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WATER AND SANITATION FOR HEALTH PROJECT

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PLANNING STUDY FOR AN INDUSTRIAL ESTATE FOR INDUSTRIES WITH WATER INTENSIVE AND POLLUTING ACTIVITIES IN MAURITIUS

WASH FIELD REPORT NO. 272

AUGUST 1989

Prepared for
the Government of Mauritius
through REDSO/ESA, Nairobi
WASH Task No. 051

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by

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and
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ACRONYMS

BOD	Biological oxygen demand
COD	Chemical oxygen demand
CWA	Central Water Authority
EPZ	Export Processing Zone
GOM	Government of Mauritius
KVA	Kilovolt-ampere
kWh	Kilowatts per hour
MEDIA	Mauritius Export Development and Investment Authority
MOW	Ministry of Works, Mauritius
Rs	Rupees (1 R = approx. US$.168)
REDSO/ESA	Regional Economic Development Services Office/East and South Africa
WASH	Water and Sanitation for Health Project
USAID	U.S. Agency for International Development

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Individual industries were most cooperative, both in arranging for plant visits and in providing detailed information related to water and wastewater issues. Such organizations as the Mauritius Chamber of Commerce and Industry, the Mauritius Export Processing Zone Association, and the Joint Economic Committee provided useful guidance and information, as well. We thank them all.

EXECUTIVE SUMMARY

At the request of the U.S. Embassy in Mauritius, the Water and Sanitation for Health (WASH) Project sent a two-person consulting team to Mauritius in May-June 1989 to study and also recommend practical solutions to the problem of industrial wastewater treatment, particularly in the textile and leather industries.

FINDINGS

1. To date, industry has not adequately addressed wastewater pollution control.

2. Industries served by existing sewers provide little or no meaningful on-site pretreatment but are considered by the Government of Mauritius (GOM) to be in compliance with acceptable practice. Approximately two-thirds of the water-intensive and polluting industries discharge to public sewer systems that provide minimal, if any, treatment prior to discharge to the ocean or the lagoon.

3. The existing sewer systems have limited capacity to accommodate any wastewater increase. Some industries are now required to discharge at off-peak hours. Despite this practice, however, overflows presently occur during periods of moderate to heavy rainfall.

4. Industries discharging wastewaters directly to rivers, ground, or intermittent streams pollute these watercourses and groundwater aquifers and render them unfit for certain uses.

5. Mauritius has no secure landfills for disposal of toxic sludges and industrial waste. Sludges and wastes are dumped indiscriminately at uncontrolled areas.

6. GOM, supported by a major World Bank effort, has initiated a comprehensive program for environmental protection.

7. Master plans are scheduled to be prepared for wastewater, solid wastes, and physical planning.

8. A demand exists for industrial sites with provision to handle water-intensive and polluting activities.

CONCLUSIONS

1. A comprehensive wastewater master plan with recommendations for both industrial and domestic wastewaters is urgently needed.

2. GOM should establish a single strong regulatory capability in an environmental protection authority and promulgate appropriate regulations regarding industry pretreatment and full treatment of wastewaters.

3. Enough support exists both in the private sector and GOM to implement an industrial estate catering to water-intensive and polluting industries.

RECOMMENDATIONS

The WASH team recommends that GOM take the following actions:

1. Give the highest priority to implementing the proposed wastewater master plan studies.

2. Establish wastewater effluent quality standards for discharges to

   - Ministry of Works (MOW) sewers
   - groundwater
   - fresh water
   - lagoon and ocean marine water

3. Require new industries to submit construction plans and specifications for pollution-control facilities early in the authorization process. Require industries to certify that they will comply with discharge standards.

4. Establish a compliance schedule requiring that each industry discharging effluent to surface waters must provide satisfactory wastewater treatment.

5. Establish a compliance schedule requiring that industries discharging process wastewaters to absorption pits or groundwater cease these discharges and either connect to an MOW sewer, move to the proposed new industrial estate, or provide full treatment with discharge to surface water. Exceptions for discharge to absorption pits should be given only if the treated effluent meets drinking water standards.

6. Prohibit new industries from discharging to absorption pits.

7. Continue with the planning and design process for developing an industrial estate catering to water-intensive and polluting industries. Provide space for new industries and relocation of existing industries that cause problems by polluting groundwater, surface water, or lagoons.

8. Provide a secure sludge disposal facility.

PRELIMINARY ESTIMATED COST OF THE WASTEWATER COMPONENT OF THE PROPOSED INDUSTRIAL ESTATE

1. The estimated capital cost for a secondary wastewater treatment plant for the estate is between Rs 20 and Rs 25 million. The estimated cost for a secure sludge disposal facility is Rs 2.5 million.

2. MEDIA should increase rental rates by 10 to 15 percent over the rate for existing buildings to recover the capital cost of wastewater facilities.

3. The estimated annual operating cost for the wastewater facilities is Rs 7.2 million. The operating cost should be assessed to the tenants in proportion to their process and sanitary water use. Based on a wastewater flow of 1860 cubic meters per day, the tariff would be Rs 12.50 per cubic meter.

4. For an industry renting 5000 square meters and discharging an average of 100 cubic meters per day, the cost for wastewater facilities (included in the rental fee) plus the operating cost would amount to Rs 460,000 per year.

5. The estimated annual operating cost for the secure landfill is Rs 1 million, assuming the landfill would be full after two years. To recover the landfill's capital and operating costs and thereby be prepared to construct a new landfill when the first reaches capacity, the tipping fee should be 1500 Rs per cubic meter.

Chapter 1

INTRODUCTION

1.1 Background to the Report

In recent years Mauritius has experienced rapid economic development, and demand is growing for suitable industrial space. The textile sector seeks space for additional dye houses, and leather tanning/finishing, metal fabrication, electronics, and other industrial categories have a potential need for accommodation as well.

Rapid industrialization has conflicted with the goal to protect and develop the limited water resources in some parts of the island. Proper siting and adequate pollution control measures for water-intensive industries are critical to the island's economic growth and well-being.

The country now must take action to ensure continued development while at the same time addressing pollution issues in an environmentally acceptable manner. Recognizing this need, the government of Mauritius (GOM) has adopted a policy to support establishment of industrial estates for water-intensive industries. These estates would include wastewater treatment capabilities along with other necessary site infrastructure.

In view of the current situation, USAID, through the Regional Economic Development Services Office/East and South Africa (REDSO/ESA), Nairobi, agreed to support GOM in addressing environmental concerns; arrangements were made for a two-person WASH team to conduct studies and make recommendations regarding water-intensive and polluting industries.

1.2 Scope of Work

The objectives of this study were to weigh the relative financial, technical, and policy concerns, and then recommend practical solutions to the problem of industrial wastewaters, particularly in the textile and leather industries. The scope of work as developed by USAID was to

- review current, pending, and planned environmental regulations concerning water use; assess monitoring and enforcement capabilities; and assess GOM plans for future wastewater treatment;

- assess current water use and waste disposal practices and the associated environmental and economic impacts;

- make a preliminary assessment of local water quality problems and needs, in-plant waste treatment capabilities, alternative technologies, and combined industrial/municipal sewage treatment;

- develop alternatives to resolve problems in the textile and leather sectors;

- analyze the various alternatives based on technical, economic, fiscal, and policy implications.

In tandem with the development of the USAID scope of work, GOM, through MEDIA, prepared terms of reference for a comprehensive study for the development of an industrial estate for water-intensive and polluting activities. Following discussions by the WASH team with the U.S. Embassy in Port Louis and with MEDIA and other GOM ministries and authorities, all parties agreed that the WASH team would also develop the first-phase findings and recommendations called for in the MEDIA terms of reference.

1.3 Activities of the WASH Consultants

Leo A. St. Michel, team leader, and Robert Dangel, environmental engineer, arrived in Mauritius on 24 May 1989, following a team-planning meeting at the WASH offices and the team leader's meetings with REDSO in Nairobi. The team presented findings and recommendations to USAID and GOM representatives on 13 June and completed the assignment in Mauritius on 15 June. Lists of interviews and plant visits are provided in Appendix A.

1.4 Contents of this Study

This study provides recommendations for implementing a wastewater treatment program for existing and proposed industries. The study also addresses the preliminary criteria for an industrial park, including the necessary infrastructure and a stand-alone wastewater treatment facility. These criteria are based on estimates derived from preliminary MEDIA information and some existing Mauritian industries. Ideally, more specific data should be collected simultaneously with the site selection process, and as occupancy commitments are obtained from prospective industrial tenants.

Site selection for the park would involve working with the local community to gain acceptance. Because several locations should be evaluated for comparative development costs, MEDIA and GOM should proceed immediately to evaluate specific sites and initiate local participation.

The final design for the park's wastewater treatment facilities should be based on several considerations:

- for new industries, reliable estimates of water consumption, wastewater flow rates, constituents, and concentrations

- for relocation of existing industries, representative wastewater sampling and analysis data

- review of occupants' unit operations, raw materials, and chemical consumption as a check on the wastewater data
- number of employees, days and hours of operation
- chemical characterization of the water supply and discharge receiving stream
- availability and adequacy of existing sewerage and treatment facilities

Most of the above information was unavailable from GOM ministries or the industries. For example, no government authority with wastewater responsibility had any detailed data about types and quantities of chemicals currently discharged from textile plants. There has been some focus on dyes, but most pollution comes from scouring, sizing, washing, and auxiliary dyeing chemicals that are subsequently washed out of the finished product.

1.5 Relationship of this Study to the Proposed Wastewater Master Plan

A detailed scope of work for the preparation of a wastewater master plan for the islands of Mauritius and Rodrigues has been completed by the Ministry of Works and the African Development Bank.

The proposed master plan studies will focus on the need to provide sewers in unsewered areas, increase sewer capacity in underserved areas and provide wastewater treatment. Because of increased population and industrial development since the existing sewers were installed, and the prevalence of inadequate on-site wastewater disposal at individual properties, the master plan will likely recommend extending sewers and installing wastewater treatment facilities. Some of these improvements may allow treatment of combined industrial and domestic wastewaters. A large facility treating such a combination may be less expensive than separate industrial and domestic facilities.

Despite the potential advantages of a combined treatment system, this study focused on a stand-alone industrial facility because implementation of the Master Plan recommendations are unlikely to begin for at least 2 to 5 years. The industrial estate could be operating by then.

Chapter 2

EXISTING SITUATION

2.1 General

GOM authorities have prepared several industry inventories, which note industries that should install or upgrade wastewater treatment because their effluents compromise water resources. The following summarizes data prepared by the Ministries of Health and Industry and the Central Water Authority.

▪ textile industries discharging to MOW sewers	25
▪ textile industries discharging into rivers and streams	13
▪ textile industries discharging to absorption pits	8
▪ textile industries with dye houses	34
▪ cloth and linen washing plants	14
▪ galvanizing industries	2
▪ electroplating industries	1
▪ battery manufacturers	3
▪ leather tanning industries	2
▪ slaughter houses	1

The location of dye houses operating or under construction in Mauritius is shown in Exhibit 1.

2.2 Water Pollution Control

The administration of water pollution control in Mauritius involves several ministries and authorities. Industries must obtain agreement from the Ministry of Health that manufacturing processes and the effluents will cause no serious adverse effects on health and the environment. The Ministry of Industry obtains clearance from both the Central Water Authority and the Ministry of Works (Sewerage Department) before approving new applications. If a factory building is to be erected in an urban area, the industry must obtain development and building permits from the municipality concerned. If the building is located in a rural area, the development permit must come from the district council and the building permit from the Ministry of Works.

LOCATION OF DYE HOUSES IN MAURITIUS

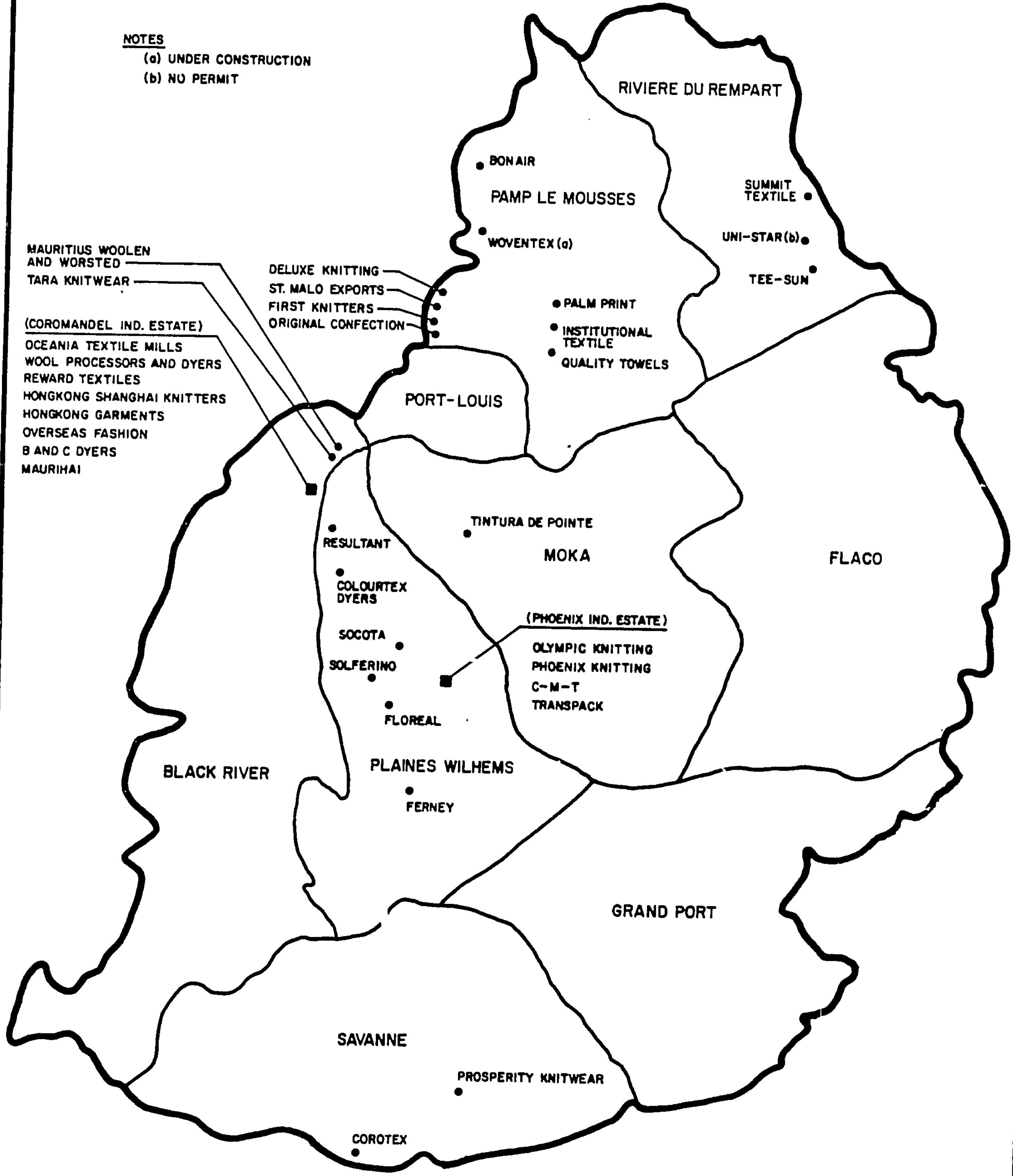

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EXHIBIT 1

To ease problems of shared responsibility, GOM created a ministry-level National Environment Committee to coordinate policies of all organizations involved in water pollution control and the environment. The newly established Environmental Department in the Ministry of Housing, Lands and the Environment, when staffed, will coordinate routine implementation of these policies. Within the Ministry of Works, the Sewerage Department will continue to be responsible for operating sewerage and treatment facilities located in Port Louis, Pointe Moyenne, and Pointe Aux Sables.

2.3 Existing Sewerage

Four treatment systems currently serve Mauritius:

(a) **Port Louis.** Two facilities, north and south, serve the urban area and have preliminary treatment with outfalls beyond the reef. The initial collection system was constructed in the early 1970s along with the outfalls. Extensions were made to the collection system in 1983.

(b) **Point Aux Sables.** This system serves some urban areas and also the Coromandel industrial area. Preliminary treatment is provided with an outfall beyond the reef.

c) **Pointe Moyenne.** This system serves parts of the urban area extending from Beau Bassin to Curepipe. Preliminary treatment is provided, followed by two parallel series of anaerobic ponds (four ponds in each series) that partially treat a portion of the wastewater. High flows bypass the ponds. If secondary facilities are provided in the future, part of the effluent may be used for irrigation. The existing treatment facilities discharge at the shore.

According to the MOW, the equipment at these four treatment systems needs rehabilitation. This judgment was confirmed by WASH team site visits to two of the facilities.

2.4 Water Supply to Industry

The Central Water Authority controls all water supply in Mauritius, including both ground and surface water. The current supply is half groundwater and half surface water, with the latter treated at several water filtration plants.

In addition to providing water through existing distribution systems, CWA also authorizes construction of boreholes for industrial or private water supplies. All water, whether from the distribution system or boreholes, is metered by CWA.

AREAS SERVED BY SEWERS (1989)

EXHIBIT 2

CDM

Water demand exceeds supply in the northern part of the island. During the dry season, water resources are inadequate for irrigation, industrial, hotel, and domestic demands. To some extent, a similar situation exists in the western part of the island, where there is no water surplus. The largest undeveloped water resources are in the southeast part of the island.

2.5 Water Pollution Concerns

2.5.1 Industrial Wastewater Treatment at Textile Facilities

Ministry of Industry and CWA investigations and WASH team visits confirm that no satisfactory wastewater treatment facilities currently exist for dye houses discharging to ground or surface waters. Only one textile facility, which is under construction, appears to have adequate provision for wastewater treatment, based on a WASH team evaluation of the design drawings and construction completed to date. No information was available on wastewater treatment at facilities in other industrial sectors.

2.5.2 Groundwater

Because of natural soil and bedrock conditions on Mauritius, there is hydraulic connection and rapid transfer between surface waters and groundwater aquifers. Consequently, discharge of untreated wastewaters to the ground, in lava tubes or even surface water can result in contamination of groundwater aquifers.

In the past few years, new pollution sources from both the textile industry and hotel developments have increased sharply, along with the demand for industrial, hotel, commercial, and domestic water. This has raised a concern about the quality and quantity of borehole water, as more boreholes are developed. Chapter 4 discusses a prohibition on the discharge of wastewaters directly or indirectly into the groundwater aquifers.

2.5.3 Surface Water

Water quality in rivers and streams must be protected to satisfy projected demands for safe and dependable water. Chapter 4 discusses restrictions on the discharge to surface waters of insufficiently treated wastewater.

Chapter 3

NEED FOR AN INDUSTRIAL ESTATE

3.1 Current Demand

The previously noted National Environment Committee was set up by the Ministry of Industry in February 1988 to both review the problem of wastewater-effluent disposal and recommend action regarding applications for new industries with polluting potential. The committee has approved seven applications thus far; ten applications are pending, awaiting resolution of such issues as adequate water supply and adequate facilities for wastewater disposal. Four applications seek additional production capacity for existing industries and six are for new plants.

Both the Ministry of Industry and MEDIA, as well as the private sector, represented by the Joint Economic Committee and The Mauritius Chamber of Commerce and Industry, strongly endorse an industrial estate as a means to address wastewater disposal. The need has been further demonstrated by the expressed interest of industrialists and investors in new industries (e.g., Rogers & Co. in relation to a new tannery), and the expressed interest by existing industries to achieve vertical integration (e.g., Beta Industrial--a textile operation that has no space to construct a dye house where it currently operates).

3.2 Advantages of Centralizing Water-Intensive Industries

3.2.1 Appropriate Siting

A government-sponsored industrial estate administered by MEDIA would provide both GOM and industry the means to optimize siting, particularly in regard to providing adequate water and power supply. Past problems of industries proceeding to final site selection without a thorough consideration of water supply and wastewater treatment requirements would be avoided.

3.2.2 Cost Savings on Infrastructure

Considerable savings would be realized in providing water, power, communications, utilities, roads, and landscaping at one location rather than several.

3.2.3 Easier Monitoring of Compliance

Consolidating the selected industries with the necessary infrastructure would improve environmental protection of both ground and surface water and centralize facilities management.

At present, GOM cannot adequately monitor the wastewater disposal practices of industrial plants throughout the island. Neither laboratory facilities nor trained personnel are available to confirm compliance with disposal standards. However, by locating selected new industries and relocating poorly sited operations within an estate dedicated to providing adequate treatment, pretreatment compliance monitoring could be readily conducted from the same laboratory used to control the central treatment plant.

Chapter 4

RECOMMENDATIONS FOR POLICY ON INDUSTRIAL WASTEWATER TREATMENT

4.1 General

Both fresh and marine waters are important assets to the Mauritian economy. This section sets forth the WASH team's recommendations for water resource protection and the level of wastewater treatment appropriate for different discharge locations.

4.2 Priorities for Water Resources Protection

4.2.1 First Priority

Discharges to groundwater and intermittent inland rivers (which recharge groundwater during the dry season) require the highest priority for protection from contamination because when pollutants enter groundwater, there is little biological or chemical activity to eliminate them. The government should allow only effluents meeting drinking water standards, or noncontact, once-through cooling water to be discharged to waters in this category. Only variances for dissolved inorganic salts, e.g., sodium chloride or sulfate should be allowed. Otherwise, there is a serious risk of contaminating existing and potential potable water resources.

4.2.2 Second Priority

Discharges to fresh water rivers with reliable, year-round flow (which do not recharge groundwater) or directly into the lagoon pose no hazard to potable water. Wastewaters containing suspended solids and nitrogen or phosphorous nutrients could change the turbidity of the lagoon, stimulate algal growth, and if certain organic chemicals are present, taint fish. These detrimental impacts would be largely avoided if wastewaters discharged to the lagoon received full secondary biological treatment with nitrification (after appropriate industrial pretreatment) and the outfall provided adequate dilution.

4.2.3 Third Priority

The deep ocean outside the lagoon is the least sensitive environment because of the large dilution available. The design of outfalls to the ocean must consider the length and location necessary to achieve the desired dilution and also the potential for wash-back into the lagoon. Injury to marine life is also possible, particularly with pretreated or untreated industrial wastewaters. Outfall siting and design should be a part of the island-wide wastewater master plan.

4.3 Wastewater Treatment at the Proposed Industrial Estate

The WASH team recommends that the new estate provide secondary biological treatment after appropriate pretreatment at each industry. This treatment level is important for industrial wastewaters because of the need to oxidize deleterious chemical compounds not commonly found in sanitary wastewaters.

Several government officials in Mauritius have expressed interest in recycling treated effluents, as practiced in the Jurong Industrial Estate in Singapore. At that site, the effluent from a biological treatment facility serving the western part of the island is further purified by physical/chemical processes prior to reuse. This treatment takes place at considerable expense, which is justified only because of the lack of available water. In contrast, Mauritius has fresh water, as long as the resources are not abused, and needs only to collect and distribute the water. (See Appendix B for notes on the Jurong Estate operations.)

4.4 Equitable Treatment of New and Existing Industries

As explained in Chapter 7, industries located in the proposed new industrial park would have to pay more for wastewater disposal than existing industries currently discharging untreated or partially treated wastewater to the ground, rivers, or MOW sewers. The new industries should not be penalized, relative to their competition, for participating in a complete treatment system. To equalize costs, non-estate industries that consume more than about 50 cubic meters per day of process water should be subject to the following conditions:

- If discharging untreated effluent to surface or groundwaters, the water supply tariff would be the same as the total for water and sewer at the new estate. If the industry installed the equivalent of secondary treatment and the discharge met (CWA) standards and the restrictions in Section 4.2, the water supply tariff would be reduced to deduct the cost of the treatment portion. This scheme would create an incentive for industries to move to the new estate to avoid the capital cost of biological wastewater treatment facilities.

- If discharging to a MOW sewer, a similar cost structure would be established, except that partial credit would be given to industries with the applicable pretreatment and an effluent meeting the revised MOW limits. The credit would help offset the industry's cost of pretreatment and secure sludge disposal.

The above policies would be applicable to both Export Processing Zone (EPZ) and non-EPZ industries. Enforcement and assessment of the new tariff structure would begin simultaneously with the start-up of the wastewater treatment facilities at the new industrial estate. Exhibit 3 summarizes the policy. GOM should consider implementing a loan program to assist existing industries with these proposed new treat-or-relocate requirements.

EXHIBIT 3 - POLICY FOR WASTEWATER MANAGEMENT

A. FOR POLLUTING INDUSTRIES IN NON-SEWERED AREAS

1. New facilities or expansion of existing facilities

   Actions by GOM

   - Prohibit discharge of untreated wastewaters.
   - Establish an industrial estate with required infrastructure and wastewater treatment facilities including handling and disposal of sludge. Discharge to a river or a sewer flowing directly to the deep ocean.

   Actions by Industry

   - Move to industrial estate and provide pretreatment facilities, or provide secondary treatment if CWA authorizes discharge to surface waters.
   - Comply with effluent standards.

2. Existing facilities

   Actions by GOM

   - Establish compliance schedule for provision of adequate treatment for each industry.

   Actions by Industry

   - Provide treatment as above or cease discharge within established compliance schedule (no longer than 3 years suggested).

B. FOR POLLUTING INDUSTRIES IN SEWERED AREAS

1. Pretreatment

   Actions by GOM

   - Establish compliance schedule for each industry to implement pretreatment. Provide for further treatment along with domestic wastes wherever possible and as recommended in the proposed master plan studies.

   Actions by Industry

   - Construct and operate on-site pretreatment facilities to achieve required effluent standards.

2. Prevention of Overflows from existing MOW sewers

   Actions by GOM

   - Implement master plan recommendations related to sewerage extensions and capacity required to handle projected flows.

   Actions by Industry

   - Provide detailed information on volume and rate of wastewater discharge from existing and proposed plants.

EXHIBIT 3 - POLICY FOR WASTEWATER MANAGEMENT (continued)

C. INFRASTRUCTURE

1. Deleterious/toxic sludge disposal

Actions by GOM

- Establish dedicated secure sludge landfill with leakage collection and treatment.
- Provide sludge transport service to industry for a fee.

Actions by Industry

- Dewater all wastewater sludge to greater than 15 percent solids (non-flowable).

2. Design and construction standards

Actions by GOM

- Establish design and construction standards for wastewater treatment systems to ensure proper operation.
- Prohibit in-ground tanks in areas of high groundwater.

Actions by Industry

- Comply with design and construction standards.

4.5 Policy for Diversification into New Industry Categories

The purpose of diversification is to provide long-term employment stability, improved island-wide infrastructure, an increased tax base, and improved personal income. Because land is limited and island water resources can be easily damaged, Mauritius must prevent industries from moving to the island believing that only modest restrictions on environmental pollution apply. New industries should be required to meet the same environmental standards as in developed countries.

Some industries may generate too much hazardous waste to operate in Mauritius without unreasonable pollution risk. For example, a large tannery starting from raw, salted hides would generate enormous quantities of sludge containing chromium, sulfides, and putrescible matter. Diversification into the leather industry could proceed more safely by importing the "crust" (tanned, dried hides) needing only surface coloring or, if necessary, wet in-the-blue hides (already dehaired and tanned) requiring only fat liquoring, coloring, and drying. In either case, there would be enough flexibility to respond to the needs of the domestic and EPZ shoe or garment industry. The chemical industry, particularly herbicides or pesticides for export, is another example of a category poorly suited to the Mauritius environment.

Chapter 5

POLLUTANTS AND ABATEMENT TECHNOLOGIES

5.1 Introduction

Pollutants from industrial operations may be categorized as follows:

- acidity/alkalinity (low/high pH)
- color
- dissolved salts
- nutrients (e.g., phosphorous and nitrogen)
- suspended solids
- metals (soluble and suspended)
- organic material as measured by biochemical oxygen demand (BOD) or in the case of industrial waste, the reduction of chemical oxygen demand (COD) by biological treatment with an acclimated culture
- phenols, sulfides, and cyanides
- oil and grease
- synthethic organic compounds difficult or impossible to degrade

Industrial discharges may be regulated in at least three ways: restricting the concentration of specific pollutants in treated wastewater, restricting the mass of pollutants per unit of manufacturing production that may be discharged, or specifying the wastewater treatment processes to be applied.

The remainder of this chapter describes the pollutants likely to be found in wastewaters from the current and proposed EPZ sector industries, and the applicable treatment methods. The degree of treatment would depend upon whether the discharge would receive further treatment at a facility serving several industries and/or sanitary wastewater from municipal sewers. Preliminary treatment at an industry is termed pretreatment.

5.2 Textile Sector

For this report, the wet manufacturing operations would include initial scouring (excluding scouring of raw wool), sizing/slashing, washing to remove dye or lubricants, bleaching, mercerizing, carbonizing (woolens only), fulling (woolens only), printing, and dyeing. Cotton, wool, and polyester are the primary fibers considered for this report.

Printing and dyeing introduce auxiliary chemicals: soluble organic compounds (such as acetic acid) and salts, plus either dissolved or colloidal colorants. Polyester dyeing adds a dye carrier, typically a phenol derivative or an alkyl or chlorinated benzene derivative, to the above ingredients; these carriers are difficult to treat biologically. Certain dye families for wool, including mordant and premetallized dyes, contain metals such as chromium and copper. Fabric-printing wastewaters may contain metal-bearing pigments and hydrocarbon solvents.

The other textile processes produce wastewaters with dissolved solids, pH changes, oil and grease, and some nondegradable compounds. In some cases, fiber loss may also be significant. Applicable treatment technologies include fine screening, pH adjustment, and skimming to remove oil and grease. Aerobic biological treatment is the only practical method to reduce BOD because many of the organic compounds are soluble and cannot be removed by physical or chemical methods.

Treatment of printing and dyeing wastewaters may include initial coagulation with aluminum sulfate and polymer, followed by sedimentation to collect the sludge. This process can remove metals, pigments, and colors from the wastewater, but the treatment efficiency will change with different dyes and pigments. Coagulation is most effectively used in pretreating colloidal dyes and printing-pigment wastewaters that contain hydrocarbon solvents. Coagulation cannot remove soluble organic chemicals.

Although dyes and carriers may be adsorbed on activated carbon, this process is rarely practical for treating raw dye wastewaters because auxiliary chemicals compete for adsorption sites. Also, new carbon is expensive, as is regenerated carbon. Carbon adsorption can take place after biological treatment, but only low loadings can be achieved because the color and carriers are more dilute. And, during the process, the carbon will likely be fouled by biological growth.

In summary, pH adjustment, equalization, screening, and biological treatment are the technologies most applicable to textile wastewaters. When pigments and/or metal-bearing dyes are present, coagulation and sedimentation should be considered as a pretreatment step for only those wastewaters containing metals. The fully treated wastewater will still contain some nondegradable organic compounds, nutrients, and dissolved solids, and will not be potable.

Waste reduction technologies common in the textile industry include evaporation to recover caustic for mercerizing and ultrafiltration to recover synthetic sizes.

5.3 Leather Sector

Hide processing involves dehairing, washing, tanning, retanning/fat liquoring to lubricate the leather fibers, paste-up and drying, trimming and splitting, and tinting. Wastewaters from the dehairing process contain high concentrations of salt, lime, sulfide, and suspended solids. The latter can be collected by sedimentation as a sludge, which can be up to 25 percent of the dry weight of the raw hides. The sludge is loaded with sulfides and putrescible animal matter. Wastewater from dehairing must be maintained at pH 9.5 or higher to prevent release of odorous and toxic hydrogen sulfide, until the sulfide biologically oxidizes to sulfate.

Wastewaters from tanning and retanning processes typically contain high levels of chromium and suspended solids, which can be treated by adding lime and coagulating with alum and polymer, followed by settling to collect yet more sludge. The clarified wastewaters will still contain a high BOD.

Paste-up plate washing produces a wastewater with some BOD from the adhesive. The tinting operation generates some waste oil and solvent vapor emissions, but little wastewater.

In summary, assuming that the tannery started with rawhides, the applicable treatment technologies would be chemical precipitation and settling to remove chromium and suspended solids, followed by biological oxidation.

5.4 Metals Industry

Electroplating, anodizing, printed circuit board fabrication, precious metal refining, and related industries generate wastewaters containing dissolved salts and metals. Metal hydroxide precipitation is the treatment method normally employed. In this process, which uses a series of mixing tanks, the wastewater pH is first raised with lime and/or caustic to between 8 and 10 (the optimal pH depends upon the metals present). Then, an iron coagulant (derived from ferrous sulfate or ferric chloride) and an anionic polymer are added. The floc generated by this chemistry is allowed to settle in a clarifier, from which the sludge is pumped to a filter press for dewatering to about 50 percent solids. The filter cake requires secure disposal.

Several wastewaters from the metal industries require special treatment. Chromium-plating wastewaters and some aluminum-anodizing processes contain chrome VI, which must be reduced to chrome III before the wastewater is mixed with others for metal hydroxide precipitation. This reduction is done with sulfites under acid conditions. The cyanide in wastewaters from gold-plating, alkaline copperplating, and rinses following certain molten salt quenching operations must be oxidized with chlorine. Electroless copperplating wastewaters from printed circuit board fabrication requires metals removal on carbon or precipitation with proprietary sulfur-bearing reagents, because chelating agents interfere with metal hydroxide precipitation. After treatment, these wastewaters must be kept separate from other metal-bearing wastewaters; otherwise, the chelating agents will pick up metals again.

Metal-working and -plating factories may use organic (chlorinated) solvents to clean parts. These solvents should be recovered by distillation and never discharged with the wastewater. The metal-machining industry uses oils and oil-water emulsions to lubricate and cool parts. The oil-water emulsions are best treated by ultrafiltration to concentrate the oil, which can then be burned in an industrial boiler.

Numerous water conservation and process chemical recovery methods are available for the metals industry, such as counter-current rinses, reverse osmosis, and evaporation. These technologies become attractive as wastewater discharge costs increase and pollutant limitations become more stringent.

In summary, waste reduction and metal hydroxide precipitation are the wastewater treatment methods applicable to the metals industry. Equipment is readily available from developed countries and should be implemented independently at each factory. Biological wastewater treatment is often unnecessary for the metals industry.

5.5 Food Processing

Wastewaters from food processing industries contain primarily BOD, suspended solids, and oil and grease as pollutants. After skimming to recover grease, the wastewaters are best treated by anaerobic and/or aerobic biological treatment. In most cases, the effluent can be used for irrigation.

5.6 Sludge Handling and Disposal

5.6.1 General

Most wastewater treatment processes, including sedimentation, chemical precipitation, and biological treatment, generate sludge. Designing the sludge-handling equipment and preparing for sludge disposal are important, and often expensive, components of all treatment plants.

5.6.2 Sludges Beneficial to Agriculture Land

Sludges from the sedimentation of raw wastewaters and/or biological treatment of food processing and sanitary wastewaters containing no other industrial wastes typically contain low concentrations of metals and objectionable, non-degradable organic compounds. These sludges can be applied to the land to help improve the soil structure. Bacteria in the soil further treat the sludge. The sludge may be applied to the land in a dilute form at 2 to 4 percent (dry weight) suspended solids in a volume of about 1 percent of the flow to the wastewater treatment plant. Alternatively, the sludge can be concentrated to between 15 and 20 percent solids in equipment designed to remove water. The concentrated sludge can be more readily transported to distant disposal sites.

These factors must be considered in selecting sites for land application of sludge:

- Distance and land slopes to surface water needed to prevent contamination from runoff.

- Application rates, which are limited by the nitrogen and certain mineral components of the sludge.

- The crop to be grown. Cane is an ideal crop because it is further processed before human consumption. Hence, any residual sludge components can be removed when the sugar is refined. Nevertheless, sludge application should be terminated about eight weeks before harvest.

Sludge may applied to the land by spray irrigation if the solids content is below about three percent. Concentrated sludges are normally applied as semi-solids and must be turned in the soil like manure.

5.6.3 Deleterious/Toxic Sludges

Sludges from chemical coagulation of wastewaters from dye houses, metals industries, tanneries, and other such industries contain metals and undegraded organic compounds. These sludges are hazardous and require secure, permanent disposal at restricted-access sites. The disposal area must be above the groundwater table, and underlain by an impermeable barrier to prevent sludge leachate from percolating into the groundwater and contaminating it. Rain water collected on top of the liner (e.g., in the containment area) would be contaminated and would require extensive treatment prior to discharge.

Because of the expense of siting, constructing, and operating a secure disposal site, the disposal cost per ton of sludge at such a facility is extremely high. Consequently, industries have an incentive to concentrate sludges by removing water prior to disposal, and also to minimize the volume of material wasted.

Industries may try to avoid the expense of secure disposal by finding alternative, less environmentally suitable sites. Therefore, requirements for sludge disposal in secure (and expensive) containment areas must be complemented with a strong enforcement capability and severe financial penalties for noncompliance.

Chapter 6

PRELIMINARY DESIGN CRITERIA FOR AN INDUSTRIAL ESTATE

6.1 General

Although specific tenants have made no firm commitments to occupy a new industrial estate for water-intensive industries, this chapter establishes preliminary design criteria for the proposed estate based on the assumption that tenants would be comparable to existing mid-size industries in Mauritius. Design criteria should be refined as the space, water, and electricity requirements and tenant types are identified. This report focuses on the wastewater management aspect of the estate.

6.2 Location

Water supply is a major concern for the proposed estate. As the southeast side of the island possesses the largest undeveloped water resources, locating the estate in that region would avoid the need to construct a major water transmission main. Convenient water supply must be balanced with labor availability and a suitable outfall for the effluent, either direct or through an MOW sewer. The scope of this study did not permit selection of specific candidate sites.

In addition to water supply, the selection process should evaluate three factors:

- Acceptance of the local community. Assurances that air, water, and land pollution will be prevented through careful facilities planning and rigorous enforcement of standards would help promote good relations.
- Sufficient nearby labor force and/or measures to bring workers from outlying areas.
- Road improvements to eliminate the need for heavy trucking and employee traffic through residential areas.

6.3 Estate Size and Building Design

For planning purposes, this report assumes that the estate would have, when fully occupied, 12 single-story buildings with floor plans of 5000 square meters each, for a total of 14.8 acres (U.S.) under roof. To accommodate roads, open areas, parking, outside utilities, and wastewater treatment facilities, a total land area of 60 acres should be acquired. In addition, a 250 meter (or greater) agricultural buffer zone should be provided around the estate by acquiring a right to restrict use to forest, cane, or other crops not directly eaten before processing. This peripheral land, amounting to 200 acres, would also be available for land disposal of certain biological wastewater treatment sludges.

The process equipment in water-intensive industries often requires special foundation design and free-space clearances. Consequently, buildings for the new estate should be designed after tenant requirements have been specified.

6.4 Tenants and Water Requirements

For preliminary planning, the WASH team developed the following list of possible tenants after discussions with the Ministry of Industry and MEDIA. The tenants would be new industries to the island or those determining that relocation to the estate was less expensive than providing adequate wastewater treatment at their current sites.

TABLE 1

Water Requirement Projections of Potential Tenants

TENANT CATEGORY	NUMBER IN CATEGORY	DAILY PROCESS WATER REQUIRED PER TENANT (cubic meters)
Integrated Textile Manufacture	5	200
Commission Dye House	2	100
Metals fabrication, electroplating, or electronics	3	120
Tannery, starting from wet, in-the-blue hides (see Section 5)	1	200
Other	1	100
Total all tenants	12	1860

Since process water demand will be uneven over the course of the day, a 1000 cubic meter reservoir should be provided.

In addition to process water, the industries may require some noncontact cooling water, and the estate must provide water for fire fighting. This nonpotable water may be obtained from a stormwater holding pond, which would also serve as a landscaping feature.

6.5 Electrical Requirements

Based on data provided by MEDIA, each 5000 square meter building should have a supply of about 300 kilovolt-amperes (KVA). In addition, the wastewater treatment plant would require about 200 KVA, for a total connected load of 3800 KVA. A supply of about 3000 KVA should be adequate because the total connected load will probably never all draw power simultaneously. This large load may strain electric supply, and provision should be made to provide two independent feeders to the estate. Also, a standby diesel generator should be available to provide emergency electrical power to selected lights, computer systems, and alarms throughout the estate if the primary power supplies fail.

6.6 Sewers

A sewer system should be provided to transmit process wastewaters (pretreated in some cases) to the equalization tank at the central treatment facility. Sanitary wastewaters should be piped directly to the aeration tanks. Roof drains and surface runoff should be directed via drains or culverts to the holding pond. All process water drains in each building should lead to a single manhole equipped with a weir or parshall flume for flow measurement and sample collection.

To eliminate the need for collecting potentially contaminated rainfall runoff in chemical storage areas, all such storage should be located inside buildings. Storage areas should have appropriate ventilation and fire protection. Drains should be prohibited in these areas.

6.7 Wastewater Treatment

6.7.1 General

Wastewater treatment would consist of two steps. The first would be pretreatment at each industrial site to remove certain deleterious substances and reduce the wastewater strength. The second step would be an extended aeration-activated sludge treatment system to remove BOD and COD. The relationship between the two steps is shown in Exhibit 4.

PRETREATMENT AND SECONDARY TREATMENT BLOCK DIAGRAM FOR WATER INTENSIVE INDUSTRIES ESTATE

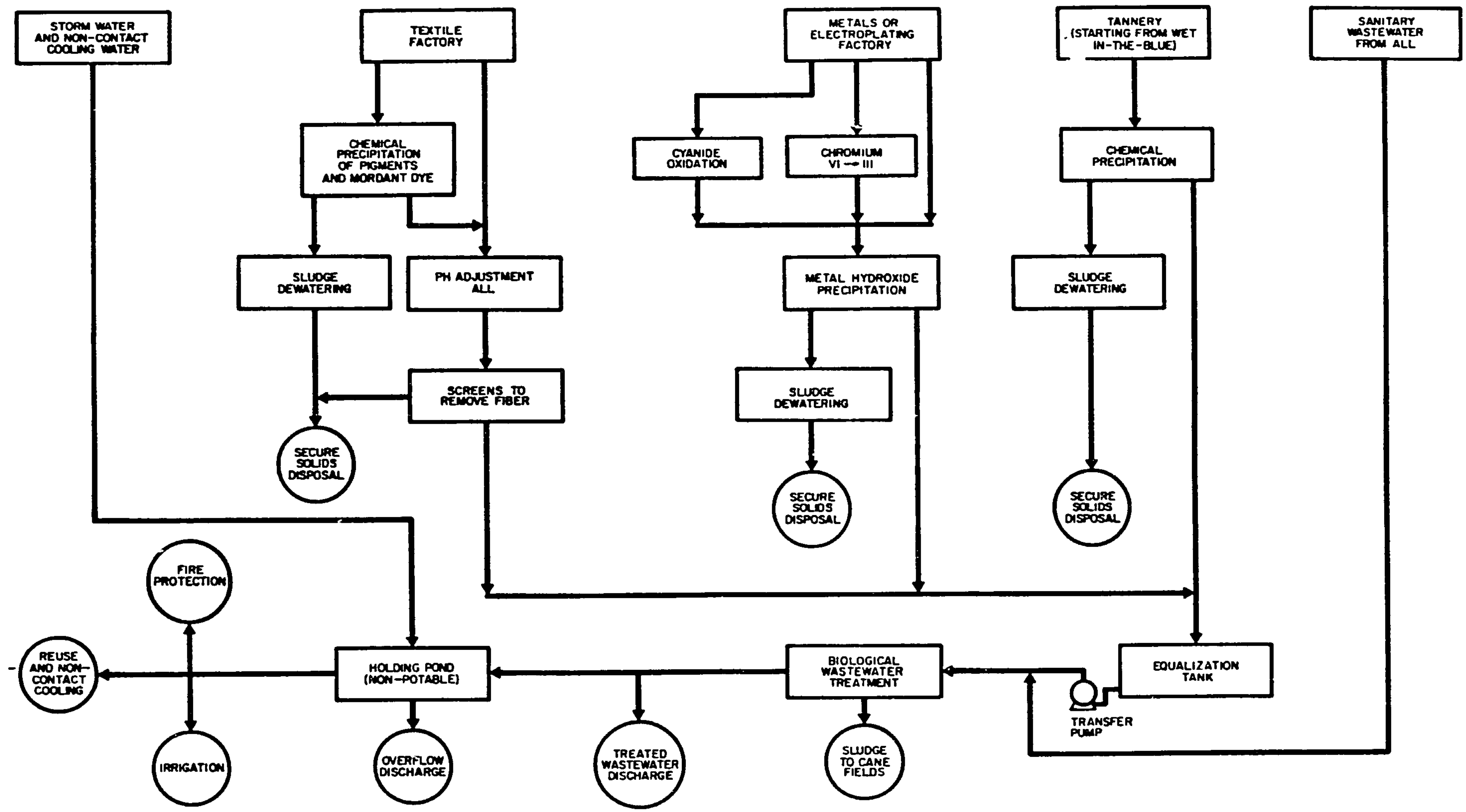

EXHIBIT 4

CDM

6.7.2 Pretreatment

The objectives of pretreatment would be to

- prevent obstruction/damage to the sewers, such as from acids, heavy solids, or congealable grease

- prevent accumulation of flammable or explosive vapors in the sewer

- remove compounds such as metals that could accumulate in the secondary biological sludge and render it unfit for application to cane fields

- remove compounds that could interfere with biological treatment or pass through untreated, such as color

Pretreated wastewater would be subject to general standards to meet these objectives, as well as specific numerical limits for pH, metals, oil and grease, phenols, solvents, and certain other organic compounds. Both MOW and CWA have made initial lists of sewer limits, but these lists need refinement. Limits applicable to the new industrial estate should be set during final design, based on references such as those available in the United States for specific industry categories (published in the Code of Federal Regulations, Vol. 40, Chapters 400 to 500) and the standard of performance normally achievable with the specified pretreatment technologies. Exhibit 4 shows pretreatment processes for three categories of prospective estate tenants. The industrial tenant would be responsible for the design, construction, and operation of its pretreatment facilities. Chapter 5 of this report provides some additional process details.

6.7.3 Secondary Treatment

The second treatment step would be biological oxidation to remove BOD and COD, including many of the so-called toxic compounds.

Prior to this step, an equalization tank with low-power mixers would be provided to protect the biological system from hydraulic surges and slug discharges, and also to dilute any compounds that might be toxic in high concentrations. The equalization tank could be fabricated from reinforced concrete or earth-lined with an impermeable plastic sheet (e.g., 1 mm high-density polyethylene). Wastewater from the equalization tank would be pumped to the aeration tanks, rather than allowed to flow by gravity, to achieve a constant rate. Some wastewater should be stored in the equalization tank to feed aeration tank microorganisms on days when the industries were not in operation. This procedure would prevent upset problems otherwise encountered with cyclic fluctuations in wastewater load.

The aeration, clarifier, and recycle systems would be constructed in three parallel trains. This modular concept would permit expansion from one to three units in operation as estate occupancy increased to the projected 12 buildings. Exhibits 5 and 6 show the preliminary design concept. The aeration tanks would be constructed of either reinforced concrete or plastic-lined earth. The clarifiers would be made of prefabricated steel or reinforced concrete, and would include modern sludge-withdrawal capability. Only the rates are shown for pumping and for blowers, only the projected electrical power consumption. The number, sizing, and degree of redundancy for each piece of equipment would be determined in final design. Equalization and aeration tank depth would depend on site conditions, but should be about 3.5 meters plus freeboard.

6.8 Wastewater Treatment—Other Design and Operation Considerations

Either employees of the estate manager (e.g., MEDIA) or a private contractor could operate and maintain the wastewater treatment facility, and monitor the industrial discharges. Contract operation may offer more flexibility in staffing, better access to skilled labor through less-restrictive salary structure compared to the government, and more contacts with outside expertise. If the contractor had an industrial/environmental engineering affiliate, the firm could also provide advice on pretreatment for the individual industries.

Training for treatment plant operators would benefit initially from a "twinning" arrangement with a similar facility in a developed country, as no comparable treatment facilities exist in Mauritius. Under this arrangement, Mauritian operators would learn from twin staff at both the Mauritian and the twin's facilities.

As noted in Chapter 1, combining estate wastewater with domestic sewage from the surrounding communities may prove environmentally beneficial and economically attractive compared with two separate facilities. The island-wide wastewater master plan should provide recommendations and direction on this issue. If implementation of the industrial estate proceeds quickly, there would only be time to consider including sanitary wastewaters from the adjacent community.

Wastewater treatment and sludge disposal impoundments may be constructed from reinforced concrete or plastic-lined earthen lagoons. To achieve leak-free operation with reinforced concrete, the structure must be rigid, with enough reinforcing to prevent cracks from uneven settlement or groundwater pressures. Water stops must be provided at all construction and expansion joints. Such a structure would have a long life, but would be relatively expensive compared with a lined earthen lagoon.

Experience in the United States has shown that it is impossible to install a completely leak-free plastic liner, despite advertising claims. Leaks arise from small flaws in the plastic, improperly sealed joints, tears occurring during installation or subsequent maintenance, and attack by sunlight and chemicals. To prevent liner flotation, the lagoon bottom elevation must be above the maximum groundwater elevation. With proper installation, the leakage can be kept to an acceptable level. Lagoons should be located where minor leakage would not have a detrimental effect, and liner integrity should be checked by an underdrain system or nearby groundwater monitoring wells.

EXHIBIT 5 - PRELIMINARY DESIGN CRITERIA

SECONDARY BIOLOGICAL TREATMENT

FLOW TO THE EQUALIZATION BASIN	1600 M3 /DAY
EQUALIZATION BASIN	1600 M3
EQUALIZATION MIXER POWER CONSUMPTION	20 KVA
TRANSFER RATE TO THE AERATION TANKS (MAX)	70 M3 /HR
SANITARY FLOW TO THE AERATION TANKS	260 M3 /DAY MAX 20 M3 /HR
TOTAL COD OXIDIZED IN ALL AERATION TANKS	3500 KG/DAY
TOTAL BLOWER POWER CONSUMPTION	120 KVA
AERATION TANK SIZE (1 OF 3)	1240 M3
AERATION TANK HYDRAULIC DETENTION	2 DAYS
CLARIFIER DIAMETER (1 OF 3)	7.5 M
RECYCLE PUMP RATE, EACH CLARIFIER	35 TO 70 M3 /HR
RATIO OF DAILY COD OXIDIZED TO ACTIVATED SLUDGE MASS	0.35
TOTAL EXCESS SLUDGE PRODUCTION	875 KG/DAY AT 2% SOLIDS - 50 M3 /DAY
SLUDGE HOLDING POND CAPACITY	1500 M3

SECONDARY BIOLOGICAL TREATMENT BLOCK DIAGRAM

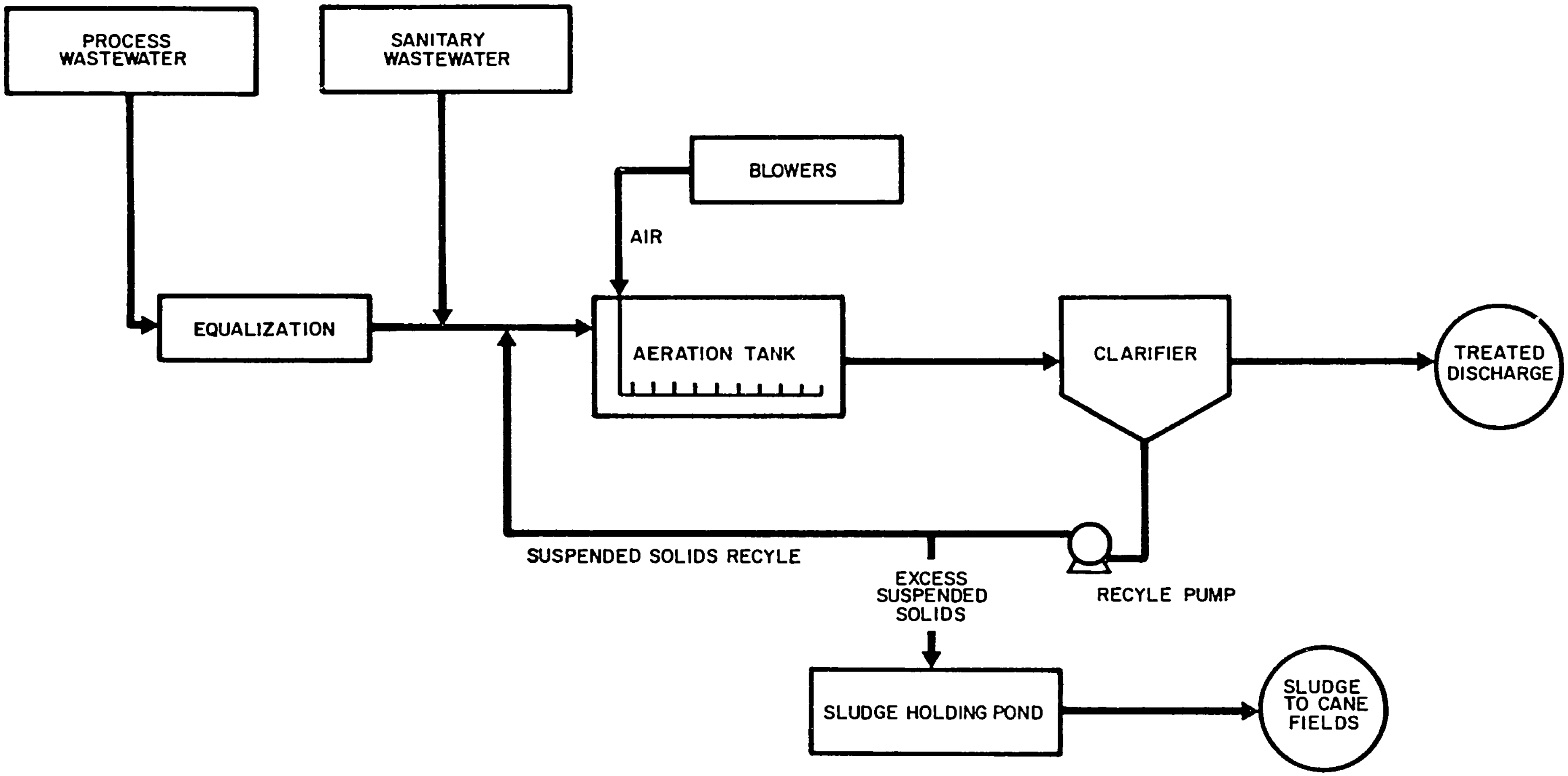

EXHIBIT 6

CDM

6.9 Secure Sludge Disposal

Sludges from the industrial pretreatment systems would contain metals, pigments, and other compounds that must be placed in a secure containment area designed to permanently prevent contamination of the surrounding soils, surface water, and groundwater. The site must be so designated in the land records that it will never be re-excavated once the containment has reached capacity and been capped. Site selection should consider these factors:

- Protection of any down-gradient groundwater withdrawal.
- Feasibility of construction above the highest local groundwater elevation.
- Amount of rainfall. Because all water collected in the containment would become contaminated and require treatment at the estate, the site should be in a "dry" part of the island.

The containment should be constructed with two plastic liners on the bottom, separated by a 0.7 m layer of 5 to 10 mm diameter stone and a collection system of perforated, heavy-wall PVC pipe. This interliner drain system would prevent leachate leaks from the primary containment liner from reaching the groundwater and would facilitate monitoring liner integrity. To further reduce leakage possibility, a similar collection/drain system should be installed inside the primary liner so that leachate can be pumped out of the landfill for treatment. To minimize the volume of rainfall requiring treatment, the containment should be constructed in cells of about 4000 cubic meters, with a 3-to-4-meter depth. As each cell reaches capacity, it would be capped with a plastic liner, which would be protected with 1 meter of soil and seeded with grass to prevent erosion. The cap would be sloped to enhance precipitation runoff. Initially, only one cell should be constructed until the rate of sludge generation by the tenant industries has been established. If space permits, containment may also be made available for disposal of sludges from industries outside the estate.

Chapter 7

COST ESTIMATES FOR WASTEWATER TREATMENT

7.1 Assignment of Costs

This section identifies the cost for industrial wastewater collection and centralized treatment for industries to be located at the proposed estate.

Utility and infrastructure costs such as water storage and distribution, electrical power, standby power, sanitary sewers, and roof drains would be part of the basic costs of any industrial estate, whether or not it provides treatment of significant industrial wastewater flows. Land acquisition would also be part of the estate development costs, and therefore not be included as part of the additional incremental costs of wastewater treatment. Acquiring rights in the proposed buffer zone for land application of effluents and land disposal of sludge would be a factor in determining the cost of providing special industrial wastewater services. Because land costs largely depend on local conditions and because owners may benefit from the irrigation water and sludge nutrients, this report does not estimate the cost of acquiring the buffer zone as part of the wastewater costs. Each industry would be responsible for its own pretreatment costs.

7.2 Estimated Capital Costs

Because of the preliminary planning nature of this study, the capital cost estimate for treating the industrial wastewaters was based on comparisons with similar treatment facilities being constructed in Mauritius. When preliminary designs for specific sites are prepared, detailed cost estimates based on quantities and unit costs for each component should be prepared.

This study relied on the cost information available for the wastewater component of the Woventex complex, since that facility will be similar to the suggested design criteria for secondary treatment presented in the previous chapter. The Woventex treatment facility, exclusive of land costs, was reported to cost Rs 10 million. Information on facilities under construction at the Bonair complex in Triolet was helpful in estimating pretreatment costs for chemical coagulation.

Extensive data are available on the cost of constructing and operating industrial and municipal waste treatment facilities in the United States. Although this information cannot be directly applied to conditions in Mauritius, such references were used in this report to develop approximate relationships between costs for individual treatment elements at different flows.

For the purpose of this initial planning report, the estimated incremental cost for the centralized industrial wastewater facilities at the proposed industrial estate would be between Rs 20 and 25 million. This cost is based on a treated effluent discharge to fresh surface water or the lagoon, rather than a deep ocean outfall. Estimating the cost of an ocean outfall was beyond the scope of this report.

The cost estimate for the wastewater facility includes the following:

Direct cost components

- civil works
- purchased equipment and installation
- instrumentation and controls
- piping
- electrical equipment
- support buildings
- yard improvements (treatment site only)
- service facilities (specifically for the WWTP)

Indirect cost components

- engineering and construction supervision
- construction expenses
- contractors fee
- contingency

Based on the estimating procedures outlined above, a secure sludge disposal facility for the estate would cost Rs 2.5 million.

Assuming that MEDIA would be the builder and manager of the industrial estate, the capital cost of wastewater treatment facilities would add 10 to 15 percent to the current rental rate of Rs 36 per square feet per year (Rs 388 per square meter per annum).

7.3 Estimated Annual Wastewater Treatment Operation and Maintenance Costs

Estimated total annual operating costs were developed from assumptions as to labor, power, consultant, laboratory, material, chemical, and other direct costs in Mauritius, and from values presented in the literature as to practice in other countries.

The following provides a brief description of the individual cost components:

Direct Costs

- **Labor costs.** These include the manpower required to operate and maintain the facility, plus support tasks such as supervision and administration, clerical and laboratory operations, and yard work. This category also includes labor for preventive maintenance and minor repairs.

- **Power costs.** Each mechanical operation at a treatment facility, such as pumping, mixing, and aeration, consumes energy. Power costs were estimated using a demand charge of Rs 58.50 per month per kWh of maximum demand and a running charge of Rs 1.32 per kWh. These costs were taken from the current maximum-demand tariff for industrial consumers holding a development certificate.

- **Consultants.** The estimate includes advisory services from an outside consultant based on three visits per year, for a total of 30 days of technical assistance.

- **Laboratories.** Specialized wastewater analytical services would be provided by a private-sector laboratory. These analyses would supplement routine analyses at the treatment facility.

- **Material costs.** This item covers materials such as paint, grease, and replacement parts required for routine facility maintenance.

- **Chemicals.** Substances required for the various unit processes fall within this category. Estimated quantities should be developed during the design phase.

Indirect Costs

- An allowance covers plant overhead, insurance, general and administrative expenses, and depreciation, based on a percentage of operating costs.

Estimated annual operating costs appear in Table 2.

TABLE 2

Estimated Total Annual Operating Costs

		Rupees
DIRECT COSTS		
1. Labor		1,425,000
2. Power		2,400,000
3. Consultant		525,000
4. Laboratory		300,000
5. Materials		750,000
6. Chemicals		150,000
7. Other direct costs		150,000
	SUBTOTAL	5,700,000
INDIRECT COSTS		
8. Allowances for overhead, insurances, expenses, and a portion of depreciation		1,500,000
	TOTAL	7,200,000

Direct costs amount to about Rs 10.00 per cubic meter of process and sanitary wastewater, and indirect costs amount to approximately Rs 2.50 per cubic meter for a total of Rs 12.50 per cubic meter.

7.4 Estimated Annual Secure Landfill Operating Costs

The costs for constructing and closing a secure landfill cell can be considered operating rather than capital costs, because the cell has a short life and no salvage value. Both capital and operating costs should be recovered in the tipping fee, so that funds are available to complete construction of a new landfill cell as the first reaches capacity. Assuming a two-year life per cell, the tipping fee would be about Rs 1500 per cubic meter of waste. This tariff would recover the following costs:

- Construction, including evacuation, liners, backfill, drains, interim cover material, and final cover.

- Staff to determine whether wastes were acceptable, supervise disposal, place wastes in the cell after delivery to the site, keep records, and collect on invoices. Waste hauling to the site would be by a private contractor.

- Maintenance of liners, cover material, special equipment for placing wastes in the cells, collection and treatment of leachate, and chemical analyses.

- Staff and laboratory fees to monitor industrial compliance with disposal regulations.

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REFERENCES

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APPENDIX A

Meetings and Interviews

APPENDIX A

Meetings and Interviews

1. U.S. Agency for International Development REDSO/ESA/, Nairobi

Satish P. Shah	Director
Monica Sinding	Deputy Director
Gene Morris	Chief, Products Division
Donald E. Greenberg	Private Sector Advisor
Iqbal Chaudhry	Regional Engineering Officer
Ed McGowan	Environmental Advisor
John Gaudet	Now with Africa Bureau; Previously Environmental Advisor at REDSO (Met in WASH office 5 May)

2. U.S. Embassy in Port Mauritius, Mauritius

Robert C. Perry	Counselor of Embassy
Francis Bostock, Jr.	Second Secretary (Economic/Commercial)
Shariff Jathoonia	Economic/Commercial Specialist

3. Mauritius Export Development and Investment Authority (MEDIA)

Benoit Arouff	Chairman
Chand Bhadain	Director
S. Soondrum	Manager (Industrial Estates)
Sulaiman Hossen Hansrod	Assistant Manager (Industrial Estates)
Y.S. Wong Sin Wai	Assistant Manager

4. Ministry of Industry and Industrial Technology

Hon. J.D. Clarel Malherbe	Minister
M.P. Mohith	Permanent Secretary
Ashok Kumar P. Aubeeluck	Principal Industrial Development Officer

5. Ministry of Health

L. Hurpaul	Chief Sanitary Engineer

6. Ministry of Works (Sewerage Department)

R. Laulloo	Principal Engineer

7. Central Water Authority

A. Kauppaymuthoo	Chief Surveyor/Water Rights Administrator
Mr. Loudiere	Head of Master Plan Team, French Consultant
Mandhub	Pollution Advisor
Dhaneswar Soobrah	General Manager

8. Ministry of Housing, Lands and the Environment

Hon. Sir Rakmesh	Minister
Jeewoolall Seebaluck	Environment Protection Department

9. Mauritius Export Processing Zone Association

Arif Currimjee	President 1989

10. World Bank

Michael S.V. Rathnam Sr.	Financial Analyst, Infrastructure Operations Division, Eastern Africa Department

11. Mauritius Chamber of Commerce and Industry

Gerard Sanspeur	Assistant Secretary General

12. Joint Economic Committee

J. Maurice Paturau	President

13. Afasia Group

Mr. Chan	Managing Director

14. Bonair Group

Arif Currimjee — Managing Director

15. First Knitters

16. Original Confection Ltd.

Patrick Lee Chung — Manager

17. Rogers & Co.

Pierre Raffray — Project Analyst

18. Beta Industries

Dr. Lee — Manager

19. Socota Textile Mills

Aliraza Mamodaly — Factory Manager

20. Hexagon Limited

Laurent Sainctavit — Chemist

21. Woventex

A.C. Nahaboo — Structural Engineer for the Construction Contractor

22. Luxor Tannery

Jabeer Beekun — Manager

23. L'Association des Consommateurs de l'Ile Maurice

Janen Chellum — Secretary
Krish Valydon

APPENDIX B

Notes on Water Supply and Wastewater Treatment at the Jurong Industrial Estates in Singapore

APPENDIX B

Notes on Water Supply and Wastewater Treatment at the Jurong Industrial Estates in Singapore

1. Water Supply

A substantial portion of water supply for industries in the Jurong Industrial Estates comes from recycled wastewater. The industrial water treatment plant, constructed around 1965, treats final effluent from an activated sludge wastewater treatment plant. Treatment processes include flocculation, rapid sand filtration, aeration, and chlorination. The plant has a capacity of 10 MGD (IMP).

If a higher water quality is required, some industries further treat this water (e.g., boiler feed water)

2. Wastewater Treatment

By Industry

The Industrial Wastewater Act (in Singapore) is very specific. Basically, industries must treat their wastes by either of two standards: one set is for discharge into public sewers, the other for discharge into watercourses. No collective pretreatment facility is available.

At present, industries separately treat their wastewater to a standard laid down by the Industrial Wastewater Act, before discharge into sewers. After discharge, the wastewater is further treated in Ministry of Environment (ENV) wastewater treatment plants.

Under the wastewater act industries can also treat their wastewater to a higher standard and discharge treated effluent into a watercourse, provided effluent meets established standards. In this event, no further treatment is necessary.

By Ministry of Environment

Pretreated industrial waste that is discharged into sewers receives further treatment at an ENV plant. Industries are charged based on volume of waste discharged into sewers. ENV wastewater treatment plants also treat domestic wastes; householders are charged waterborne fees based on the number of toilets in the house.

3. Sludge Disposal

By Industry

Handling and disposing of sludge from individual pretreatment plants presents more of a problem than dealing with liquid effluent from the facilities. Treated effluent is discharged into public sewers or watercourses (drains, streams, etc) depending on the degree of treatment and quality of effluent.

Individual waste treatment plants in the Jurong Industrial Estates and other industrial estates in Singapore have no facilities for handling sludge from their respective treatment plants. Sludges from these plants are tankered regularly to an ENV sludge treatment facility for treatment and final disposal. Individual industries pay ENV for this service based on volume and percent solids of the sludge.

Although nothing prevents industries from treating and disposing of sludge produced at their plants, this course does not appear economical unless large quantities of sludge are produced daily.

By Ministry of Environment

Treatment and disposal of sludges are generally as follows:

- Sludge from primary treatment is thickened in gravity thickeners.
- Waste-activated sludge from secondary treatment is thickened in air flotation thickeners.
- The combined sludge after thickening is digested. (Sludge gas produced is used to power dual-fuel engines for power generation.)
- Digested sludge is mechanically dewatered to obtain approximately 35 to 45 percent solids. (At one time digested sludge was dried on sludge drying beds but this practice is now being phased out.)
- Mechanical dewatering equipment now used in Singapore includes low and high pressure fixed-volume presses, vacuum filters, and belt presses.
- Dewatered sludge is being used as a soil conditioner or for landfill. Ultimately, disposal will be by incineration.

The above information was provided by A. Neysadurai of Camp Dresser & McKee in Singapore.

APPENDIX C

Documents Received from the Central Water Authority

APPENDIX C

Documents Received from the Central Water Authority

Lists

1. Dyeing Industries Operating in Mauritius

2. Polluting Industries Visited by Hon. Minister of Energy, Water Resource and Postal Services In Connection with the Preservation of Water Resources in Mauritius

3. Industries Discharging Effluents into MOW Sewerage Systems

4. Garment Manufacturers, Paints and Printing Industries Discharging Effluents into Rivers, Streams, and Canals

5. Dyeing, Washing, and Printing Industries Discharging Effluents into Pits

6. Cloth and Linen Washing Industries

7. Operating Sugar Mills

8. Operating Galvanizing Industries

9. Operating Electroplating Industries

10. Battery Making Industries

11. Leather Tanning Industries

12. Slaughter Houses

13. Industries That Submit Regular Water-Quality Records

14. Dyestuffs Used by Industry

15. Chemicals Used in Dye Houses

16. Topographical Surveys Carried out in Connection with the Preservation of Water Resources

17. Existing Legislation Pertaining to the Preservation of Water Resources in Mauritius

APPENDIX D

Dye Houses

APPENDIX D

Dye Houses

Coromandel Industrial Estate

1. Oceana Textile Mills Ltd.
2. Poul Lee Textiles
3. Sunshine T-shirt
4. Wool Processors & Dyers
5. Reward Textiles
6. Hong Kong Shangai
7. Overseas Fashion
8. Maurihai

Coromandel-Outside Industrial Estate

1. Resultant Ltd.

Plaine Lauzun

1. Mauritius Woolen & Worsted Mills Ltd.
2. Tara Knitwear

Le Hochet Terre Rouge

1. Palm Print
2. Institutional Textiles
3. Quality Towels & Linen

Tombeau Bay

1. De Luxe Knitting
2. Original Confection
3. First Knitters
4. St. Malo Exports

North

1. Summit Textiles (Ile d'Ambre)
2. Bon Air Knitwear (Triolet)
3. Unistar (no permit to operate)
4. Tee Sun
5. Woventex (under construction)

St. Pierre

1. Tinturia Da Ponte (Verdun)

Ebene (Rose Hill)

1. Colourtex Dyers

Phoenix Industrial Estate

1. Olympic Knitting
2. Phoenix Knitting
3. Compagnie Mauricienne de Textile
4. Transpack

Upper Plaine Wilhems

1. Textile Dyeing and Printing (Solferino)
2. Dyers & Finishers (Ferney Group)
3. Floreal Manufacturing (Floreal Group)
4. Socota Textile Mills

South

1. Prosperity Knitwear (Tyack)
2. Corotex (St. Felix)