,

(2) When the river water is abstracted at intake, pollutant load of the river is decreased. The decreased load is expressed as (Abstracted volume x Water quality),

(3) Urban domestic and manufacturing wastewater in coastal area is discharged not to river, but to sea directly after treating,

(4) A part of abstracted water from river is reduced to river. The reduced volume is equal to (SD-CD)/2,

(5) Intake point of abstruction of surface water is the same point of outlet of effluent from pollution source, and

(6) I-ratio of groundwater into sewer pipe in city having public sewerage system is 20% of the average daily treatment capacity.

7.3.2 Net unit pollutant load (NUPL)

In order to know the degree of water pollution of river, five parameters such as pH, BOD, SS, DO and NH_4-N will be used. Of these parameters, BOD is the most suitable parameter to know the organic pollution of river water. The reason is described hereunder.

The river water is generally polluted organically in the beginning period because of the direct discharge of domestic wastewater and night soil. And then industrial effluent with heavy metal and chemical materials pollutes the river water chemically but industrial effluent with heavy metal should not be discharged to water body without treated. Therefore, heavy metals are not suitable parameters to know organic pollution of river water. River has the self purification phenomena to purify the organic pollution under flowing down. This phenomenon is that aerobic bacteria in river water transforms organic matters to inorganic matters using dissolved oxygen. Then volume of dissolved oxygen used by aerobic bacteria is BOD. For the above reason, BOD load was used in the Study as pollutant load.

NUPL was estimated based on several reports (Refs. 15, 16, 36 & 37), assuming that the purification measures remain at the present level of BOD concentration in 1990 and 2000. NUPL of non-sewerage-urban-domestic was estimated based on assumed development of septic tank in urban area as shown in Tables 82 and 83. NUPL of manufacturing by State was estimated by weighted average of demand water by state and NUPL by type of manufacturing. NUPL by type of manufacturing and demand water by state are given in Table 84. And NUPL of manufacturings by state is shown in Table 85. Estimated NUPL is given in Table 86.

Data for NUPL of sewerage, urban, rural, manufacturing, palm oil processing, rubber processing and animal husbandry were available in Malaysia (Ref. 37).

7.3.3 Discharge ratio (D-ratio)

Pollution sources are equal to water consumers. They use clean water and then discharge polluted water to drainage, river or sea directly. D-ratio is the ratio of consumer demand water and discharged water. D-ratio of domestic consumer was determined based on the Malaysia data. D-ratio by pollution source is as shown in Table 86.

In manufacturing, D-ratio was determined with consideration of the recyclic water use development. In palm oil mills and rubber factories the land disposal system is progressively applied as shown in Table 87. D-ratio of palm oil mills and rubber factories was determined with consideration of land disposal development and outflow of 10% of pollutant load from land disposal area as shown in Table 88. In animal husbandry no water is used.

7.3.4 Runoff ratio (R-ratio)

The ratio of the reduction of discharged pollutant loads, which is the ratio before and after discharged pollutant reaches a river, is called the runoff ratio.

R-ratio is about 0.1 in rural areas but increases with the progress of urbanization. For a drainage channel made of concrete, R-ratio rises to nearly 1.0. R-ratio by pollution source is as shown in Table 86.

7.3.5 Infiltration ratio (I-ratio)

The infiltration ratio in the existing sewerage systems in Sabah is equivalent to about 25% to 30% of the average flow. Since existing systems are constructed with rigid cement joints, it is to be expected that, with the provision of flexible, water tight joints in the future, the infiltration ratio should fall to about 20% of the average daily flow (Ref. 36). I-ratio is assumed to be 20% in the Study.

7.3.6 Residual purification ratio (RP-ratio)

Pollutant load in river is decreased by deposition, adsorption, biological decomposition and so on. A concept which describes these phenomena totally is called residual purification ratio. In other words, RP-ratio is the ratio of pollutant load of upperstream and downstream. RP-ratio has a figure in the range of 0 to 1 by conditions of water quality, water velocity, water discharge, water depth, and riverbed of the river basin. The relationships between RP-ratio and water quality is close. RP-ratio is about 0.7 in a river with clean water and RP-ratio rises to nearly 1.0 in a river with polluted water. In the Study, RP-ratio by basin is assumed to be 0.7, 0.8 and 0.9 with consideration of the river water quality in 1980 and 1981. RP-ratio by basin is shown in Table 89.

7.3.7 Maintenance flow

Maintenance flow used for water quality projection is 97% probability basin discharge.

Based on the net unit basin discharge by basin, maintenance flow was calculated. Maintenance flow of effective catchment area of main river for water quality at balance point by basin is as shown in Table 90.

7.3.8 Projection of water quality

Major pollution sources assumed are domestic and industrial water consumers comprising 105 cities, 139 palm oil mills, 206 rubber factories, animal husbandry and rural areas.

Water quality of 38 Basins in 1990 and 2000 was projected for two cases. Projected BOD load and BOD concentration by basin in 1990 and 2000 are as shown in Tables 44 to 55 for Case 1 and Tables 56 to 67 for Case 2. Total BOD load from pollution sources in Peninsular Malaysia will be 1,283 ton/d for Case 1 and 1,147 ton/d for Case 2 in 1990, and 1,676 ton/d for Case 1 and 1,410 ton/d for Case 2 in 2000, respectively.

It is assumed that wastewater from 16 cities mentioned hereunder out of 105 cities is discharged to sea directly because these 16 cities are located near sea coast. These 16 cities are Butterworth, Bukit Mertajam, Georgetown, Klang, Port Dickson, Melaka, Muar, Johor Bahru, Mersing, Kuantan, Dungun, Kuala Trengganu, Kota Bharu, Kg. Pmtg Kuching, Perai and Kelebang.

BOD load from these 13 cities will be 180 ton/d for Case 1 and 96 ton/d for Case 2 in 1990 and 321 ton/d for Case 1 and 164 ton/d for Case 2 in 2000, respectively.

And BOD load into main stream will be 507 ton/d for Case 1 and 480 ton/d for Case 2 in 1990 and 622 ton/d for Case 1 and 543 ton/d for Case 2 in 2000, respectively.

In terms of BOD load from pollution source, Basin 15 will have the biggest BOD load because of the existence of big city, W. Persekutuan, Petaling Jaya, Shah Alam and Klang. It will be 250 ton/d in 1990 and 288 ton/d in 2000 for Case 1 and 220 ton/d in 1990 and 266 ton/d in 2000 for Case 2.

In terms of BOD load into river, the basin with the biggest BOD load in Case 1 and Case 2 will be Basin 15 in 1990 and in 2000. It will be 115 ton/d in 1990 and 139 ton/d in 2000 for Case 1 and 107 ton/d in 1990 and 126 ton/d in 2000 for Case 2.

Composition of BOD load into river is as shown in Tables 45 and 57. In Case 1, in 1990, palm oil mills and rubber factories will be the biggest pollution sources and those BOD load will be 268 ton/d being equivalent to 53% of the total BOD load of 505 ton/d. In 2000, the biggest pollution source will be urban domestic and urban industry followed by palm oil mills and rubber factories. BOD load of urban domestic and urban industry into river will be 324 ton/d being equivalent to 52% of the total BOD load of 627 ton/d. That of palm oil mills and rubber factories will be 267 ton/d being equivalent to 42% of the total. In Case 2, in 1990, palm oil mills and rubber factories will be the biggest pollution sources and its BOD load will be 268 ton/d being equivalent to 56% of the total BOD load of 477 ton/d. In 2000, they will be also the biggest pollution sources having the BOD load of 262 ton/d being equivalent to 49% of the total BOD load of 539 ton/d.

The projection of BOD concentration was conducted in consideration of the river maintenance flow. Projected maximum and minimum BOD concentration by basin are as shown in Tables 44 and 56.

In Case 1, the highest BOD concentration, 279 mg/lit, was projected for Basin 18 in 1990 because of the non-treated effluent from urban and rural area in Basins 217 and 234. In 2000, Basin 18 shows the highest BOD concentration of 292 mg/lit because of the non-treated effluent from urban and rural area. In Case 2, the highest BOD concentration in 1990 and 2000 is as same as that in Case 1. Distribution of BOD concentration along river of the Basin with City/Town is illustrated in Figs. 23 to 26 for Case 1 and Figs. 27 to 30 for Case 2.

These are 16 Basins, i.e. Kedah Basin with C2, Merbok Basin with C3, Perai Basin with C4 and C5, Kurau Basin with C112, Perak Basin with C11, C12, C13, C14, C15, C17, C18 and numerous palm and rubber factories, Buloh Basin with C114 and palm and rubber factories, Kelang Basin with C22, C23, C24 and C25, Langat Basin with C26, Linggi Basin with C29, Melaka Basin with C31, Muar Basin with C30, C32 and C34, Batu Pahat Basin with C35, Sekudai Basin with C38 and C39, Endau Basin with C41, Kuantan Basin with C47 and Kemasin Basin with C57.

Since the wastewater from City/Town is discharged to the sea directly after treating, these figures show low BOD concentration in spite of existing of large City/Town in these 16 Basins. Most rivers of west coast in Peninsular Malaysia will be grossly polluted in 1990 and 2000 for Case 1 and Case 2. But rivers of east coast in Peninsular Malaysia are little polluted presently and will be still clean in 1990 and 2000.

Using three ranges, 0 - 5 mg/lit, 5 - 10 mg/lit and 10 mg/lit over, maximum BOD concentration by basin are illustrated in Fig. 18 in 1990 and Fig. 19 in 2000 for Case 1 and Fig. 20 in 1990 and Fig. 21 in 2000 for Case 2. According to these figures, rivers in west coast, especially, the southern half will be largely polluted. Most rivers in the east coast will be clean in 1990 and still 2000.

8. WATER POLLUTION ABATEMENT

8.1 General

As the result of the water quality projection in Peninsular Malaysia for 1990 and 2000, most rivers in the west coast, especially, the southern half will be polluted. Therefore it is necessary to consider the water pollution abatement from the viewpoints of water use and environmental quality in river. The best method for water pollution abatement is that pollution sources control polluted effluent from sources by themselves. As mentioned in 7.3.2, BOD is the most suitable and common parameter of organic water pollution in river. Water pollution abatement is, therefore, the reduction of BOD load by some treatment method in pollution sources.

8.2 Setting of Water Quality Criteria

Water quality standards are of two kinds as follows:

(1) standards for drinking water which pertain to water delivered to consumers after treatment,

(2) standards for raw water which are classified depending upon the purpose of utilization, i.e., domestic and industrial water supply, fishery, irrigation, bathing and conservation of environment.

International Standards for Drinking Water have been promulgated by the World Health Organization (WHO) as a worldwide guide to the improvement of water quality and treatment. In Malaysia Standards of Bacteriological Quality of Water and Standards for Toxic Substances derived from the WHO Standards have been carried out.

Standards for raw water in Malaysia have been promulgated as Toxicity Limits and Water Quality Criteria for 4 categories, i.e., (i) municipal water supply, (ii) recreation, propagation of fish and other aquatic wildlife, (iii) agricultural irrigation and (iv) industrial water supply. Adopted parameters are 74 parameters except BOD. Standards of raw water in some countries, Holland, U.S.A., U.S.S.R., Philippines and Japan have adopted several parameters including BOD. Concerns the living environment, river water quality is classified according to water usage, and environmental quality standards values for BOD, DO, SS, pH and Coliform are established for each class. Japanese Standards relating to living environment is shown in Table 91 and Philippines' water quality criteria is shown in Table 92. In the Study BOD is adopted in order to observe the river water quality. Some relationships between BOD concentration in a river and environmental quality, and river water quality standard in some countries are illustrated in Fig. 31.

As water quality criteria, two alternative targets for the water pollution abatement are proposed from the viewpoint of environmental quality in the Study. Alternative P1 sets BOD concentration in a river at less than 5 mg/lit in 1990 onwards. Alternative P2 limits BOD concentration in a river at less than 10 mg/lig in 1990 onwards.

8.3 Planning of Treatment Facilities

In case of the necessity of BOD concentration reduction for the proposed limit in a river, the improvement of treatment facility in pollution sources should be proposed.

First of all pollution sources, the improvement of purification methods in all palm oil mills and rubber factories is assumed. Improved purification methods are rubber investigation in Palm Oil Research Institute of Malaysia (PORIM) and Rubber Research Institute of Malaysia (RRIM) to attain to the limit of BOD concentration for watercourse discharge from palm oil mills and rubber factories. DOE proposed 50 ppm for the future limit. Present limits for watercourse discharge in palm oil mills and rubber factories are shown in Table 93.

If there still remains a river stretch of higher BOD concentration than the proposed limit, the construction of a sewerage system in the urban area immediately upstream of the river stretch is assumed.

Urban domestic and manufacturing wastewater is collected and treated in public sewerage treatment facilities. BOD concentration in the effluent from a sewerage system is estimated to be 30 mg/lit.

No purification measure is assumed for the effluent from rural area and animal husbandry.

For purification method of effluent from palm oil mills, anaerobic digestion with extended aeration or land disposal are proposed. As treatment method of effluent from rubber factories, aerobic and facultative pond for SMR and oxidation ditch for Latex Concentrate. The layout of the stabilization pond process, combining facultative pond with maturation pond, is shown in Fig. 32.

For public sewerage system, aerated lagoon process is proposed in the Study. This process is historically developed from stabilization pond. Floating aerator for surface aeration is commonly used to supply the necessary oxygen and arise reduction level of load. Maturation pond is necessary to reduce coliform after treating in the aerated lagoon. The layout of aerated lagoon process is shown in Fig. 33.

9. PLANNING MATERIALS, ECONOMIC BENEFIT AND COST AND MANPOWER REQUIREMENT

9.1 Planning Materials

9.1.1 Construction cost

Construction costs of purification facilities for palm oil mills, rubber factories and sewerage facilities for urban area composed of sewer, pumping station and treatment facilities are estimated, basing on the data from DOE and the previous studies available, i.e. Master Plan and Feasibility Study for Sewerage and Drainage System Project in Alor Setar and Its Urban Environs Malaysia Report. And construction cost of pretreatment facilities for domestic and industrial water supply are estimated using the data of the previous studies available.

Construction cost is estimated in the four categories, i.e. (1) direct construction cost, (2) engineering service & administration, (3) land acquisition, and (4) physical contingency. Engineering service and administration costs are assumed to be 10% of the direct cost. Physical contingency is assumed to be 30% of the total of the above (1) to (3).

For the sewerage facilities, direct construction costs by facility in reference of the data of Alor Setar Project are as follows:

$$C_S = 0.852Q$$
$$C_P = 0.254 + 0.0502Q$$
$$C_T = 0.930 + 0.139Q$$

where, C_S: Direct construction cost of sewer, M$\$10^6$
C_P: Direct construction cost of pumping station, M$\$10^6$
C_T: Direct construction cost of treatment facilities, M$\$10^6$
Q : Treatment capacity, 10^3 m^3/d

Unit direct construction cost of sewerage facilities per 100×10^3 m^3/d of treatment capacity is M$\$105.3 \times 10^6$.

Land acquisition cost for sewerage facilities in reference of the data of Alor Setar Project are as follows:

$$C_{PL} = 0.0153 + 1.30 \times 10^{-3} \times Q$$
$$C_{TL} = 0.138 \times Q^{0.787}$$

where, C_{PL}: Land acquisition cost of pumping station, M$\$10^6$
C_{TL}: Land acquisition cost of treatment facilities, M$\$10^6$
Q : Treatment capacity, 10^3 m^3/d

Unit land acquisition cost of sewerage facilities per 100×10^3 m^3/d of treatment capacity is estimated to be M$\$5.3 \times 10^6$.

Construction and land acquisition costs of sewerage facilities are generally beared by the public and the private sector. Therefore calculation of costs for sewerage systems was carried out on the following assumptions:

(1) In the existing urban area, cost of house connection pipe is beared by the private,

(2) In the new development urban area, costs of branch sewer and house connection pipe are beared by the private.

Cost and share of branch sewer and house connection pipe to total costs of sewerage systems are shown in Table 94.

For the purification facilities for palm oil mills, direct construction costs are M$3,000/$m^3$/d of treatment capacity for anaerobic digestion with extended aeration and M$2,000/$m^3$/d of treatment capacity for anaerobic digestion with land disposal. In consideration of land disposal development; 50% in 1990 and 75% in 2000, direct construction costs in 1990 and 2000 are as follows:

$$Cp = (3 \times 0.5 + 2 \times 0.5) \times Q = 2.5 \times Q \quad \text{in 1990}$$
$$Cp = (3 \times 0.25 + 2 \times 0.75) \times Q = 2.25 \times Q \quad \text{in 2000}$$

where, Cp: Direct construction cost of purification facilities, M$$10^3$
Q : Treatment capacity, m^3/d

Unit direct construction cost of purification facilities of palm oil mills are estimated to be M$2,500/$m^3$/d of treatment capacity in 1990 and M$2,250/$m^3$/d in 2000.

Purification facilities of palm oil mills is assumed to be constructed in the palm oil mills area, so no land acquisition cost is need.

For the purification facilities for rubber factories, direct construction costs are M$600/$m^3$/d of treatment capacity for SMR production and M$1,800/$m^3$/d of treatment capacity for Latex concentrate production.

Percentage of rubber factories by type of rubber production in 1980 is as follows:

Type of Rubber Production	Number of Rubber Factory	Share
Conventional and SMR	146	70%
Latex Concentrate, Mixed and Others	60	30%

On the assumption of the same share in 1990 and 2000 as in 1980, direct construction cost in 1990 and 2000 is estimated as follows:

$$C_R = (0.6 \times 0.7 + 1.8 \times 0.3) \times Q = 0.96 \times Q$$

where, C_R: Direct construction cost of purification facilities, M$$10^3$

Q : Treatment capacity, m^3/d

Unit direct construction cost of purification facilities of rubber factory is estimated to be M$960/$m^3/d$ of treatment capacity in 1990 and 2000.

As the pretreatment facilities, two treatment methods are proposed. For BOD concentration in raw water between 2 mg/lit and 20 mg/lit, pretreatment is carried out by the rapid sand-filter and activated carbon absorption (Secondary treatment). For BOD concentration between 20 mg/lit and 200 mg/lit, an aerated lagoon process such as aerated lagoon or maturation pond (Primary treatment) is further needed. The direct construction cost of the above-mentioned pretreatment facilities are estimated as follows:

$$C_{pre\,1} = 3.16 \times 10^{-6} \times L^{2.9} \times (Q_D + Q_Z)$$

$$C_{pre\,2} = 19.3 \times 10^{-6} \times L^{2.9} \times (Q_D + Q_Z)$$

where, $C_{pre\,1}$: Direct construction cost of primary pretreatment facilities, M$$10^6$

$C_{pre\,2}$: Direct construction cost of secondary pretreatment facilities, M$$10^6$

L : Reduction level of pretreatment facilities, %

Q_D : Treatment capacity for domestic water supply, $10^3\ m^3/d$

Q_Z : Treatment capacity for industrial water supply, $10^3\ m^3/d$

Unit direct construction cost of pretreatment facilities are estimated to be M$$26.7 \times 10^6$ per $100 \times 10^3\ m^3/d$ of treatment capacity for primary pretreatment facilities and M$$78.6 \times 10^6$ per $100 \times 10^3\ m^3/d$ of treatment capacity for secondary pretreatment facilities as 50% reduction level.

Pretreatment facilities is assumed to be constructed in the treatment plant area, so no land acquisition cost is need.

The unit construction cost by type of treatment facilities are estimated as shown in Table 95 and summarized below.

Type of Treatment Facility	Unit Const. Cost (M$$10^6/10^3\ m^3/d$)
Public sewerage system	157.4
Purification facilities of palm oil mills in 1990	3.6
Purification facilities of palm oil mills in 2000	3.2
Purification facilities of rubber factory in 1990&2000	1.4
Primary pretreatment facilities	38.2
Secondary pretreatment facilities	112.4

9.1.2 O&M cost

The O&M costs include O&M cost of sewer, pumping station and aerated lagoon process for public sewerage system, O&M cost of ponding process for purification facilities in palm oil mills and rubber factories and O&M cost of aerated lagoon for primary pretreatment and rapid sandfilter bed for secondary pretreatment.

Relationship between construction cost and ratio of O&M cost and construction cost by city is shown in Fig. 34. The ratio has the range from 1% to 4%. In the Study, the annual O&M cost is assumed to be 4% of the total construction cost for public sewerage system and 2% of the total construction cost for purification facilities of palm oil mills and rubber factories and pretreatment facilities.

9.2 Economic Benefit and Cost

Economic benefit for water pollution abatement is assumed to be composed with the sewerage benefit and the saving in pretreatment facility.

The sewerage benefit is the willingness-to-pay by served people and saving in the cost of purification of industrial wastewater. It is assumed to be 0.6% of real income of served people and gross value of manufacturing production of served industries in this Study.

Pretreatment facilities are necessary if BOD concentration in raw water is more than 2 mg/lit for domestic water supply or 5 mg/lit for industrial water supply. Its cost can be saved, if the proposed water pollution abatement measures reduced BOD concentration in the river across this limit. This saving in cost is counted as a part of water pollution abatement benefit.

Economic cost for water pollution abatement is estimated to be 80% of the financial cost of public sewerage system, purification facilities of palm oil mills and rubber factories and pretreatment facilities for D&I water supply.

9.3 Manpower Requirement

9.3.1 Manpower requirement for construction

Manpower requirement for construction is estimated, basing on the data of Ministry of Local Government and Federal Territory. The staff in the Construction Division of Sewerage Department is composed with four categories as follows:

Staff Category	Number of Staff
Executive Engineer	1
Assistant Engineer	3
Technical Assistant	2
Technician	3
Total	9

In consideration of the above staff-requirement and construction schedule, manpower requirement is estimated for construction schedule of every 50 x 10^3 m^3/d per year as follows:

Staff Category	Number of Staff	Share (%)
Engineer	2	25
Technical Assistant	2	25
Technician	2	25
Others	2	25
Total	8	100

9.3.2 Manpower requirement for O&M

Manpower requirement for O&M is estimated, basing on the data of the staff-requriement of the Operation Division, Sewerage Department, Ministry of Local Government and Federal Territory as well as manpower requirement for construction. The staff in the Operation Division of Sewerage Department is composed with categories as follows:

Staff Category	Number of Staff
Treatment Plant	
- Laboratory Assistants	3
IMG Workers	18
Pumping Stations	
- Mechanical Supervisors	1
IMG Workers	11
- Sewer Inspectors	2
IMG Workers	29
Other Operations	
Works Manager	1
Chemist/Biologist	2
Technical Assistant (Electrical)	1
Supervisors (Works)	1
Assistant Clerk/Typist	2
Technicians (Sampling Meter Reader)	1
Security	3
IMG Workers	22
Driver	1
Total	98

In consideration of the above staff-requirement and staff required in the D&I water supply, manpower requirement is estimated for treatment capacity of every 200 x 10^3 m^3/d as follows:

Staff Category	Number of Staff	Share (%)
Engineer	2	1
Technical Assistant	3	1
Technician	18	7
Others	240	91
Total	263	100

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