Industrial Processes & The Environment

(Handbook No. 2)

Raw Natural Rubber Industry

DEPARTMENT OF ENVIRONMENT

MINISTRY OF SCIENCE, TECHNOLOGY AND THE ENVIRONMENT, MALAYSIA

Industrial Processes & The Environment (Handbook No.2)

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FOREWORD

There is present global recognition that environmental protection demands need not impede industrial growth and expansion, and on the contrary can assure increased business competitiveness; this certainly holds true for industries that adopt the more sensible approach of efficient resource use based on cleaner production technologies. Thus, end-of-pipe solutions should rightfully be left to the last resort. In order for environmental agencies and authorities to be in a position to catalyse industry-adoption of cleaner technologies they have had to initially expand their knowledge-base and keep abreast of the rapid current developments taking place in the field of cleaner industrial production.

The Department of Environment (DOE), in also recognising this need, embarked on the preparation of a series of industry-specific environmental management handbooks within its on-going capacity-building project with support from the Danish Cooperation for Environment and Development (Danced). These handbooks aim at providing DOE Officers with adequate technical knowledge of specific industrial processes and pollution control technologies that would enable them to steer industry towards adoption of more efficient waste management and cleaner production technologies. As an integral part of this effort, the DOE is implementing dialogue/consultation sessions with various groups of individual enterprises. This stems from the realisation that the act of policing should not be the only means to enforce the Environmental Quality Act, 1974, rather it should go hand in hand with a process of consultation with the industries to bring about the desired level of regulatory compliance.

This Handbook on Industrial Processes & The Environment: Raw Natural Rubber Industry is the second handbook in the series of publications. In the course of preparation, extensive discussions have been held with appropriate industry representatives to ensure that the technical information and suggestions presented in the Handbook are both current and of practical value. Through this effort, it is my sincere hope that the future compliance-monitoring activities of the DOE with respect to the raw natural rubber industry will be more efficiently performed. It is also our desire that the technical contents will prove beneficial to raw natural rubber producers in their endeavour to comply with the environmental regulations and standards through more cost-efficient means.

Hjh. Rosnani Ibarahim

Director General of the Environment, Malaysia.

TABLE OF CONTENTS

GLOSSARY

1.0 ABOUT THIS HANDBOOK 1

1.1 Background
1.2 Tools for Enforcement
1.3 Objectives of the Handbook
1.4 Structure and Contents of the Handbook

2.0 THE RAW NATURAL RUBBER INDUSTRY IN MALAYSIA – AN OVERVIEW 5

2.1 General Perspective
2.2 Recent Trends in Raw Natural Rubber Production
2.3 Types of Raw Natural Rubber Produced
2.4 The Advent of Comprehensive Environmental Control
2.5 Present and Future Position of the Raw Natural Rubber Industry in Malaysia

3.0 RAW NATURAL RUBBER PROCESSING AND SOURCES OF POLLUTION 9

3.1 Introduction
3.2 Production Processes
3.2.1 Production of Latex Concentrate
3.2.2 Production of Crumb Rubber
3.2.3 Production of Crepe Rubber
3.2.4 Production of Sheet Rubber

3.3 Sources of Effluent
3.4 Sources of Atmospheric Emissions

4.0 ENVIRONMENTAL ISSUES 21

4.1 Introduction
4.2 Quantities and Characteristics of Effluents
4.2.1 Typical Effluent Quantities
4.2.2 Typical Effluent Quality Characteristics
4.2.3 Bacteriological Properties

4.3 Characteristics of Air Emissions from Rubber Dryers

5.0 REGULATORY FRAMEWORK 27

5.1 Introduction
5.2 Environmental Quality Act 1974 and Amendments
5.3 Regulatory Control of the Raw Natural Rubber Industry
5.3.1 Licensed Control as Prescribed Premises
5.3.2 Regulatory Control of Effluent Discharge
5.3.3 Regulatory Control of Air Emissions
5.3.4 Regulatory Control of Noise Emission
5.3.5 Regulatory Control of Toxic and Hazardous Waste Disposal

6.0 POLLUTION CONTROL PRACTICE **33**

6.1 Introduction
6.2 In-Plant Control and Housekeeping Measures
6.3 Effluent Treatment Technologies for the Raw Natural Rubber Industry
6.3.1 General
6.3.2 Anaerobic-cum-Facultative Lagoon System
6.3.3 Anaerobic-cum-Aerated Lagoon System
6.3.4 Aerated Lagoon (Extended Aeration) System
6.3.5 Oxidation Ditch System
6.3.6 Conventional Activated Sludge System
6.3.7 Anaerobic Reactor Processes

6.4 Land Application of Rubber Factory Effluents
6.4.1 Fertilizer Value of Effluents
6.4.2 Methods of Land-Application of Effluent as Fertilizer

6.5 Air Emission and Odour Control in Rubber Factories
6.5.1 General
6.5.2 Types of Wet Scrubbers

7.0 POLLUTION PREVENTION AND THE CLEANER PRODUCTION APPROACH **53**

7.1 Introduction
7.2 Cleaner Production in the Raw Natural Rubber Industry
7.2.1 The Cleaner Production Approach
7.2.2 Control of Water Usage
7.2.3 Control of Chemical Usage
7.2.4 Proper Handling and Storage of Process Chemicals
7.2.5 De-ammoniation of Skim Latex in Centrifuged Latex Factories
7.2.6 Proper Design and Operation of Rubber Traps
7.2.7 Separation of Effluent and Stormwater Drainage Systems
7.2.8 Product Substitution
7.2.9 Process Substitution
7.2.10 Waste Utilisation
7.2.11 ISO 9000 and ISO 14000

7.3 Relative Costs of Implementing Cleaner Production
7.4 Addressing Factory Constraints

8.0 INSPECTION FOCUS **63**

8.1 Introduction
8.2 Key Environmental Issues
8.3 Inspection Objectives
8.4 Inspection Procedure and Steps
8.4.1 Pre-inspection Planning and Information Review
8.4.2 Factory Inspection
8.4.3 Closing Meeting
8.4.4 Reporting and Follow-up Action

APPENDICES 75

1. Environmental Quality (Clean Air) Regulations 1978 - Air Emission Standards
2. Environmental Quality (Clean Air) Regulations 1978 - Third Schedule
3. Inspection Checklist on Status of Good Housekeeping and Cleaner Production
4. Recording Worksheet on Status of Good Housekeeping and Cleaner Production
5. Inspection Checklist on Status of Regulatory Compliance
6. Recording Worksheet on Status of Regulatory Compliance

REFERENCES 95

LIST OF TABLES

Table 1 : Malaysian Raw Natural Rubber Production from 1993-1997
Table 2 : Status of Compliance of Licensed Rubber Factories with the Prevailing Effluent Discharge Standard
Table 3 : Maximum Water Consumption Rates Based on Optimum Water Usage Practices
Table 4 : Typical Water Consumption and Effluent Discharge Rates of Malaysian Rubber Factories
Table 5 : Typical Quality Characteristics of Effluent from Different Types of Rubber Factories
Table 6 : Bacteriological Properties of Effluent from Different Types of Rubber Factories
Table 7 : Concentrations of Volatile Organic Acids in the Air Emission of a Crumb Rubber Dryer
Table 8 : Prevailing Effluent Standards for the Raw Natural Rubber Industry [Environmental Quality (Prescribed Premises)(Raw Natural Rubber) Regulations, 1978]
Table 9 : Typical Performance of an Anaerobic-cum-Facultative Lagoon System Treating Crumb Rubber Factory Effluent
Table 10 : Typical Performance of an Anaerobic-cum-Facultative Lagoon System Treating Latex Concentrate Factory Effluent
Table 11 : Typical Performance of an Oxidation Ditch System Treating Latex Concentrate Factory Effluent
Table 12 : Nutrient Content of Rubber Factory Effluents
Table 13 : Typical Performance of a Wet Scrubber for Removal of Pollutants from the Exhaust Air of a Crumb Rubber Dryer
Table 14 : Addressing Factory Constraints
Table 15 : Parameter-Based Preservation Techniques for Effluent Samples

LIST OF FIGURES

Figure 1 : Processing of Field Latex and Field Grade Materials into Raw Natural Rubber
Figure 2 : Production Process for Centrifuged Latex
Figure 3 : Production Processes for Latex Grade and Field Grade Crumb Rubber
Figure 4 : Production Process for Pale Crepe
Figure 5 : Production Process for Lower Grade Crepe Rubber
Figure 6 : Production Process for Sheet Rubber
Figure 7 : Schematic Representation of Effluent Treatment Technologies for Rubber Factory Effluents
Figure 8 : Principal Design Features of an Anaerobic-cum-Facultative Lagoon System for a 50-Tonne/Day Crumb Rubber Factory
Figure 9 : Principal Design Features of an Anaerobic-cum-Aerated Lagoon System for a 50-Tonne/Day Crumb Rubber Factory
Figure 10 : Principal Design Features of an Aerated Lagoon-cum-Extended Aeration System for a 50-Tonne/Day Crumb Rubber Factory
Figure 11 : Schematic Representation of an Oxidation Ditch System
Figure 12 : Oxidation Ditch System for a 50-Tonne DRC/Day Latex Concentrate Factory
Figure 13 : A Wet Scrubber System for Cleaning Exhaust Air from Crumb Rubber Dryers
Figure 14 : Typical De-ammoniation Tower for De-ammoniation of Skim Latex
Figure 15 : Principal Design Features of a Typical Rubber Trap
Figure 16 : Relative Costs of Various Elements of Cleaner Production

GLOSSARY

The following are definitions of the common terms used in this Handbook.

Aerobic	:	A condition in which "free" (atmospheric) or dissolved (molecular) oxygen is present in the aquatic environment.
Algae	:	Microscopic plants which contain chlorophyll and live floating or are suspended in water or attached to structures. Algae produce oxygen during sunlight hours and use oxygen during the night hours.
Anaerobic	:	A condition in which "free" (atmospheric) or molecular (dissolved) oxygen is not present in the aquatic environment.
Biodegradable	:	Organic matter that can be broken down by bacteria to more stable forms which will not create a nuisance or give off foul odours.
Biodegradable Organics	:	Composed principally of proteins, carbohydrates, and fats.
Biomass	:	A mass or clump of living organisms feeding on the wastes in wastewater, dead organisms and other debris.
Biosolids	:	A primarily solid product, produced by wastewater treatment processes , that can be beneficially recycled.
BOD	:	Biochemical Oxygen Demand. The rate at which organisms use the oxygen in water or wastewater while stabilising decomposable organic matter under aerobic conditions.
BOD_3	:	Refers to the 3-day biochemical oxygen demand.
Centrifuge	:	A mechanical device that uses centrifugal or rotational forces to separate solids from liquids.
Clarifier	:	Settling Tank, Sedimentation Basin. A tank or basin in which wastewater is held for a period of time during which the heavier solids settle to the bottom and the lighter materials float to the water surface.
Cleaner Production	:	An approach to production and manufacturing that focuses on source reduction, waste minimisation, energy efficiency and low-waste and non-waste technology.
Coagulant	:	A chemical that causes very fine particles to clump or floc together into larger particles. This makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

Coagulation : The clumping together of very fine particles into larger particles caused by the use of chemicals (coagulants). The chemicals neutralise the electrical charges of the fine particles and cause destabilisation of the particles. This clumping together makes it easier to separate the solids from the liquids by settling, skimming, draining or filtering.

COD : Chemical Oxygen Demand. A measure of the oxygen-consuming capacity of organic matter present in wastewater.

Counter-current : Two different media moving in opposite directions of each other.

Cropland : Agricultural land cultivated with any type of agricultural crop.

Cup Lumps : Late drippings of latex which are left to coagulate biologically in the latex receiving cup and collected as solid lumps of rubber that are processed into lower grade crepe or crumb rubber.

De-mister : A device that causes condensation and entrapment of fine liquid particles from an air stream or liquid vapour.

Detention Time : The time required to fill a tank at a given flow rate or the theoretical time required for a given flow of wastewater to pass through a tank.

Effluent : Wastewater or other liquid - raw (untreated), partially or completely treated - flowing from a reservoir, basin, treatment process, or treatment plant.

End-of-pipe : Waste management solutions that are applied to the waste at the point of emission or discharge.

Facultative : Facultative bacteria can use either molecular (dissolved) oxygen or oxygen obtained from food materials such as sulphate or nitrate ions. Facultative bacteria can live under aerobic or anaerobic conditions.

Neutralisation : Addition of an acid or alkali to a liquid to cause the pH of the liquid to move toward a neutral pH of 7.0.

Noxious : Substances that are harmful to human beings and have deleterious effects on human health and well-being due to their toxic and hazardous properties.

Raw Natural Rubber : Rubber produced from naturally occurring rubber tree latex in the primary processed form which includes the technically-specified form (Standard Malaysian Rubber), latex form including prevulcanised or the form of special purpose rubber and conventional sheet, skim and crepe rubber.

Scrap Rubber	:	Dried rubber associated with the tree bark and latex spilled into the earth around the tree and collected as earth scrap that are processed into lower grade crepe rubber of various types.
Screening	:	The use of wire mesh or perforated steel plate screens to remove solid rubber and other dirt materials from the wastewater.

1.0 ABOUT THIS HANDBOOK

1.1 BACKGROUND

As part of its capacity-building effort in the area of industrial pollution control, the Department of Environment has initiated the preparation of various industry-specific environmental management handbooks. These handbooks, which will contain comprehensive industry process and waste management information, are being developed for major Malaysian industry sectors and with relevance to the industrial situation in Malaysia, as well as the Malaysian context of environmental management and pollution control.

This Handbook is the second of five(5) industry-specific information handbooks initially identified for preparation as follows:

- *Industrial Processes & The Environment (Handbook 1):*

  Metal Finishing – Electroplating
- *Industrial Processes & The Environment (Handbook 2):*

  The Raw Natural Rubber Industry
- *Industrial Processes & The Environment (Handbook 3):*

  The Crude Palm Oil Industry
- *Industrial Processes & The Environment (Handbook 4):*

  The Textile Industry
- *Industrial Processes & The Environment (Handbook 5):*

  The Food Industry

1.2 TOOLS FOR ENFORCEMENT

The DOE Manual on Practical Enforcement prepared earlier, and this series of industry-specific environmental information handbooks, are together aimed at serving the DOE as supporting enforcement tools to enhance the quality and effectiveness of its enforcement activities under the Environmental Quality Act 1974. Thus, the Enforcement Manual and the industry-specific handbooks are designed to complement each other in terms of the information which they provide, and as enforcement tools are intended to broaden and strengthen the scope of the Department's enforcement functions and activities.

1.3 OBJECTIVES OF THE HANDBOOK

The objectives of this Handbook are to assist DOE Officers to:

- Enhance their knowledge of the raw natural rubber industry, the production processes for raw natural rubber, and cleaner production approaches for more cost-efficient waste management and pollution control;
- Conduct on-site inspections more expeditiously and effectively; and
- Disseminate information on cost-efficient waste management technologies, based on pollution prevention and cleaner production approaches;

However, the Handbook may also serve as a tool for improving the flow of information between DOE and the owners and operators within the Raw Natural Rubber Industry. Therefore, the Handbook also aims at providing the industry with a better perception and understanding of the DOE's present approach of enhancing DOE-industry interaction and information exchange. In this way, it aims to:

- Change the attitude of the industry towards better compliance and housekeeping;
- Increase the awareness on environmental issues and potential impacts; and
- Highlight the advantages and opportunities of cleaner production and technologies.

To help accomplish the above objectives, the Handbook specifically provides technical information on;

- The raw natural rubber industry and the production processes for raw natural rubber;
- Related environmental issues;
- The requirements of the Environmental Quality Act 1974 and subsidiary legislation pertinent to the raw natural rubber industry;
- The current environmental management practices of the industry; and
- Cleaner production approaches and cost-efficient end-of-pipe solutions that can help the industry maintain its business competitiveness while meeting the desired environmental goals.

This handbook is specific to the raw natural rubber industry and therefore excludes the downstream manufacturing of raw natural rubber into manufactured rubber goods and products.

1.4 STRUCTURE AND CONTENTS OF THE HANDBOOK

There are eight (8) sections in this Handbook, the contents of which are as follows:

Section 1: General information about the Handbook.

Section 2: An overview of the raw natural rubber industry in Malaysia, highlighting its historical past and present status.

Section 3: Brief description of the various processes involved in the production of raw natural rubber and an identification of the sources of pollution.

Section 4: A highlight of the environmental issues of the raw natural rubber industry, including wastes ordinarily generated and their respective waste characteristics.

Section 5: Regulatory framework and requirements.

Section 6: Pollution control practices of the raw natural rubber industry, including in-plant waste minimisation and housekeeping measures, available end-of-pipe technologies, and some air pollution control measures for rubber factories.

Section 7: Pollution prevention approaches, including waste minimisation and cleaner production technologies.

Section 8: Suggested areas of inspection focus, essentially to guide DOE officers on what to look for during an inspection of rubber factories to ensure effective enforcement.

⬆ Conventional tapping and collection of field latex

⬅ Newer innovations for latex tapping and collection

2.0 THE RAW NATURAL RUBBER INDUSTRY – AN OVERVIEW

2.1 GENERAL PERSPECTIVE

Up until the 80's, the agro-based industrial sector played a very significant role in Malaysia's economy and comprised a major segment of the employment base; the principal contributing agricultural crops being rubber, oil palm, cocoa, coconut and pepper. However, in the mid-80's, as a result of government policy to transform Malaysia from an agricultural primary producer to an industrialised nation, large tracts of rubber land which were initially located in the outer periphery of urban areas were converted for industrial, commercial and supporting residential uses. In tandem with this transformation was also the large-scale conversion of rubber estates to oil palm estates due to the increasingly attractive world markets and rapidly rising price of palm oil. The above changing scenario in the last two decades was responsible for a gradual decline in raw natural rubber production, and Malaysia losing its position as the world's largest natural rubber producer which it held for the past many decades. Presently, Malaysia is the third largest producer in the world – after Thailand and Indonesia.

2.2 RECENT TRENDS IN RAW NATURAL RUBBER PRODUCTION

As a consequence of the declining planted area for rubber in the mid-80's, there followed a corresponding reduction in the total number of processing factories as well as the total quantity of raw natural rubber produced. For example, while the DOE licensed 191 factories in 1993, this number was reduced to 144 in 1997 - refer *Table 1*. The present indication is that this downward trend is likely to continue for many years to come, and perhaps with Malaysia losing its position as the third largest rubber producer to India.

Table 1: Malaysian Raw Natural Rubber Production from 1993 to 1997

Year	No. of Factories Licensed by DOE	Raw Natural Rubber Production (Tonne)
1993	191	1,074,300
1994	178	1,100,600
1995	156	1,089,300
1996	150	1,082,500
1997	144	971,100

2.3 TYPES OF RAW NATURAL RUBBER PRODUCED

In the 60's, raw rubber production was mostly in the form of ribbed smoked sheet (RSS) and air-dried sheet (ADS). But in the early 70's, crumb rubber (block rubber) production became popular due to a variety of reasons. Today, sheet production is less than 4% of the total production. The bulk of Malaysian rubber is now produced in the form of technically-specified crumb rubber (block rubber) called Standard Malaysian Rubber (SMR). The SMR production involves several quality grades referred to as SMR 5L, SMR 5, SMR 10, SMR 20 and SMR 50.

About 25% of the production is in latex concentrate form, mostly centrifuged latex concentrate. There are presently two types of centrifuged latex concentrate: the high-ammonia concentrate with about 0.7% ammonia content as preservative, and the low-ammonia concentrate with a combination of about 0.2% ammonia content and about 0.025% TMTD-ZnO content. In addition, Malaysia also produces a small quantity of specialty rubbers such as DPNR; the production of DPNR increased from 175 tonnes in 1995 to 236 tonnes in 1997.

2.4 THE ADVENT OF COMPREHENSIVE ENVIRONMENTAL CONTROL

The environmental problems traditionally caused by the rubber industry are essentially three-fold:

- Pollution of rivers and streams due to discharge of large quantities of highly polluting wastewater containing high organic content and/or ammoniacal nitrogen;
- Air pollution caused by odorous organic contaminants in the air emission from the rubber drying process (dryers); and
- Odor emission from the wet storage of cup lumps and scrap rubber in open or non-enclosed areas.

Comprehensive environmental control of the raw natural rubber industry commenced soon after the enactment of the Environmental Quality Act, 1974 and the establishment of the Department of Environment in 1975. In order to regulate the discharge of effluent from the rubber industry as well as to exercise other environmental controls, the Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Order, 1978 and Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations, 1978 were promulgated under the Environmental Quality Act, 1974.

To ensure that the raw natural rubber industry would not be stifled by unnecessarily prohibitive environmental costs and to facilitate timely regulatory compliance by the industry, the formulation of the effluent standards and promulgation of regulations were both preceded by in-depth government-industry consultation and consensus through the following arrangements:

- Establishment of a consultative and advisory body consisting of the Department of Environment, the Malaysian Rubber Research and Development Board (MRRDB), the Malaysian Rubber Producers Council (MRPC), and the RRIM. The primary task of this body was to initiate and monitor the progress of waste treatment research, establish appropriate technology-based effluent discharge standards, and recommend an acceptable implementation schedule; and

- Appointment of the RRIM to undertake and coordinate research and development on effluent treatment technologies, and the formulation of technology-based effluent discharge standards.

The above pro-active consultative approach of the Government prior to embarking on environmental control of the rubber industry and similarly for the palm oil industry is often cited as being exemplary and certainly the prime factor which has contributed to the environmental management success of these economically important primary industries.

The status of compliance of rubber factories with the prevailing effluent discharge standards has reached a satisfactory level based on the compliance information presented in *Table 2*. Notwithstanding this measure of success, further effort is needed on the part of industry, not only to improve the overall status of compliance of the industry, but also for industry to improve profitability through the adoption of cleaner production technologies.

Table 2 : Status of Compliance of Licensed Rubber Factories with the Prevailing Effluent Discharge Standards

Year	No. of Factories Licensed by DOE	Compliance Status (%)	No. of Factories Prosecuted
1993	191	75	12
1994	178	87	-
1995	156	88	8
1996	150	89	31
1997	144	90	1

2.5 PRESENT AND FUTURE POSITION OF THE RAW NATURAL RUBBER INDUSTRY IN MALAYSIA

The Malaysian raw natural rubber industry continues to be important in the overall context of Malaysian economy. Malaysia is presently the third largest natural rubber producer in the world, producing about 970,000 tonnes of rubber from about 140 factories in operation. The current export value of raw natural rubber and manufactured rubber goods is estimated at about RM 4.7 billion.

The raw natural rubber industry can be considered as having done quite well in managing its environmental problems. The status of regulatory compliance of the raw natural rubber industry in terms of factories meeting the effluent discharge standards has reached about 90%, and it is expected to improve further with continued DOE intervention.

There is also a changing scenario in the raw natural rubber industry in Malaysia, following the advent of the rapidly growing rubber wood furniture industry and related developments. The concerted efforts of the Rubber Research Institute of Malaysia (RRIM) and the Forest Research Institute of Malaysia (FRIM) in developing rubber wood as a quality wood for a variety of uses including furniture, as well as its export as sawn timber, are responsible for Malaysian rubber wood processing being transformed into a major industry. Other than raw natural rubber, Malaysia also produces rubber wood products. The value of rubber wood products has reached about RM 2.0 billion.

Environmentally, this may be considered as one of the greatest achievements for the country. Prior to the 70's, rubber replanting which occurs every 20 to 25 years was usually preceded by the wasteful practice of tree-felling, stacking and open-burning. Plantation owners commonly paid as much as RM 1,000 per hectare for tree-felling and on-site open-burning, which also contributed to serious air pollution problems. But today, the utilisation of rubber wood as a resource material has not only resulted in a billion Ringgit industry, but also the elimination of a significant source of open-burning and air pollution.

It is interesting to note that the RRIM and FRIM are now looking into the possibility of creating "rubber forests", with a view towards using the rubber crop more for rubber wood production rather than latex production.

3.0 RAW NATURAL RUBBER PROCESSING AND SOURCES OF POLLUTION

3.1 INTRODUCTION

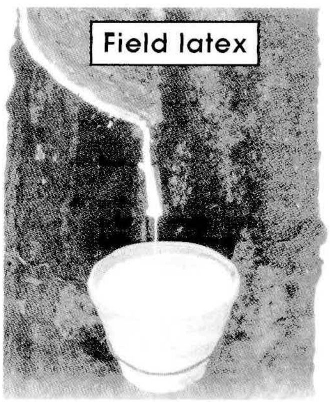
Field latex with about 30% dry rubber content (DRC) can be processed into a concentrated liquid form of about 60% DRC, or solid forms of raw natural rubber through natural or controlled coagulation, as follows:

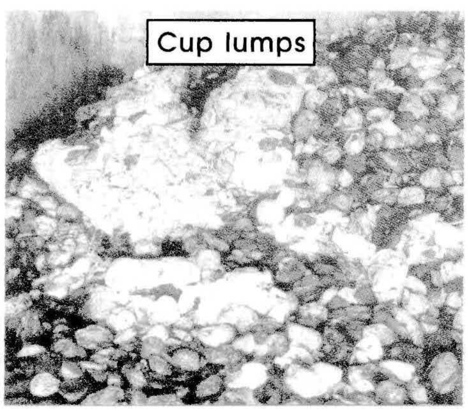
- Latex Concentrate;
- Sheet Rubber - Ribbed Smoked Sheet (RSS), or Air Dried Sheet (ADS);
- Crumb Rubber (SMR 5L and SMR 5); and
- Pale Crepe.

Some clones, particularly, the high yielding ones, drip for a longer period. These late drippings which sometimes can be as much as 20%, are left to coagulate biologically in the receiving cups and collected as cup lumps after 2 or 3 days (depending on the frequency of tapping) and processed into lower grade crumb or crepe rubber. The dried tree lace i.e. dried rubber associated with the bark and latex spilled onto the earth around the tree and collected as earth scrap, are also processed into lower grade crepes of various types. These solid forms of naturally coagulated rubber are processed into the following lower grades of raw natural rubber:

- Lower Grade Crumb (SMR 10, SMR 20 and SMR 50);
- Brown, Blanket and Bark Crepe.

A schematic representation of the various raw natural rubber products produced is presented in *Figure 1*.





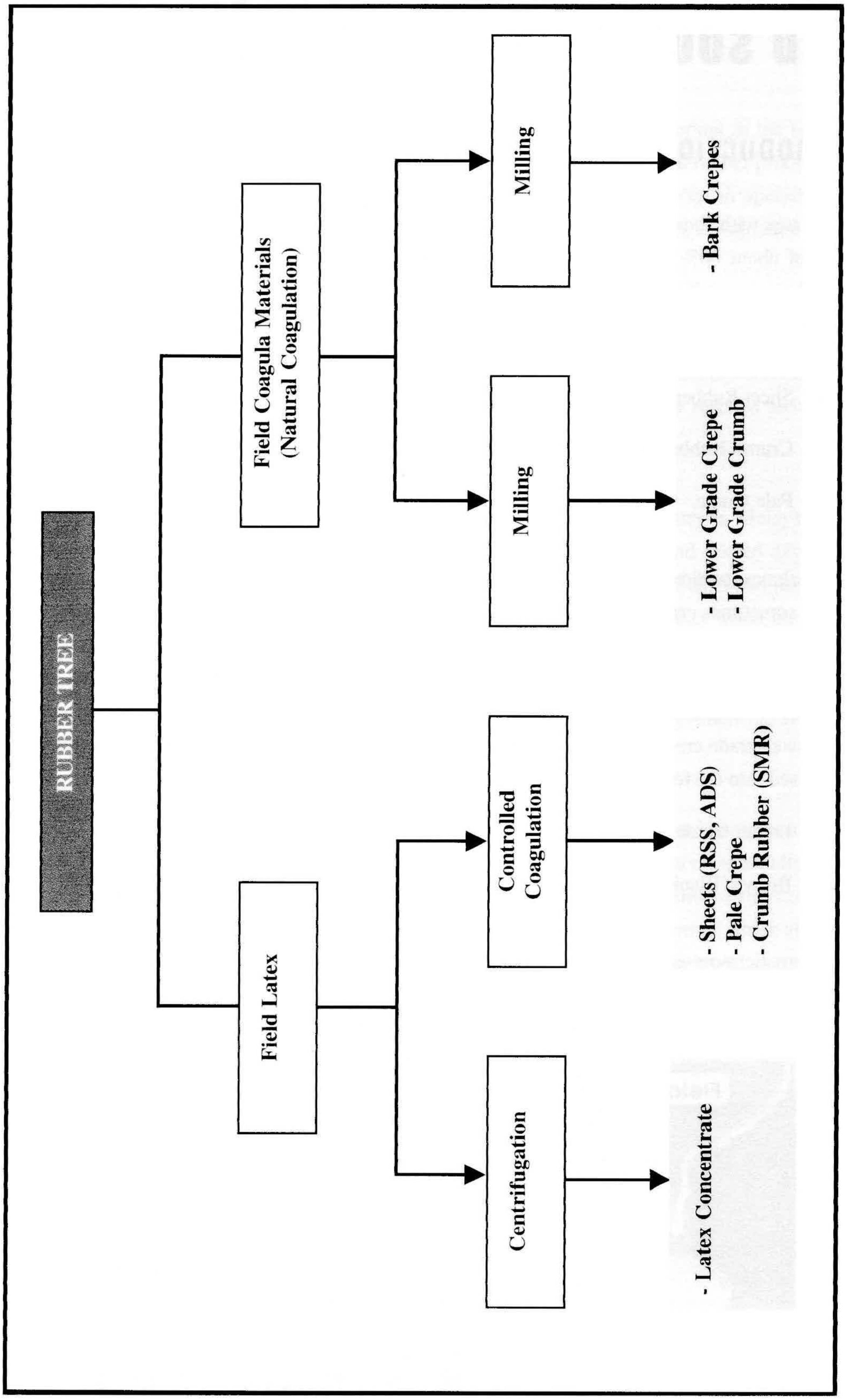


Figure 1 :Processing of Field Latex and Field Grade Materials into Raw Natural Rubber

3.2 PRODUCTION PROCESSES

3.2.1 Production of Latex Concentrate

A simplified process flow diagram for the production of latex concentrate is given in *Figure 2*. The diagram also shows the main points of chemical and water inputs and sources of waste generation.

Raw latex as it leaves the tree has about 30% dry rubber content (DRC) and 65% water, the rest being non-rubbers. Various methods used to concentrate the field latex are as follows:

- Centrifugation;
- Creaming; and
- Evaporation.

Most of Malaysia's latex concentrate is produced by centrifugation. In this process, the rubber particles from the serum phase are separated-out by centrifugal force using a centrifuge, producing standard latex concentrate of about 60% DRC and an equal volume of residual skim latex of about 6% DRC. The resulting concentrate is further treated with suitable preservatives; ammonia, or a combination of ammonia and TMTD-ZnO. Two types of centrifuged latex concentrate are produced: the high-ammonia concentrate with about 0.7% ammonia content, and the low-ammonia concentrate with about 0.2% ammonia content and about 0.025% TMTD-ZnO content. After the addition of preservatives, the concentrate is blended and transferred to storage tanks to mature before it is ready to be shipped-out.

Skim rubber is defined as the rubber produced from skim latex. Coagulation of skim latex can be either spontaneous or by acid treatment. It is important that the ammonia content be as low as possible; otherwise, spontaneous coagulation would take too long and acid coagulation would require large amounts of acid. A de-ammoniation tower can be used to reduce the ammonia content of the skim latex prior to coagulation. The coagulum produced is usually processed into a thick crepe using liberal amounts of wash water. It can also be used for producing granulated and other forms of crumb rubbers.

3.2.2 Production of Crumb Rubber

A simplified process flow diagram for the production of crumb rubber is presented in *Figure 3*. The diagram also shows the main points of water and chemical inputs, and sources of effluent generation and atmospheric emission. Several methods are available for the processing of crumb rubbers.

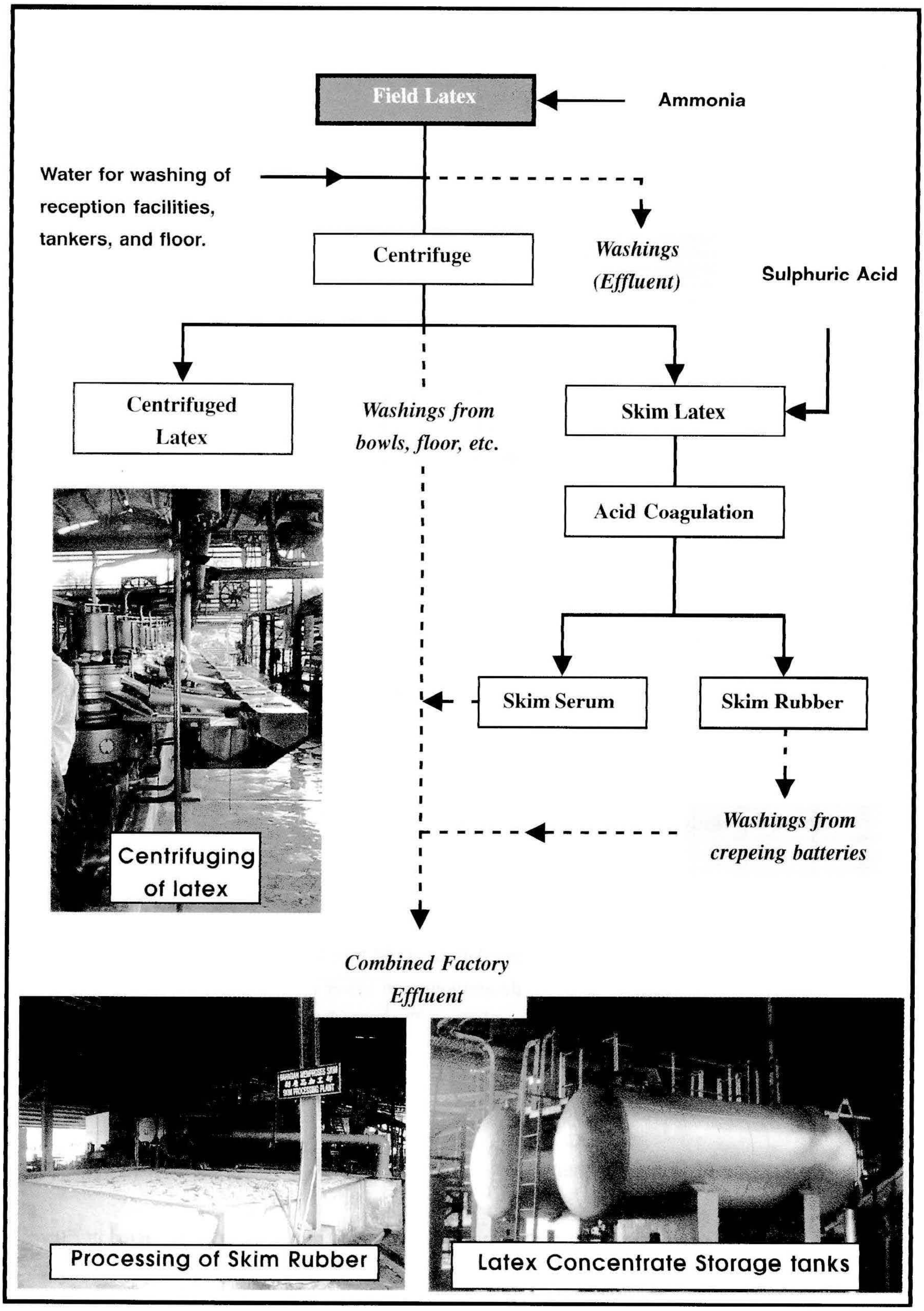


Figure 2 : Production Process for Centrifuged Latex

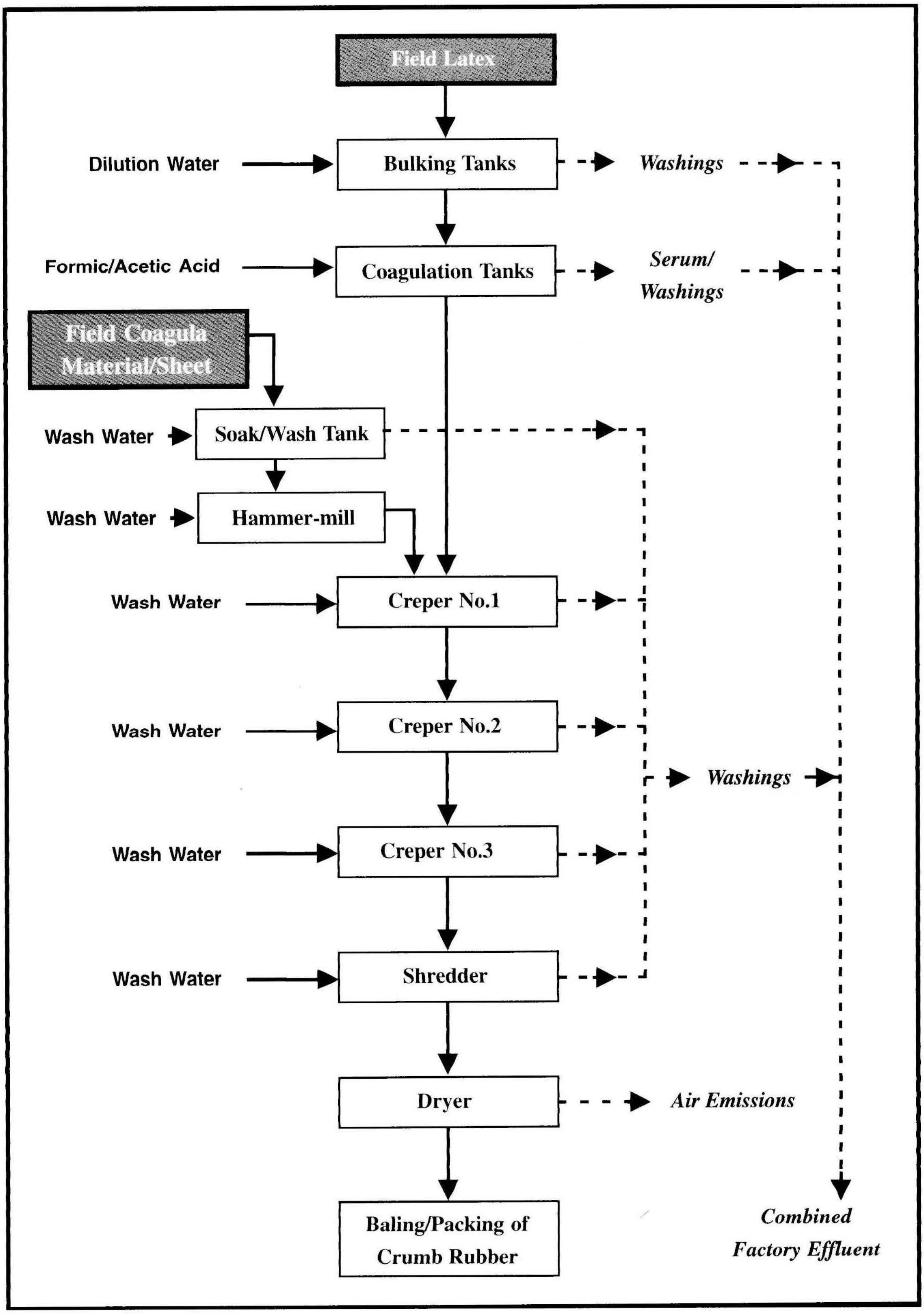
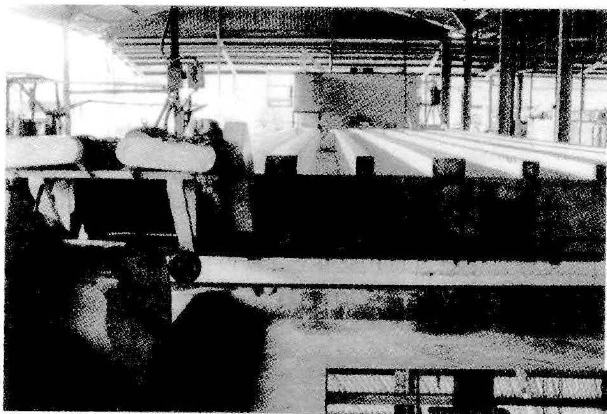
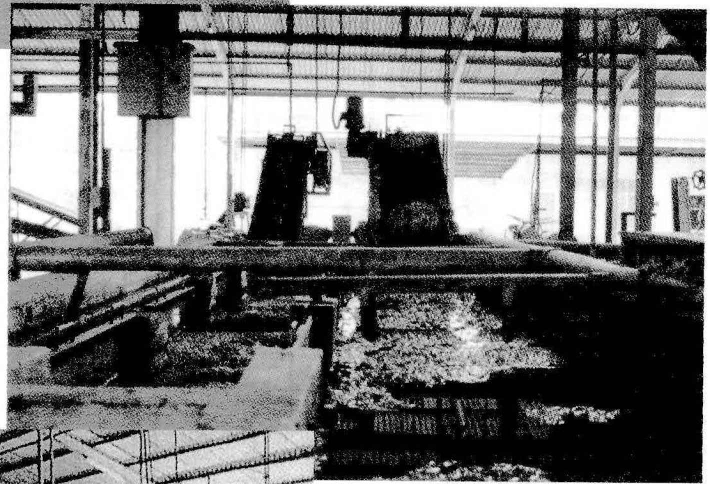


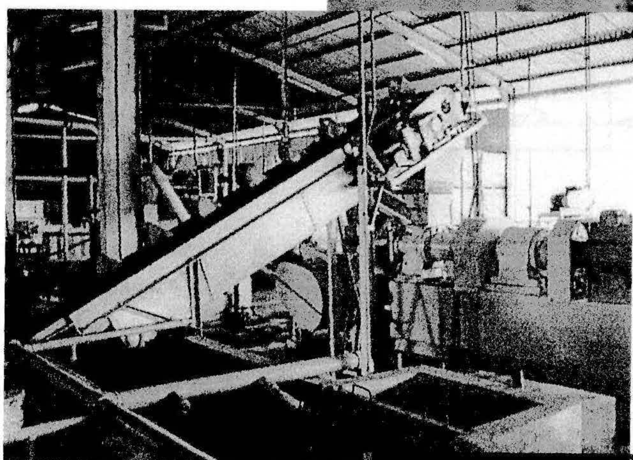
Figure 3: Production Processes for Latex Grade And Field Grade Crumb Rubber



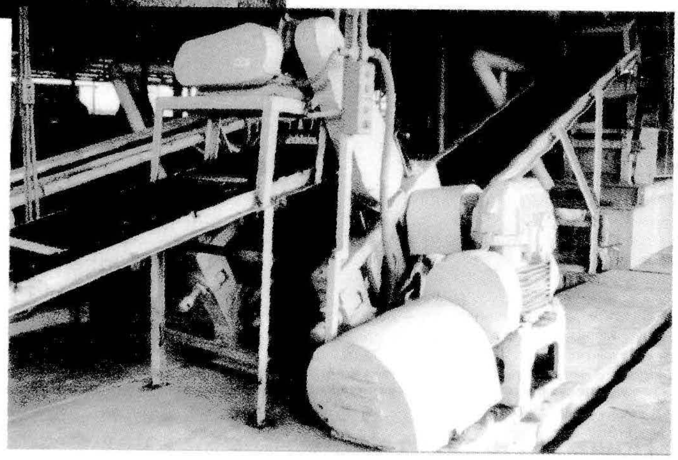
Coagulation Pit



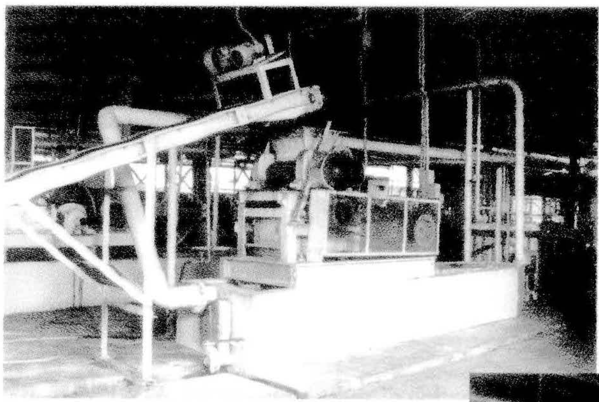
Soaking and Washing for Cup Lumps Processing



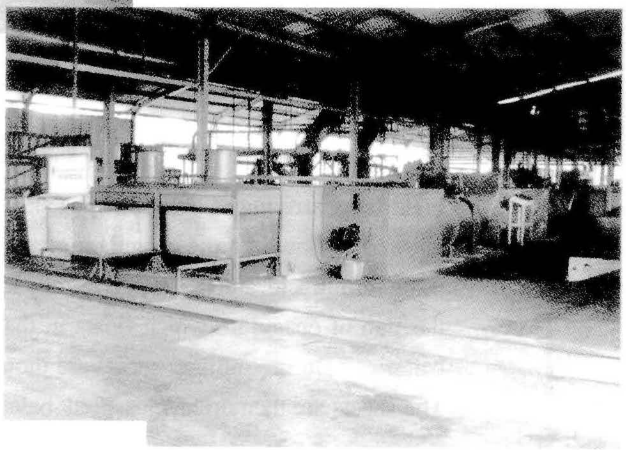
Shredder for Cup Lumps Processing



Creper



Hammer Mill



Rubber Dryers

Crumb Rubber (SMR 10)

3.2.3 Production of Crepe Rubber

Simplified process flow diagrams for the production of pale crepe from field latex, and lower grade crepe (Brown, Blanket and Bark) from field coagula materials are presented in *Figure 4* and *Figure 5* respectively. The diagrams also show the main points of water and chemical inputs and sources of effluent generation.

3.2.4 Production of Sheet Rubber

A simplified process diagram for the production of sheet rubber (RSS, ADS) is given in *Figure 6*. The diagram also shows the main points of water and chemical inputs and sources of effluent generation.

Field latex arriving at the factory is sieved, bulked and diluted to about 15% DRC. It is then allowed to flow into the coagulating tanks or pits. The pH of the latex is reduced to about 4.5 using formic acid, and the latex is usually left to coagulate overnight. When completely coagulated, the slab of coagulum which floats in the clear residual latex serum is fed to a set of sheeting batteries. During milling, sheets are thoroughly washed with a water spray fitted to the rollers. The sheets are then dried, classified, baled and packed.

Air-dried sheet (ADS) is another form of sheet prepared from field latex, especially for the manufacture of goods which require a clean, light coloured rubber. The manufacture of ADS is very similar to that of RSS, except that the rubber sheets are air-dried in a smoke-free atmosphere. In addition, about 0.04% sodium meta-bisulphite is added to the latex to prevent any discoloration.

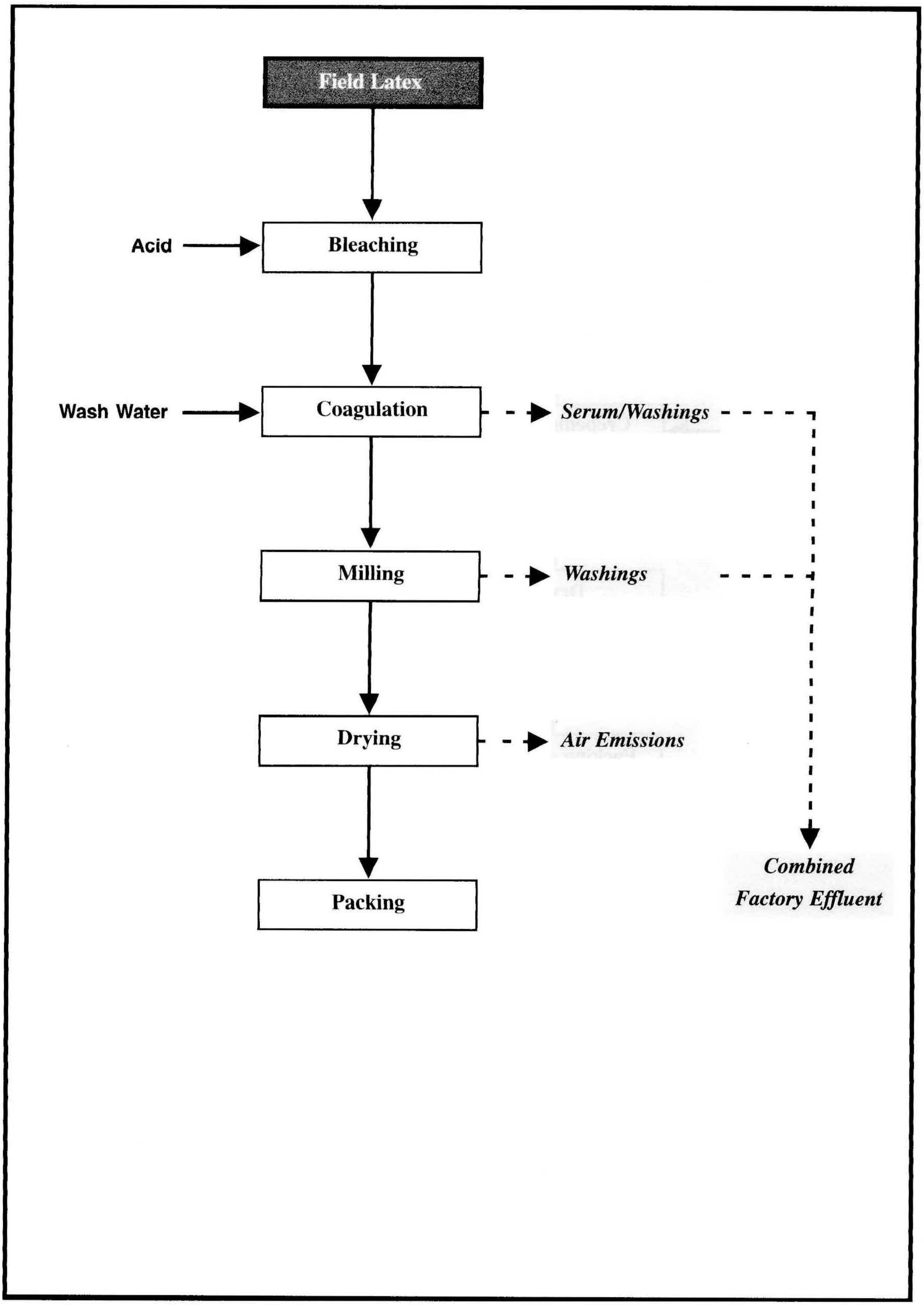


Figure 4: Production Process for Pale Crepe

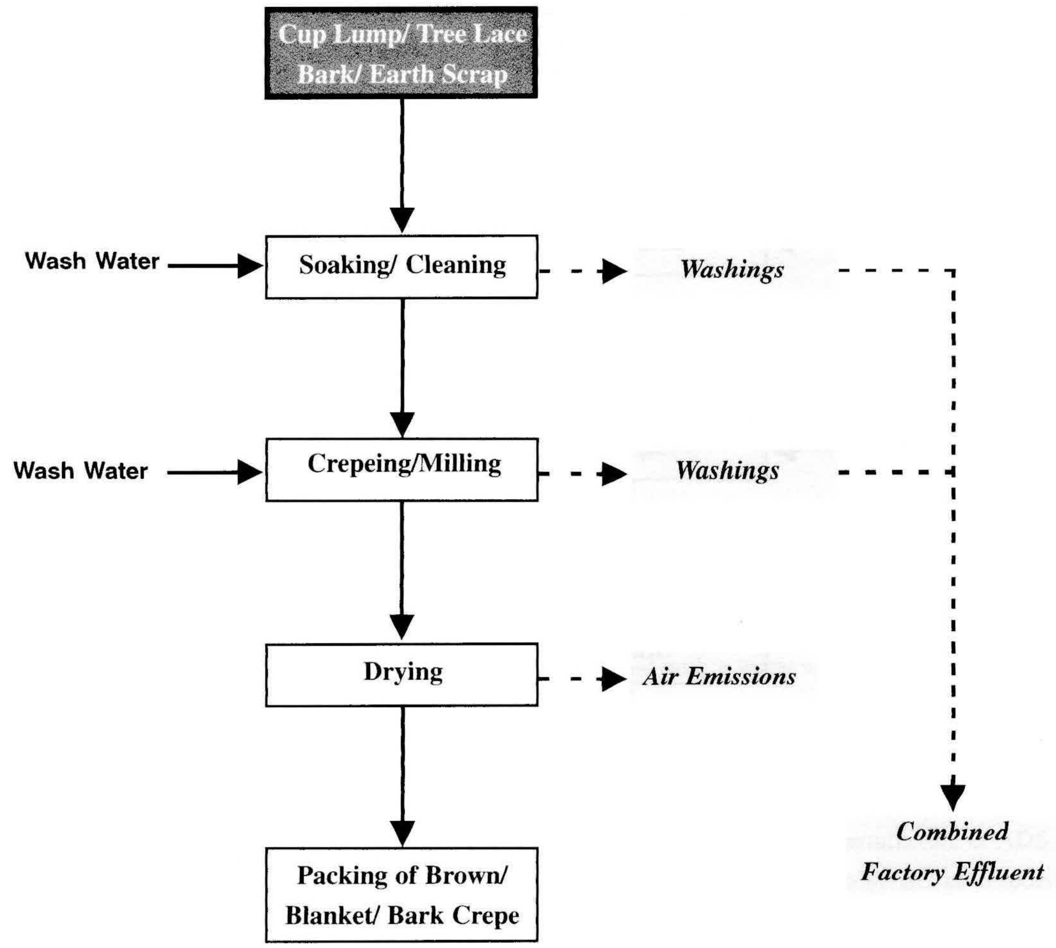


Figure 5: Production Process for Lower Grade Crepe Rubber

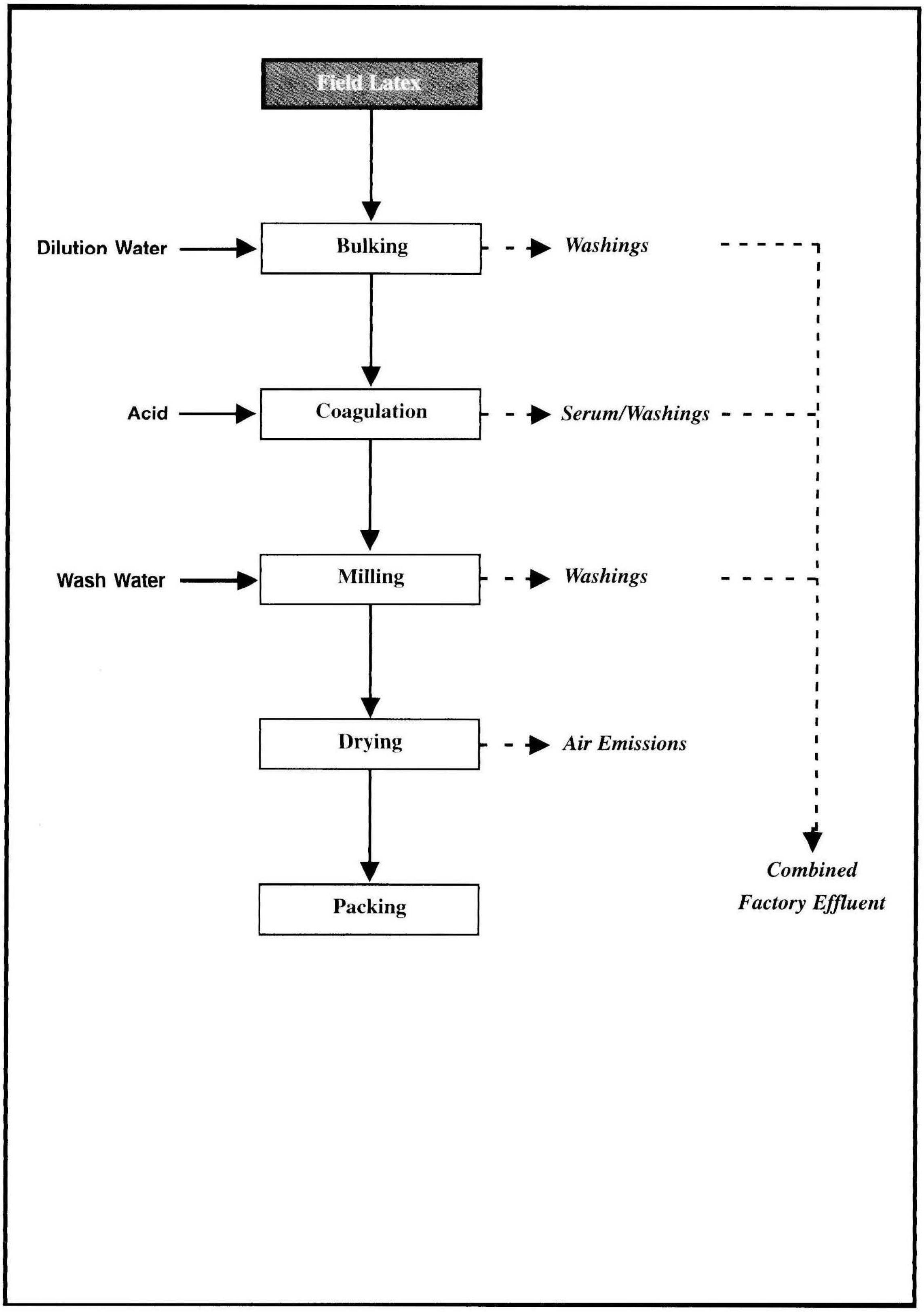


Figure 6: Production Process for Sheet Rubber

3.3 SOURCES OF EFFLUENT

The sources of effluent generation for the various raw natural rubber processes were identified in the process flow diagrams presented as *Figure 2, 3, 4, 5 and 6.* During the processing of rubber large quantities of water are used for dilution of field latex and the washing and cleaning of materials and machinery. Wide variations of water consumption and effluent discharge rates are observed in rubber factories depending on the types of products and processes, the effectiveness of in-plant process control and housekeeping measures. In raw natural rubber processing, the total quantity of effluent generated in the different types of rubber processes almost always equals the respective factory's total water consumption. Therefore, in the absence of actual effluent flow measurements, the total daily water consumption of the factory is ordinarily taken to represent the total daily effluent quantity discharged.

With optimum water usage practices, the water consumption in rubber factories should generally not exceed the rates presented in *Table 3*.

Table 3 : Maximum Water Consumption Rates Based on Optimum Water Usage Practices

Type of Rubber Processed	Maximum Water Consumption (m^3/tonne DRC)
Latex Concentrate	<20
Sheet/Crumb/Crepe	<25
Remilled Rubber	<30

In the case of rubber remilling factories, water consumption and effluent discharge rates may exceed 30 m^3/tonne DRC, if the cup lumps and scrap rubber raw materials received by the factory have extremely high dirt content.

3.4 SOURCES OF ATMOSPHERIC EMISSIONS

The most common air pollution problems caused by the rubber industry are due to malodour and smoke. In rubber factories, especially those producing lower grade rubbers, the malodour originates mainly from the rubber drying process as well as the open storage of scrap rubber and cup lumps especially in a wet condition. The malodour is attributed to volatile fatty acids produced from the breakdown of non-rubbers during the drying process, and by microbial action during the storage of scrap rubber and cup lumps. Smoke emanating from the smokehouse during the processing of the ribbed smoked sheet (RSS) is often a source of problem when the smokehouse is located close to neighbouring residents.

4.0 ENVIRONMENTAL ISSUES

4.1 INTRODUCTION

Factories involved in the primary processing of raw natural rubber typically generate:

- Large quantities of organic effluents of medium to high strength;
- Air emissions;
- Odour; and
- Noise.

The environmental issues of the raw natural rubber industry are to a greater extent related to:

- Water pollution due to indiscriminate discharge of untreated or partially treated factory effluents to watercourses;
- Odourous air emissions from rubber dryers;
- Localised problems of odour due to the open storage of field grade materials (cup lumps and scrap rubber), especially in a wet condition and in close proximity to neighbouring residents; and
- Odour emission from poorly managed effluent treatment systems, particularly, those treating latex concentrate effluents and which are located in close proximity to neighbouring residents.

Noise is usually a much lesser external environmental concern; noise levels are ordinarily within acceptable limits at the factory perimeter fencing, but can be of occupational health concern for workers involved in the milling operations especially in factories using hammer-mills.

4.2 QUANTITIES AND CHARACTERISTICS OF EFFLUENTS

During the processing of rubber, large quantities of water are used for dilution of field latex, washing and cleaning of materials and machinery. The effluent typically contains materials originating from field latex as well as the process chemicals used, as follows:

- Small amounts of uncoagulated latex;
- Substantial quantities of proteins, sugars, lipids, carotenoids, inorganic and organic salts;

- Formic, acetic, phosphoric or sulphuric acids depending on whichever is used for controlled latex coagulation; and
- Latex preservatives, mainly, ammonia and TMTD-Zinc oxide.

Some of the above substances form excellent substrates for the proliferation of microorganisms, and generate a high biochemical oxygen demand and objectionable odour.

Wide variations of water consumption and effluent discharge rates are observed in rubber factories. Aside from the types of products and processes, in-plant process control and housekeeping measures also greatly influence water consumption rates. The effluent discharge rates and water consumption rates do not differ significantly and for practical purposes are taken as equal.

4.2.1 Typical Effluent Quantities

Data on water consumption rates obtained by the Rubber Research Institute of Malaysia (RRIM) from extensive field studies are summarized in *Table 4*. Also, presented in *Table 4* are water consumption and effluent discharge rates that are commonly used as the design basis for the sizing of effluent treatment facilities for rubber factories.

Table 4: Typical Water Consumption and Effluent Discharge Rates of Malaysian Rubber Factories

Type of Rubber Processed	Rate of Water Consumption and Effluent Discharge, Cubic Meters per Tonne DRC		
	Range	Mean	Design Basis
Latex Concentrate	7 - 25	14	18
Crumb Rubber:	21 - 44*	32*	-
- Latex	-	-	22
- Cup Lump	-	-	34
Sheet (RSS)	12 - 29	19	22
Sheet (ADS)	16 - 36	27	22
Brown Crepes	33 - 47	36	36

* *Note: Typical factory processing a combination of 80% field latex and 20% cup lumps*

4.2.2 Typical Effluent Quality Characteristics

The relevant pollutant parameters for rubber factory effluents are based on their physical, chemical and bacteriological properties. These usually include:

- pH;
- Biochemical Oxygen Demand (BOD; 3-Day, 30°C);
- Chemical Oxygen Demand (COD);
- Total Solids, Suspended Solids, Settleable Solids, Dissolved Solids, and their respective volatile fractions;
- Total Nitrogen, Ammoniacal Nitrogen, and Albuminoid Nitrogen;
- Sulphates; and
- The bacteriological properties are usually determined in terms of Total Coliform, E. Coli and Streptococci.

The typical physical and chemical properties of effluents from latex concentrate, crumb, sheet (RSS) and lower grade rubbers (remilling factories), are as shown in *Table 5.*

Table 5: Typical Quality Characteristics of Effluent from Different Types of Rubber Factories (Source: RRIM)

Parameter	Type of Factory				
	Unit	Latex Concentrate	Crumb Rubber	Sheet (RSS)	Remilling*
pH	-	4.2	5.7	4.9	6.2
BOD (3-Day; 30 °C)	mg/l	3,580	1,750	2,630	740
COD	mg/l	6,590	2,740	3,300	900
Suspended Solids	mg/l	390	240	140	350
Total Solids	mg/l	8,040	1,920	3,750	480
Ammoniacal Nitrogen	mg/l	700	66	10	15

*Note: * Factories processing lower grade crumb or crepe from field coagula materials.*

Rubber factory effluents are usually acidic as indicated by the typical pH values of less than 6.5 and as low as 4.0. The acidic nature of the effluent is due to the use of formic, acetic, phosphoric, or sulphuric acids for latex coagulation. The factories using field latex as the principal raw material (excluding remilling factories) also have characteristically high concentrations of dissolved and suspended solids in their effluents. The high organic contents of these effluents, which originate from the latex serum, result in typically high BOD and COD concentrations. The extremely high ammoniacal nitrogen concentration typical of latex concentrate factory effluent is due to the higher quantity of ammonia added for latex preservation.

Ammoniacal nitrogen can adversely affect the aquatic environment. Free ammonia is toxic to fishes. The presence of ammoniacal nitrogen and other forms of inorganic nitrogen in rivers and streams is undesirable as it promotes algal blooms. The presence of ammonia in raw water supplies also increase its chlorine demand during chlorine disinfection of the drinking water.

4.2.3 Bacteriological Properties

The bacteriological properties of rubber effluents are not routinely determined, but can be important in the case of rubber factories that discharge effluents upstream of drinking water intake points. The bacteriological properties of effluent from the rubber factories processing various types of products in terms of typical bacterial counts are given in *Table 6*.

The effluent discharged from the remilling factories contain the largest total viable bacterial population and population of Coliforms, E. coli and Streptococci. As, public water supplies are routinely monitored for total coliforms and E. coli as indicator organisms of potential sewage contamination, the results can be generally misleading when rubber effluents contribute to these counts. This is because the raw materials used in remilling, such as cup lumps, latex lumps and other wet coagula, are stored over many days or weeks and create favourable conditions for the proliferation of these microorganisms that utilise the non-rubbers in them.

Table 6: Bacteriological Properties of Effluent from Different Types of Rubber Factories

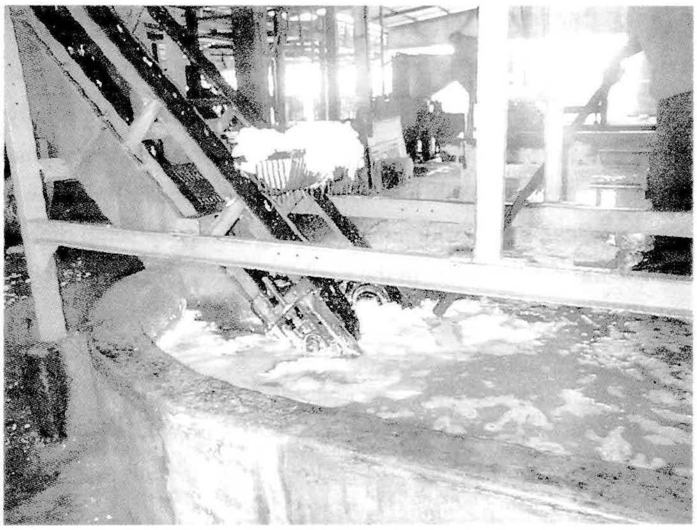
Rubber Factory	Log Count/mL (22°C)	Presumptive Count/100 mL x 10^3		
		Coliform	E. coli	Streptococci
Block Rubber	6.50	10,655	2,272	6,294
Ribbed Smoked Sheet	5.81	1,540	191	3,127
Remilling	7.17	41,875	7,488	16,950
Latex Concentrate	4.38	415	24	31

4.3 CHARACTERISTICS OF AIR EMISSIONS FROM RUBBER DRYERS

In rubber factories, the major sources of malodour are the drying process for rubber, especially those producing lower grade rubbers, and the open storage of scrap rubber and cup lumps within the factory premises. The malodour is attributed to volatile fatty acids produced from the breakdown of non-rubbers during the drying process, and by microorganisms during storage of scrap rubber and cup lumps. An analysis of the volatile organic acids in the gases emitted by a crumb rubber dryer are presented in *Table 7.*

Table 7: Concentrations of Volatile Organic Acids in the Air Emission of a Crumb Rubber Dryer

Type of Pollutant in Dryer Air Emission	Pollutant Concentration (Parts per Million, ppm)
Acetic Acid	585
Propionic Acid	524
Isobutyric Acid	211
Butyric Acid	280
Isovaleric Acid	368
Valeric Acid	312



Sources of effluent:
Materials washing

Sources of effluent:
Washing of equipments

Sources of air emission:
Rubber dryers

5.0 REGULATORY FRAMEWORK

5.1 INTRODUCTION

The Environmental Quality Act 1974 (EQA), together with its amendments (Act A636, A 953 and A 1030), is the most comprehensive environmental legislation in Malaysia for the prevention, abatement, control of pollution and enhancement of the environment. The EQA is a Federal legislation and therefore enforced by a Federal agency, the Department of Environment (DOE), under the administration of the Director General of Environmental Quality. The EQA and industry-specific regulations made thereunder for the raw natural rubber industry, i.e., the Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations, 1978, are the principal legislative instruments in operation for systematic environmental control of this industry. The relevant provisions of other subsidiary legislation under the EQA, which are not industry-specific, may also be applied directly to the raw natural rubber industry as and when deemed appropriate. These are:

- The Environmental Quality (Licensing) Regulations, 1978 - for licensing of prescribed premises;
- The Environmental Quality (Clean Air) Regulations, 1978 - for control of air emissions; and
- The Environmental Quality (Scheduled Wastes) Regulations 1989 - for control of the disposal of toxic and hazardous wastes.

There also exist other pieces of legislation administered by Federal, State and Local Government authorities, which have certain provisions for environmental control, that can be generally applied to the raw natural rubber-processing factories. The exercise of environmental control (if any) under such legislation is usually *ad-hoc* and non-industry-specific, and are therefore not discussed in this Handbook.

5.2 ENVIRONMENTAL QUALITY ACT 1974 & AMENDMENTS

In brief, the Environmental Quality Act 1974:

- came into force on 15 April 1975;
- has since been amended 3 times: in 1985, 1996 and 1998, respectively, to increase its effectiveness; and
- has 20 subsidiary legislations: 11 sets of regulations; 1 set of rules and 8 sets of orders for the exercise of control over pollution sources, as at end of 1998.

The 1996 amendment of the EQA was particularly significant in that, among others, it:

- increased the penalties for offences from RM 10,000 to RM 100,000;
- empowered the DOE to inspect an offending site without a warrant; and
- authorised the DOE to request for an environmental audit, if deemed necessary.

The major changes in the recent 1998 amendment were:

- introduction of guidelines for activities exempted from the open-burning prohibition;
- however, notwithstanding this, the DOE can prosecute an alleged offender after getting the written approval of the Public Prosecutor; and
- increase in the penalty for open-burning from RM 100,000 to RM 500,000.

5.3 REGULATORY CONTROL OF THE RAW NATURAL RUBBER INDUSTRY

The promulgation of environmental quality regulations under the EQA for industrial pollution control commenced during the latter half of the 70's. At that time, the raw natural rubber industry was considered as second to the palm oil industry vis-à-vis the major pollution sources by industry sectors. It was therefore decided that environmental control of both these industries warranted a licensed approach that would enable intimate control of individual factories, as well as provide a mechanism for permitting variable effluent standards to be applied based on the demands of environmental circumstances.

5.3.1 Licensed Control as Prescribed Premises under Section 18 and 19 of the EQA

The "prescribed premises" approach of Section 18 of the EQA, which provides for licensed environmental control of factories, was therefore deemed appropriate and chosen for the raw natural rubber industry.

- The Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Order 1978, prescribed factories that produce or process the following raw natural rubber products as "prescribed premises", which shall require a licence under Section 18 of the EQA for the occupation or use of their respective premises:
    - Raw natural rubber in technically specified form, latex form including prevulcanised or the form of modified and special purpose rubber; and
    - Conventional sheet, skim, crepe or any other form of raw rubber not already described, promulgated under the powers of section 51 of the EQA provided that the factory production or processing capacity is not less than 5 tonnes per day.

- Environmental control of raw natural rubber factories is therefore exercised through the imposition of appropriate conditions of licence which may pertain, not only to acceptable conditions of effluent discharge, but also to other types of waste disposal including air emissions and scheduled waste. However, the control of air emissions and disposal of scheduled wastes are ordinarily exercised through direct application of their specific regulations. New rubber factories that are to be constructed, which fall within the definition of "prescribed premises", must obtain the prior written permission of the Director General of Environment under Section 19 of the EQA before commencement of site-preparation or any other construction work.

- As a matter of procedure, the project proponent is also required to obtain environmental clearance for the proposed site of the factory at the earliest planning stage to ensure its suitability and minimal environmental control cost.

5.3.2 Regulatory Control of Effluent Discharge

The Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978, promulgated under the enabling powers of Section 51 of the EQA, are the governing regulations that contain the effluent discharge standards and regulatory requirements for environmental control that can be imposed on individual rubber factories through conditions of the licence.

The principal regulatory requirements and elements of regulatory control are:

- Application for an annual licence using *Form 1* and according to procedures in the *Environmental Quality (Licensing) Regulations 1977*;

- Licence fees charges consisting of processing fee of RM 100.00 plus an effluent–related amount computed according to the rates and procedures in the *Fifth Schedule* of the *Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978*;

- Compliance with the applicable effluent standards [*Second, Third or Fourth Schedule* of the *Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978*] and other acceptable conditions of effluent discharge imposed as conditions of the *Licence* (*Form* 2 of the Licensing regulations). The current effluent discharge standards ordinarily applicable to latex concentrate factories, and factories producing block rubber and conventional grade rubber of all types, respectively, presented in *Table 8*. Effluent treatmenttechnologies based on current pollution practices and available cleaner production measures that are reasonably cost-effective in enabling compliance with the effluent discharge standards are presented in *Section 6* and *Section 7*, respectively;

- Submission of quarterly information on effluent discharge in the format of the Quarterly Return Form in the *First Schedule* of the *Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations 1978*.

Table 8: Prevailing Effluent Standards for the Raw Natural Rubber Industry (Environmental Quality (Prescribed Premises)(Raw Natural Rubber) Regulations, 1978)

Parameter		Latex Concentrate Factories [Third Schedule]	Block Rubber and Conventional Grade Rubber Factories [Fourth Schedule]	Remarks
BOD (3-day; 30°C)	mg/l	100 (50)*	100 (50)*	Limit is 50 with no one sample exceeding 100 mg/l.
COD	mg/l	400	250	
Total Solids	mg/l	150 (100)*	100 (50)*	Limit is 100 with no one sample exceeding 150 mg/l.
Ammoniacal Nitrogen	mg/l	250	40	
Total Nitrogen	mg/l	300	60	
pH	-	6 - 9	6 - 9	

* *Note: The raw effluent may be utilised for land application, in which case prior approval must be obtained from the DOE*

5.3.3 Regulatory Control of Air Emissions

The processing of raw natural rubber is not a major source of air pollution. However, localised problems may arise depending on proximity to residential areas as a result of smoke emission from smoke-houses, odour emission from rubber dryers as well as the open storage of cup lumps and scrap rubber especially in a wet condition:

- The raw natural rubber industry is directly subject to the requirements of the Environmental Quality (Clean Air) Regulations 1978.
- The following provisions of the Clean Air Regulations are also generally applicable to rubber factories on the basis of their relevance:
  - Siting of new facilities adjacent to residential areas (Part II);
  - Burning of waste (Part III);
  - Dark smoke emission (Part IV); and
  - Emission of air impurities (Part V).
- Based on the relevance of specific parameters, the Air Emission Standard C for new facilities and Standard B for existing facilities in *Part V* of the Clean Air Regulations are generally enforceable with respect to rubber factories. These may be referred to in *Appendix 1*.
- *Regulation 32* of the Clean Air Regulations requires that the best practicable means approach be applied to prevent the emission of noxious and offensive substances such as those listed in *Appendix 2*.

During the processing of block rubber, rubber crumbs are dried at a temperature of about 110°C for about 3 hours. At this temperature, the non-rubber materials present in the raw rubber tend to breakdown and release noxious substances consisting mainly of volatile fatty acids (VFA) which are then discharged to the atmosphere via a chimney. Since the air emission contains fairly large quantities of volatile fatty acids, they may be noxious and offensive to the public. The best way to minimise this source of air pollution is to pass the air emission through a scrubber system, the details of which are given in *Section 7*.

5.3.4 Regulatory Control of Noise Emission

With the exception of regulations for the control of noise from motor vehicles, there are currently no DOE regulations that require the control of noise from other sources such as industrial, construction, commercial activities, etc.

DOE regulations for the control of noise from various sources and activities are still at the drafting stage. These regulations stipulate acceptable ambient noise levels at the receptor level for various situations to safeguard public health. The World Health Organisation (WHO) has also recommended various guideline limits for noise levels for purpose of hearing protection and human well-being. Fortunately, noise is not a major issue in the natural rubber industry. The ambient noise levels in a rubber factories are usually well within the acceptable level of 85 dbA.

5.3.5 Regulatory Control of Toxic and Hazardous Waste Disposal

The disposal of toxic and hazardous wastes, which are classified and regulated as scheduled wastes by the DOE, are governed by the following subsidiary legislation of the EQA:

- The Environmental Quality (Scheduled Wastes) Order, 1989; and
- The Environmental Quality (Scheduled Wastes) Regulations, 1989.

Among other things, the Scheduled Wastes Regulations require that the DOE shall be notified by the waste generator regarding the generation and storage of any scheduled wastes. The raw natural rubber industry ordinarily does not generate any scheduled wastes and this matter is therefore not an issue. A possible exception is the sludge generated in the rubber trap and the effluent treatment system which may contain traces of residual process chemicals, especially in the case of latex concentrate factories which use higher quantities of preservatives.

6.0 POLLUTION CONTROL PRACTICES

6.1 INTRODUCTION

In the decades of the 70's and 80's, the raw natural rubber industry directed its attention mainly to end-of-pipe treatment technologies as a matter of urgency and in response to government initiatives aimed at arresting the mounting water pollution problems inflicting the country's waterways. However, in the present decade of the 90's, increasing attention is being given to in-plant measures *vis-a-vis* cleaner production, primarily waste minimisation, improved water usage, and wastewater utilisation. This Section presents the pollution control practices of the raw natural rubber industry; end-of-pipe solutions are presented in greater detail in the present Section, whereas the in-plant measures are only briefly identified below, and described in more detail in the *Section 7* on Pollution Prevention and the Cleaner Production Approach.

6.2 IN-PLANT CONTROL AND HOUSEKEEPING MEASURES

Effective in-plant process control and good housekeeping measures are most essential for limiting waste generation and wastage of resources, as well as to minimise the load of pollutants to be removed in the effluent treatment process. The following are some of the essential cleaner production measures for primary rubber factories that are directed at waste minimisation at source, and reducing the cost of end-of-pipe treatment:

- Control of water usage;
- Control of chemical usage;
- Deammoniation of skim latex in centrifuged latex factories;
- Proper handling and storage of process chemicals;
- Proper design and operation of rubber traps; and
- Separation of effluent and stormwater drainage systems.

Each of these measures are described and discussed in more detail in the next section, *Section 7*, which deals with pollution prevention and cleaner production in the raw natural rubber industry.

6.3 EFFLUENT TREATMENT TECHNOLOGIES FOR THE RAW NATURAL RUBBER INDUSTRY

6.3.1 General

The contents of rubber factory effluents are primarily organic and easily biodegradable. The effluent treatment technologies for rubber factory effluents are therefore invariably combinations of physical and biological processes. Physical treatment, mainly screening, sedimentation, and rubber removal in rubber traps are usually incorporated as pre-treatment steps before the effluent is fed into the treatment system proper. The pre-treatment steps normally take the form of a sand trap and/or rubber trap; the latter consists of a baffled pit or sump that retains the effluent for about 8 to 24 hours. The uncoagulated latex is allowed to auto-coagulate and be released to the effluent surface in the rubber trap from which it is manually removed. Some suspended solids may also settle-out in the rubber trap. The net result is a reduction by as much as 65% of the solids loading on the subsequent treatment system.

A large number of biological treatment processes have been researched specifically for rubber effluents in attempts to arrive at the most cost-effective treatment systems. These include:

- Anaerobic processes such as the anaerobic lagoon, conventional anaerobic digester, anaerobic contact process, and up-flow anaerobic sludge-blanket (UASB) reactor; and
- Aerobic (and facultative) processes such as the trickling filter, conventional activated sludge, oxidation ditch system, bio-disc system, extended aeration system, aerated lagoon, and aerobic stabilization lagoons.

The available effluent treatment technologies for rubber factory effluents are generally based on the treatment system options presented in the schematic form of *Figure 7*. The principal treatment options are as follows:

- Anaerobic-cum-Facultative Lagoon System
- Anaerobic-cum-Aerated Lagoon System
- Aerated Lagoon System
- Oxidation Ditch System
- Conventional Activated Sludge System
- Anaerobic Reactor-cum-Oxidation Ditch System
- Anaerobic Reactor-cum-Activated Sludge System

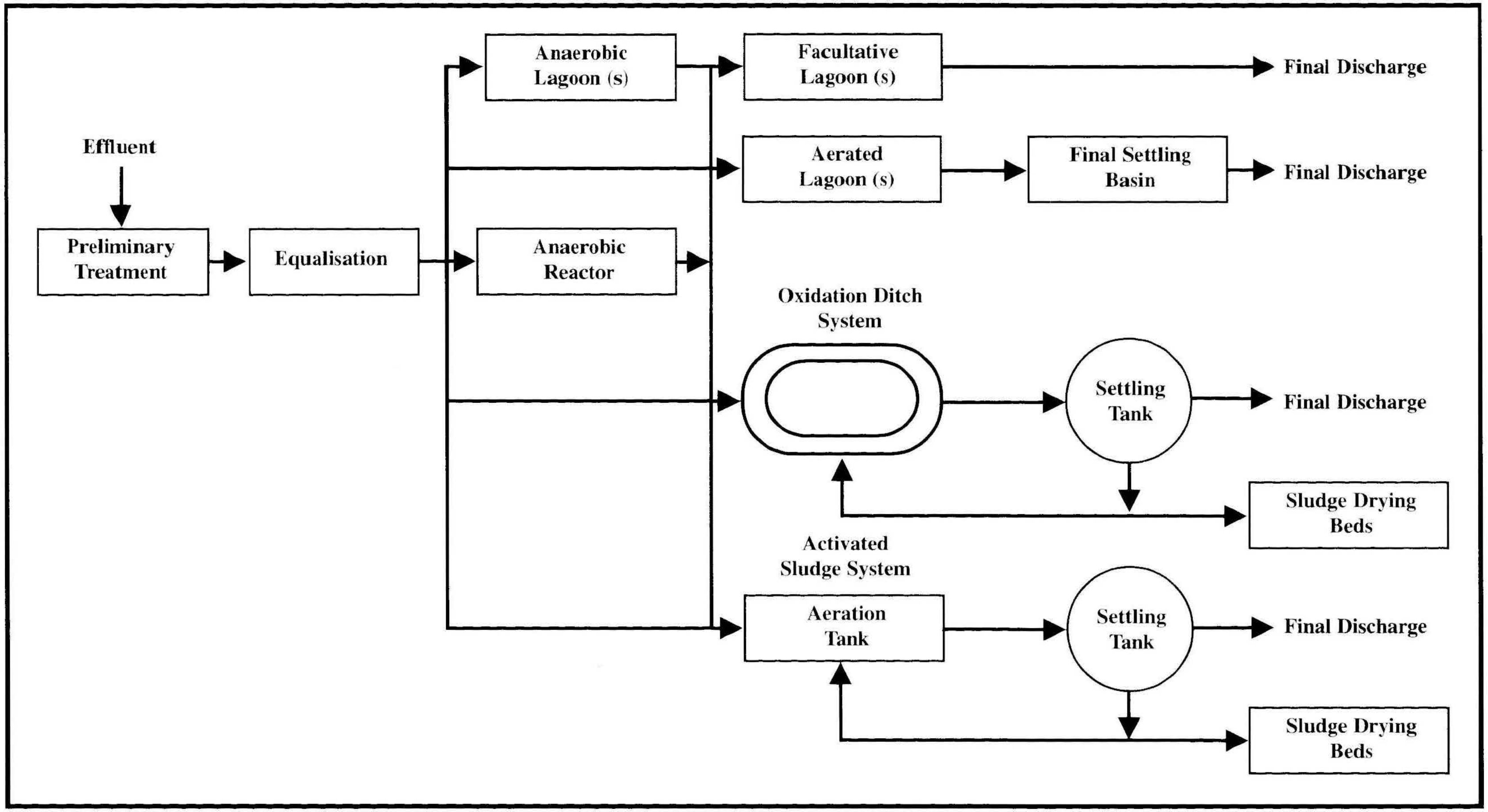


Figure 7 : Schematic Representation of Effluent Treatment Technologies for Rubber Factory Effluents (Reference 15)

Of the above treatment options, the most commonly used effluent treatment systems in the raw natural rubber industry are:

- Anaerobic-cum-facultative lagoon system;
- Anaerobic-cum-aerated lagoon system;
- Aerated lagoon system (with extended aeration); and
- Oxidation ditch system.

Among the anaerobic reactors, the conventional anaerobic digester and the up-flow anaerobic sludge blanket reactor have had only limited application and have been used for first-stage treatment of the high-strength latex concentrate factory effluents.

6.3.2 Anaerobic-cum-Facultative Lagoon System

A schematic representation and the principal design features of the anaerobic-cum-facultative lagoon system for a 50-Tonne Per Day Crumb Rubber Factory are presented in *Figure 8*.

Typical design features of the anaerobic lagoon(s) are:

- Lagoon depths of 1.8 to 3.0 meters depending on soil suitability and depth of ground water table. In suitable areas, depths up to 5 meters are used to reduce landspace requirements;
- Total hydraulic retention times (HRT) of between 10 and 15 days; and
- Optimum organic loading rate of about 0.15 kg BOD/m^3.day.

The effluent from the anaerobic lagoon(s) is stabilised in the facultative lagoon(s) by oxidation using air from natural atmospheric aeration as well as oxygen from algal photosynthesis. In the facultative lagoon, the bacteria and algae co-exist symbiotically. The bacteria decompose organic matter utilising oxygen in the process and generate carbon dioxide. During photosynthesis, the algae utilise the carbon dioxide and produce oxygen. The dominant group of algae is the chlorella group.

Typical design features of the facultative lagoon(s) are:

- Total hydraulic retention times of about 15 to 20 days; and
- Depths not exceeding about 1.8 meters.

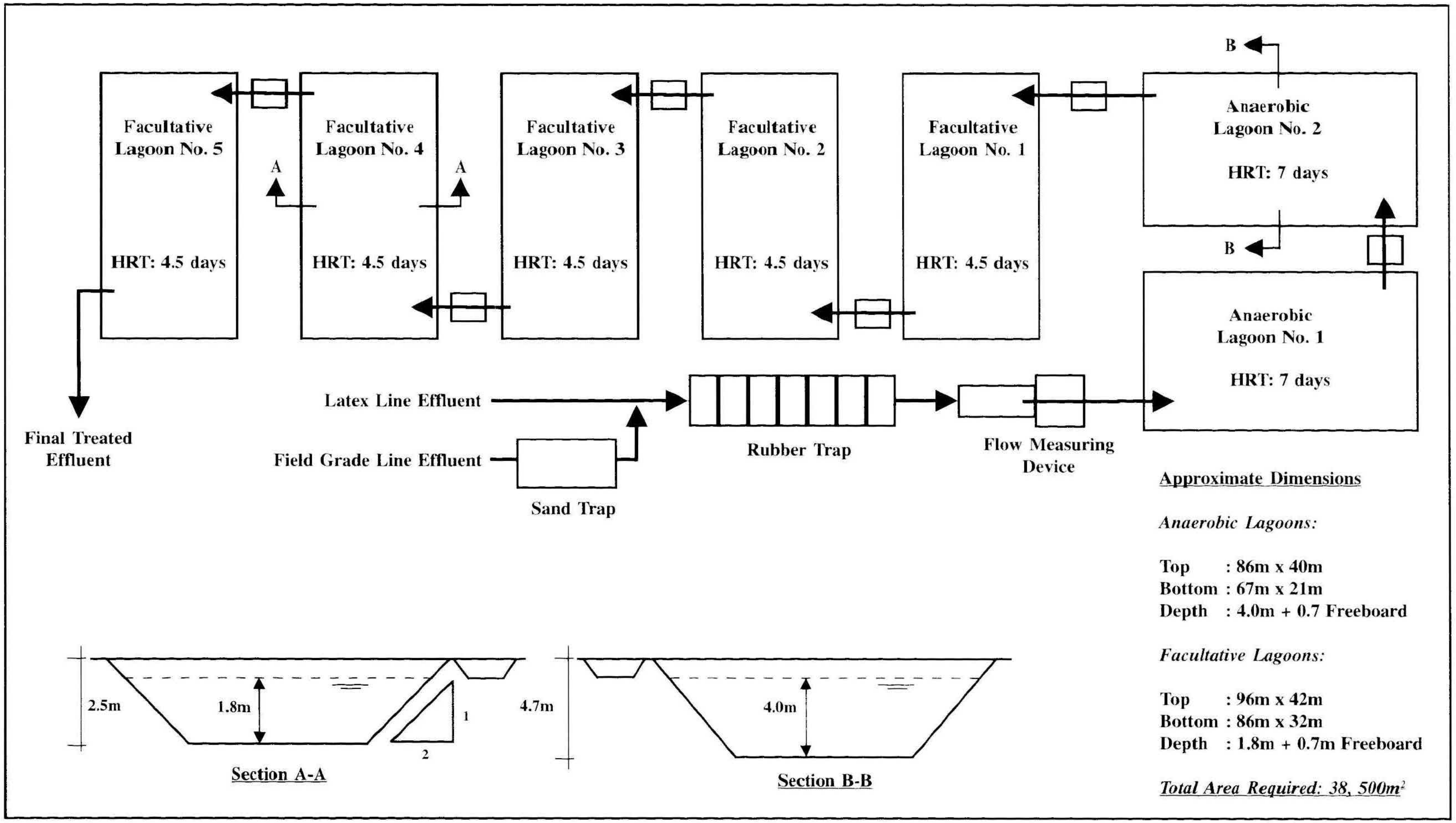


Figure 8: Principal Design Features of an Anaerobic-cum-Facultative Lagoon System for a 50-Tonne/Day Crumb Rubber Factory (Reference 15)

In the case of facultative lagoons, floating scum is removed regularly to allow diffusion of oxygen from the atmosphere and penetration of sunlight, the latter being vital for photosynthetic activity.

Typical performances of the anaerobic-cum-facultative treatment systems for crumb rubber factory effluent and latex concentrate factory effluent are presented in *Table 9* and *Table 10*, respectively.

Table 9 : Typical Performance of an Anaerobic-cum-Facultative Lagoon System Treating Crumb Rubber Factory Effluent

Parameter	Raw Effluent	Treated Effluent	Percent Removal
pH	5.5	7.5	
Total Solids	1,960	720	63
Volatile Solids	1,245	315	75
Suspended Solids	320	125	61
Settleable Solids	160	60	62
COD	2,900	230	92
BOD	1,770	60	97
Total Nitrogen	140	55	61
Ammoniacal Nitrogen	70	40	38

Note: All values except pH are expressed in mg/L

Table 10 : Typical Performance of an Anaerobic-cum-Facultative Lagoon System Treating Latex Concentrate Factory Effluent

Parameter	Raw Effluent	Treated Effluent	Percent Removal
pH	4.8	7.8	-
COD	3,525	155	96
BOD	4,850	50	99
Total Nitrogen	600	200	66
Ammoniacal Nitrogen	465	135	71
Suspended Solids	820	360	56

Note: All values except pH are expressed in mg/L

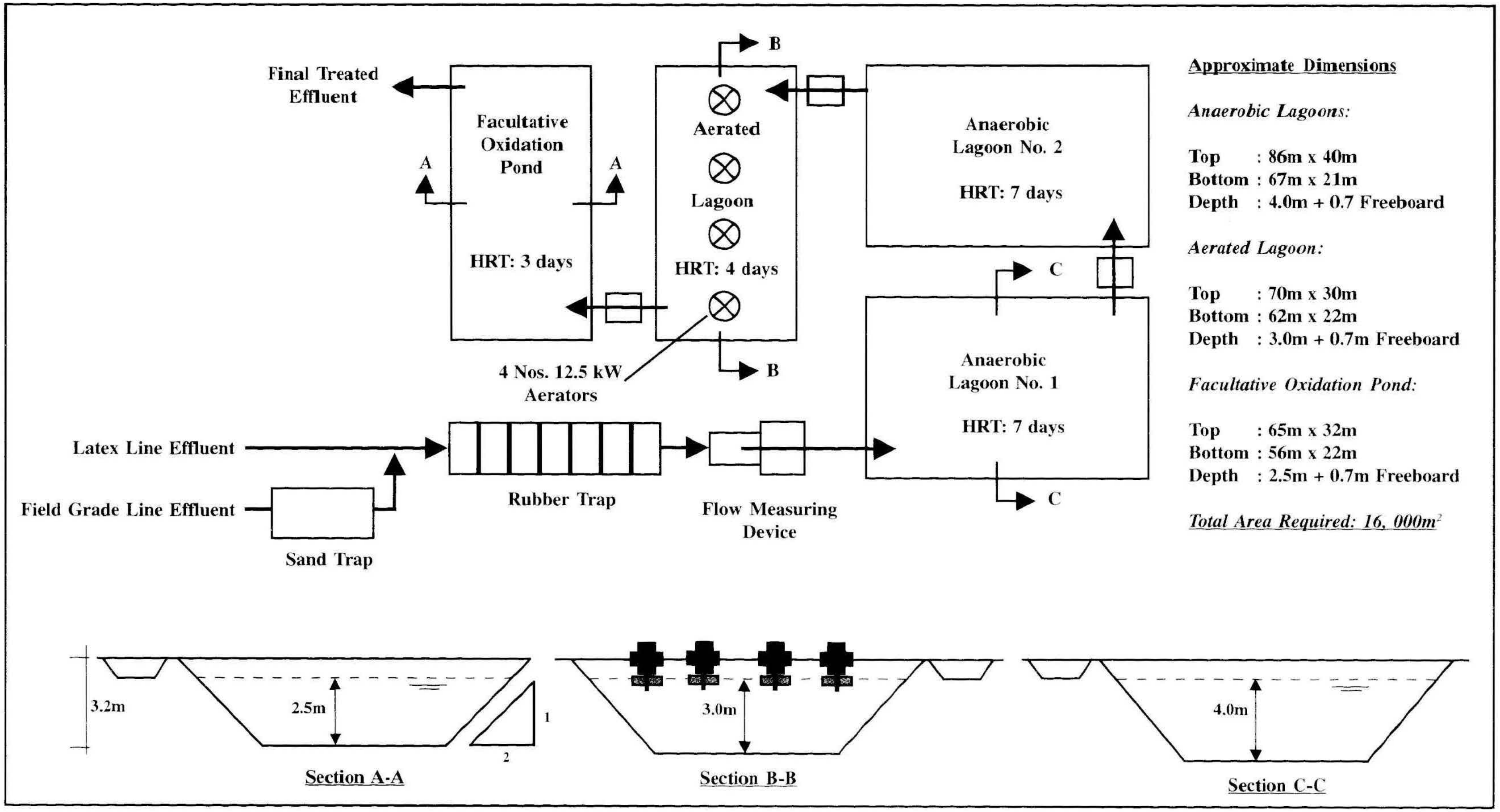


Figure 9: Principal Design Features of an Anaerobic-cum-Aerated Lagoon System for a 50-Tonne/ Day Crumb Rubber Factory (Reference 15)

6.3.3 Anaerobic-cum-Aerated Lagoon System

A schematic representation and the principal design features of an anaerobic-cum-aerated lagoon system for a 50-Tonne/Day Crumb Rubber Factory are presented in *Figure 9*.

Basically this system is similar to the anaerobic-cum-facultative lagoon system, except that the facultative lagoons are replaced by an aerated lagoon in which the oxygen to the system is provided by mechanical means using surface aerators or diffused air systems. The advantage of using mechanical means to supply the oxygen requirements of the system is that this reduces the lagoon area required. A settling tank is provided after the aerated lagoon for removal of the biological solids formed before final discharge; this is necessary as the aerated lagoon will produce a high concentration of bacterial cell mass or biomass.

Typical design features of the aerated lagoon(s) are:

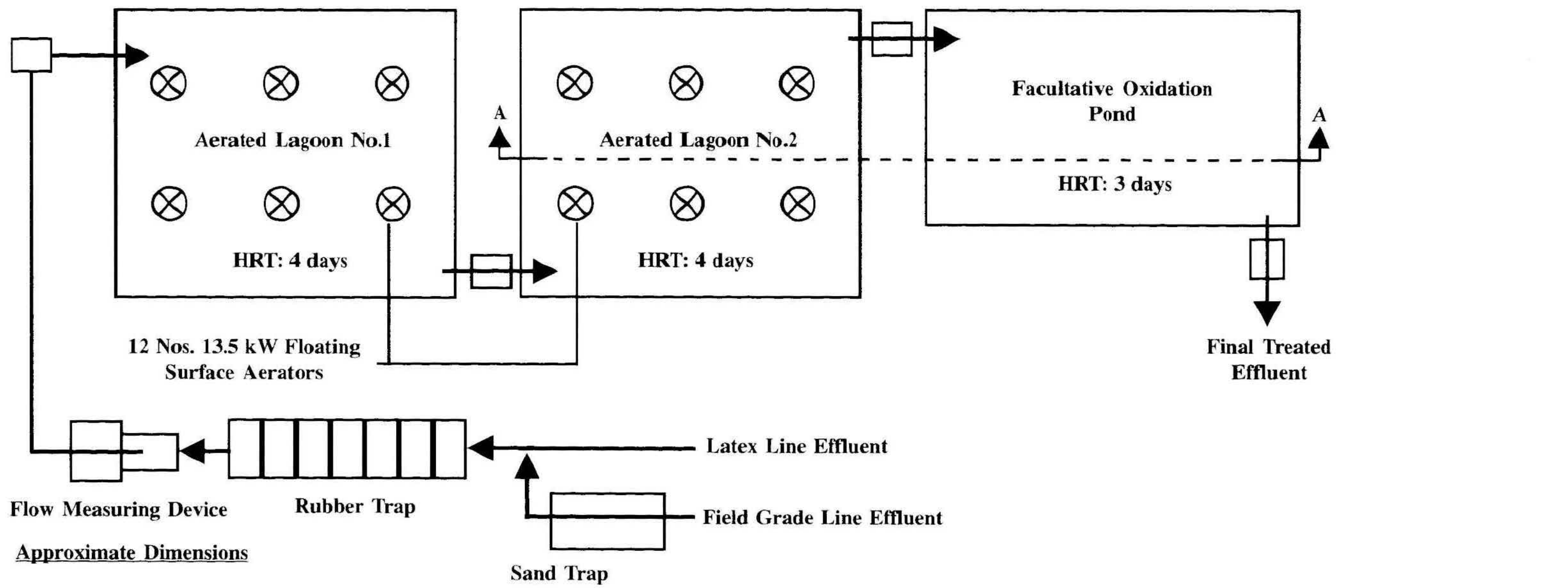
- Hydraulic retention times (HRT) of 3 to 4 days for the anaerobically treated effluent;
- HRT's of about 10 - 12 days for raw crumb factory effluent;
- A hydraulic retention time of between 1 day and 3 days is required for the settling tank or pond.

Performance of the system is good with overall BOD reductions of about 95% to 98%. Operation and maintenance costs are higher than in the anaerobic-cum-facultative lagoon system owing to the energy requirement of the aerators for supplying oxygen.

6.3.4 Aerated Lagoon (Extended Aeration) System

A schematic representation and the principal design features of the aerated lagoon-cum-extended aeration system is given in *Figure 10*.

This treatment system, which uses an aerated lagoon instead of an aeration basin (and therefore a much longer retention time of several days) is essentially an extended-aeration activated sludge system, if sludge recycle is practised. The active sludge from the Facultative Oxidation Pond may be returned to the Aerated Lagoon(s) to maintain a higher concentration of mixed liquor suspended solids (MLSS). The system is an improvement over the aerated lagoon system and produces a superior quality effluent with much less sludge to be disposed off.



<u>Approximate Dimensions</u>

Aerated Lagoon No. 1 & 2:

Top : 70m x 30m
Bottom : 62m x 22m
Depth : 3.0m + 0.7m Freeboard

Facultative Oxidation Pond:

Top : 65m x 32m
Bottom : 55m x 22m
Depth : 2.5m + 0.7m Freeboard

Total Area Required: 9,500m²

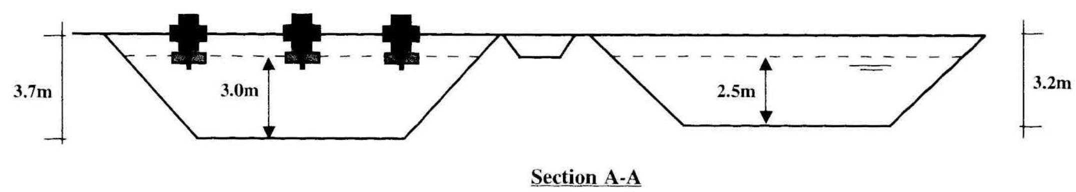


Figure 10 : Principal Design Features of an Aerated Lagoon-cum-Extended Aeration System for a 50-tonne/day Crumb Rubber Factory (Reference 15)

This type of system will also result in a final effluent quality which is better and more consistent than that of the anaerobic-cum-facultative lagoon system or the anaerobic-cum-aerated lagoon system, for which typical treatment performance data was earlier presented in *Tables 8 and 9*. There is also better assurance of meeting the parameter limits for ammonia nitrogen and total nitrogen of the effluent standards.

6.3.5 Oxidation Ditch System

The oxidation ditch system, which is a form of extended-aeration activated sludge system, is presented schematically in *Figure 11*. Oxidation ditch systems may also be designed as parallel units for larger factories as proposed in a World Bank Study for the General Rubber Corporation of Viet Nam (*Reference 15*). A conceptual design of the oxidation ditch system based on the use of parallel units for a 50-Tonne/Day Crumb Rubber Factory is presented in *Figure 12*.

The system operates on the extended-aeration principle with aeration being applied with the use of fixed horizontal-type brush rotors. The effluent is circulated in an oval-shaped concrete-lined lagoon at a speed of about 30 cm/s and oxygenated by the horizontal rotors. Compressed air may be mixed into the effluent using diffusers to supplement the oxygen-supply. The mechanical agitation also causes flocculation of the colloidal solids, and these flocs contain bacteria and fungi that absorb and assimilate the organic material and rapidly reduce BOD (90-96%). The carbonaceous material is oxidised to carbon dioxide and water, while ammonia is converted to nitrites and nitrates by the process of nitrification. The mixed liquor flows into a settling tank and the settled activated sludge is recovered and partially returned to the oxidation ditch. The clarified liquor is discharged as final treated effluent.

Typical design features of the oxidation ditch system are:

- Hydraulic retention times of up to 7 days for latex concentrate factory effluent, and about 4 days for crumb rubber factory effluent;
- Operating depths of up to about 3.0 meters; and
- Clarifier settling time of about 2 hour;

The system is stable, compact and relatively insensitive to shock loads. However, a significant amount of energy is required for the aerators and the energy-requirement is comparable to that of the aerated lagoon system. This system requires much less space than the anaerobic-cum-facultative lagoon system or the anaerobic-cum-aerated lagoon system. It is well suited for land-constrained factories and those in suburban areas where odour is a serious concern due to proximity to neighbouring residents.

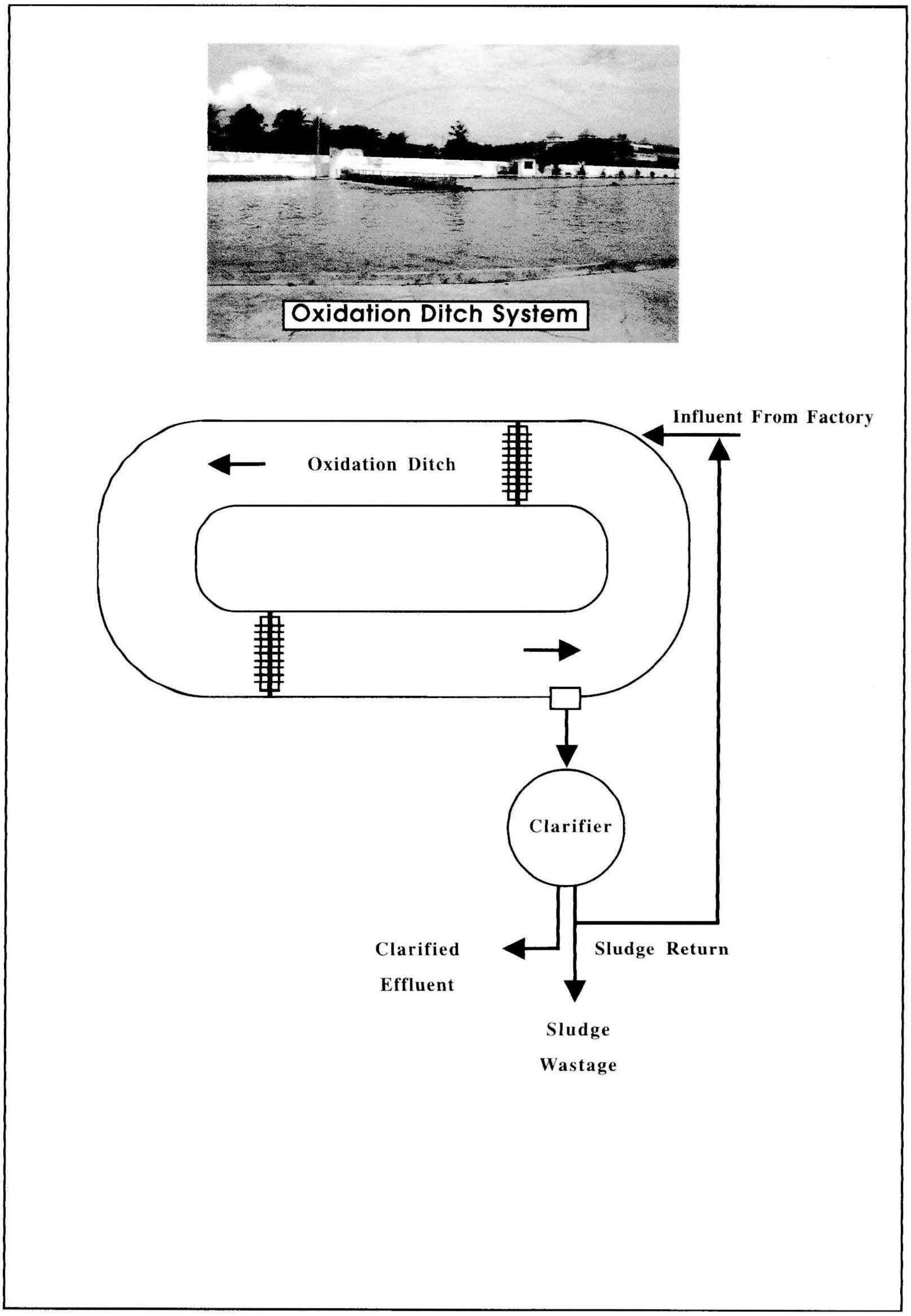


Figure 11: Schematic Representation of an Oxidation Ditch System

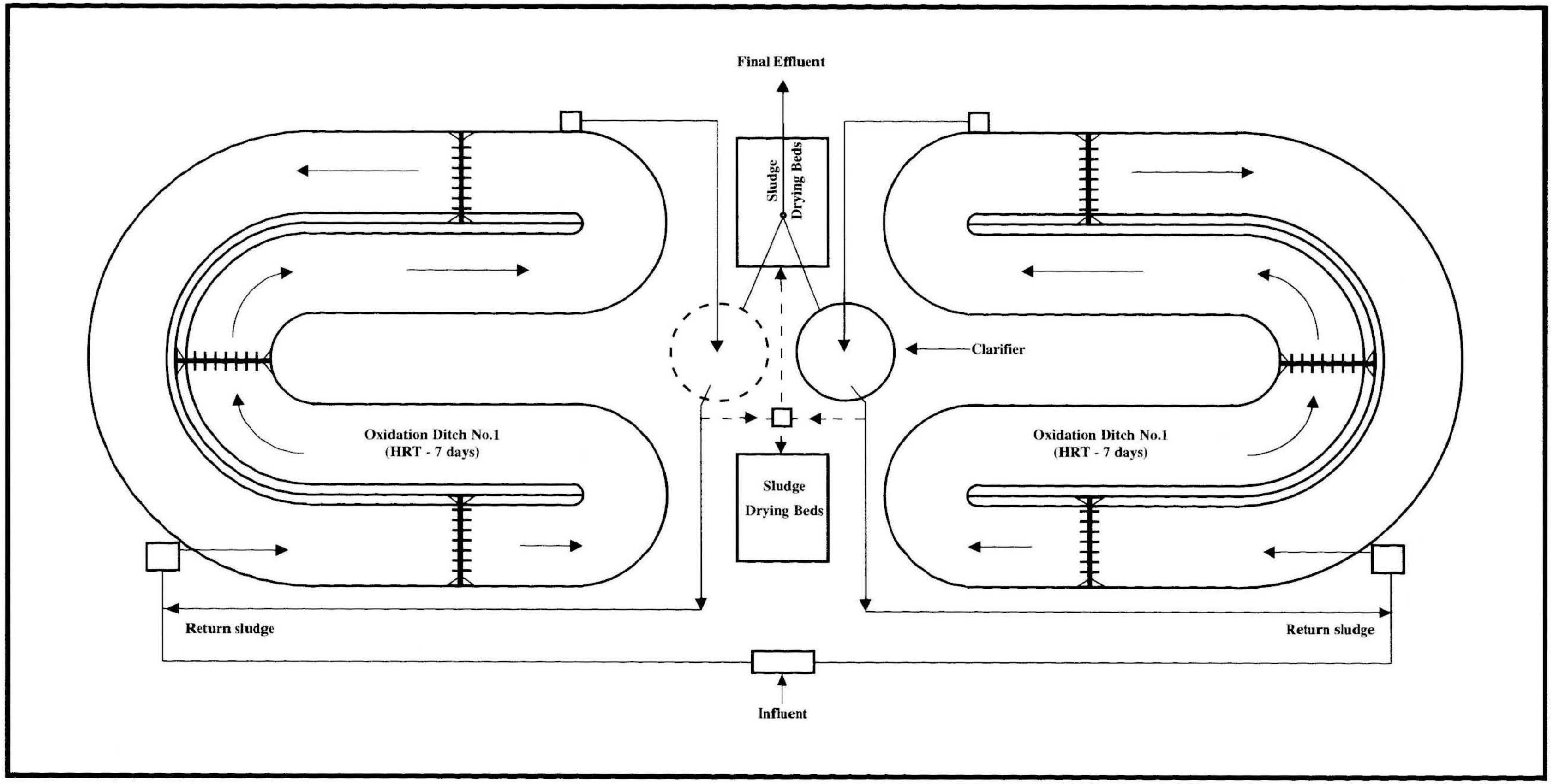


Figure 12 : Oxidation Ditch System for a 50-Tonne DRC/Day Latex Concentrate Factory (*Reference 15*)

The typical treatment performance of an oxidation ditch system treating latex concentrate factory effluent is presented in *Table 11*.

Table 11 : Typical Performance of an Oxidation Ditch System Treating Latex Concentrate Factory Effluent

Parameter	Raw Effluent	Mixed Liquor	Clarified Liquor	Percent Removal
pH	5.6	6.8	6.8	-
Total Solids	1,570	3,385	1,310	16
Suspended Solids	275	2,170	100	63
Volatile Solids	230	1,385	75	66
COD	2,165	1,875	155	93
BOD	1,275	225	45	96
Total Nitrogen	350	290	190	46
Ammoniacal Nitrogen	260	170	145	44

Note: All results are in mg/L, except for pH

6.3.6 Conventional Activated Sludge System

Activated-sludge processes are used for both secondary treatment and complete aerobic treatment without primary sedimentation. Wastewater is fed continuously into an aeration tank usually of rectangular-shape, where microorganisms metabolise and biologically flocculate the organics. The aeration equipment usually consists of air compressor-cum-diffuser systems, or turbine-type mechanical surface aerators. Active biomass (activated sludge) containing the microorganisms are settled from the aerated mixed liquor under quiescent conditions in the final clarifier and returned to the aeration tank. The supernatant from the final clarifier is the plant effluent.

Compared to stabilisation and aerated lagoon systems, activated sludge systems have been less commonly used for treatment of rubber factory effluents due to high construction and operating costs, as well as the high operator skills needed. However, these systems require the least land space and are highly efficient and consistent in terms of BOD removal.

6.3.7 Anaerobic Reactor Processes

For first-stage biological treatment, the anaerobic reactor processes have found limited application in the raw natural rubber industry due to the high construction cost, and general availability of relatively cheap plantation land for the more economical land-intensive anaerobic lagoon technologies. The anaerobic reactor processes are better suited for treatment of high-strength rubber factory effluents of the latex concentrate type. They are briefly described below.

(a) Conventional Anaerobic Digester

The conventional anaerobic digester is essentially a continuous stirred-tank reactor (CSTR) with no solids recycle, i.e. the mean cell residence time (MCRT) of the system equals the hydraulic retention time (HRT), warranting maintenance of long HRTs to prevent washout of microorganisms and to achieve desired treatment efficiency. The longer HRTs required for this type of anaerobic digestion process, e.g., 1 to 3 days for latex concentrate effluent, significantly increases the cost of the system.

(b) Anaerobic Contact Process

The anaerobic contact process is the anaerobic equivalent of the activated sludge process. In the anaerobic contact process, the raw wastewaters are mixed with recycled sludge solids and then digested in a continuously stirred digestion tank. The anaerobic contact reactor incorporates a settling tank, in addition to the continuous stirred reactor (CSTR).

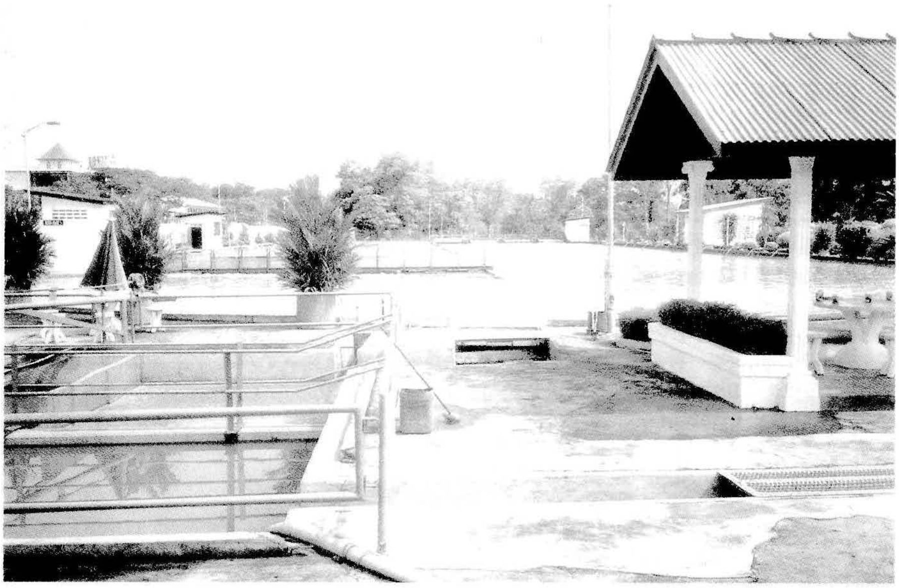
Gas formation in the digester (CSTR) tends to continue in the settling tank, thus preventing effective sedimentation which can be a major limitation of the process. Some design modifications have been attempted to overcome problems such as degasification and flocculated settling. This process has been used successfully for the stabilization of high-strength soluble wastes.

(c) Up-flow Anaerobic Sludge Blanket (UASB) Reactor

The UASB reactor system is based on upward flow of wastewater through a sludge bed of active biomass. The wastewater as it enters at the bottom of the reactor comes into contact with the biomass and is converted into methane and carbon dioxide gas. After passing through the sludge bed, the supernatant liquor and biogas enter a three-phase gas-solid-liquid separator. The biogas is separated in an inverted cone, while the liquor solids are allowed to settle in the settling zone. The treated wastewater is discharged via an overflow weir.

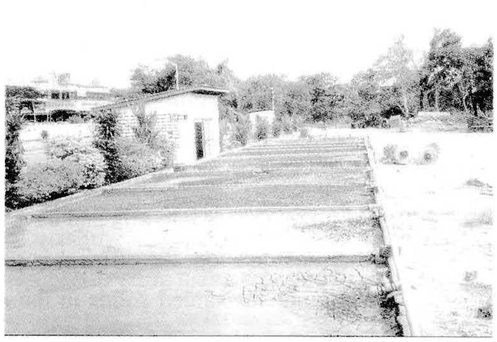
Reported data indicate very favourable performance of UASB reactors. Design loading rates range between 8 and 17 kg COD/m^3.day with COD removal efficiency of about 90%.

Aeration Systems



Oxidation Ditch System

Anaerobic Digester



Sludge Drying Beds

6.4 LAND APPLICATION OF RUBBER FACTORY EFFLUENTS

6.4.1 Fertilizer Value of Effluents

The rubber industry generates a large quantity of effluent containing high concentrations of plant nutrients, especially nitrogen and potassium, which can replace inorganic fertilizers for crops including young rubber and oil palm. *Table 12* presents data on the plant nutrients present in rubber factory effluents. The application of the effluent to a vegetated land surface, not only provides nutrients and water to the vegetation, but also provides a means of ultimate disposal of the effluent. As the effluent percolates through the soil, the organic matter is also reduced substantially by filtration, adsorption and biological oxidation.

Table 12 : Nutrient Content of Rubber Factory Effluents

Types of Effluent	Nitrogen (N)	Phosphorus (P)	Potassium (K)	Magnesium (Mg)
Latex Concentrate Factory Effluent	563 (121 - 1310)	60 (27 - 149)	386 (68 - 1050)	44 (26 - 68)
Conventional Grade Rubber Factory Effluent (Sheet and Crepe)	230 (71 - 492)	87 (7 - 180)	280 (44 - 869)	56 (16 - 112)
Crumb Rubber Factory Effluent	95 (48 - 339)	20 (10 - 30)	47 (30 - 95)	13 (8 - 20)

6.4.2 Methods of Land-Application of Effluent as Fertilizer

Rubber factory effluents are utilised by some commercial tree crop plantations as a source of inorganic fertiliser. The effluent is applied to cropland at rates corresponding to the nitrogen requirement of the particular crop.

The factory effluent is first allowed to pass through a standard 12-hour HRT rubber trap to enable recovery of remaining rubber particulates as well as removal of settleable solids. This is necessary to prevent blockage of the pumps and pipes used for distribution of the effluent onto land. The rubber trap effluent is then discharged to an equalisation tank or pond of retention time of about 24 hours to cause it to mix and have a uniform concentration of nutrients prior to land application. After equalisation, the effluent is passed through a screen (stainless steel wire mesh) to remove remaining suspended solids in the effluent before it is pumped to distribution tanks. From the distribution tanks, the effluent is applied directly onto the cropland by being allowed to flow by gravity or by pumping onto a system of inter-row flatbeds, long-beds or furrows. Other method of application of the effluent onto the cropland are also employed as described below. The choice of the method of application for any plantation depends on several factors, such as soil-type, climatic conditions and the terrain of the area.

(a) Flatbed and Long-Bed Systems

The flatbed system consists of a series of shallow bunded beds of about 15 centimeter depth. They are constructed along alternate inter-rows occupying about one third of the inter-row space between tree crops. These flatbeds are inter-connected by channels. Rubber effluent is allowed to flow by gravity, or otherwise pumped to the top-most bed and allowed to flow by gravity from bed-to-bed. When the bottom most bed is filled up, the channel is closed and the effluent is directed to the next row of beds. This is continued until all the beds are filled. In flat terrain, the long-bed system is adopted in which the construction is similar to the flatbed, except that each bed may be as much as 70 meters in length.

(b) Spray-Line-Sprinkler Irrigation System

The rubber effluent is applied by means of a fixed or movable spray-line sprinkler system. This system consists of a network of pipes with attached sprinkler heads spaced at regular intervals within the cropland. The fixed network system covers the entire cropland with a system of manually operated valves that are used to distribute the effluent to selected segments of the cropland on a rotation basis. The movable spray-line is more economical as it need not cover the entire cropland, and consists of a detachable network of pipes and valves and a set of detachable sprinkler heads that can be moved, installed and used segment by segment of the cropland.

(c) Tractor-Tanker System

The equipment required for this system is a tractor-tanker and centrifugal pump. The rubber effluent is transported to the field in a tractor-drawn tanker. The effluent is applied onto the cropland by spray-pumping with the assistance of a centrifugal pump mounted on the tanker chassis.

6.5 AIR EMISSION AND ODOUR CONTROL IN RUBBER FACTORIES

6.5.1 General

The processing of crumb rubber involves milling, washing, crumbling, drying and packing operations. Rubber drying is usually performed by indirect heating using oil-fired heaters and air as the heat exchange medium. During the rubber drying process, volatile substances including volatile organic acids are released from the breakdown of the non-rubbers and discharged to the atmosphere via a chimney which is connected to the rubber dryer. As these substances have a typical obnoxious odour they contribute to air pollution and public complaints. The prolonged storage of cup lumps and scrap rubber, especially in a wet condition, also leads to similar release of highly odorous substances.

The following measures have been developed to control air emissions and odour from crumb rubber factories, especially from those processing field-grade materials:

- Installation of a suitable wet scrubber system for each dryer to remove the air pollutants from the dryer exhaust gases prior to discharge to atmosphere;
- Rapid processing of the field-grade materials, such as cup lumps and scrap rubber, to minimise storage time and resulting microbial breakdown of non-rubbers contained in these materials;
- Avoidance of wet storage; and
- Covering of the field-grade materials with plastic sheets where prolonged storage is unavoidable.

6.5.2 Types of Wet Scrubbers

Three(3) types of wet scrubbers are available for cleaning the exhaust gases from rubber dryers:

(a) Scrubber Without Packing Media

This is the simplest system wherein the water is sprayed through a multi-nozzle sprayer into a counter-current draught of exhaust gases from the dryers which are drawn through the scrubber by an exhaust fan. The removal efficiency of this system depends very much on the rates of flow of the exhaust gases and the water spray. With optimum water flow and air exhaust suction rates, pollutant removals are about 90%.

(b) Scrubber With Packing Media

Essentially the principle involved is the same as for the scrubber without packing, except that the packing media provides a large wetted surface area for absorption of the pollutants. The exhaust gases from the dryers are directed to a common scrubber with polyethylene rings as packing materials.

The suction fan speed is 2,000 rpm and spray rate of water is about 130 Liter/minute. The spray water is recovered and recycled. Obviously this system should result in higher pollutant removal, and efficiencies of the order of 92% have been achieved.

(c) Scrubber With Double Packing Media

The scrubber with double packing is similar to the scrubber with single packing, except that the exhaust gases are drawn through 2 sections of packing against the counter-current spray of water. This enhances the efficiency and 97% removal has been achieved. However, this system is more expensive, 30-40% higher than the cost of scrubbers with single packing.

A schematic diagram of a wet scrubber of the type using double packing media is presented in *Figure 13*.

A de-mister is included to condense and collect the water vapour from the escaping exhaust gases. Several models of the wet scrubber systems are currently in operation in Malaysia, namely:

- Golstar scrubber system
- Ireson scrubber system
- Tripoly scrubber system
- Mardec scrubber system

The above scrubbers have been monitored by the RRIM and are generally found to be satisfactory. Typical removal efficiencies of the scrubber system in terms of removal of the various organic acids present are given in *Table 13*.

Table 13 : Typical Performance of a Wet Scrubber for Removal of Pollutants from the Exhaust Air of a Crumb Rubber Dryer

Pollutants	Without Scrubbing (ppm)	With Scrubbing (ppm)	% Removal
Acetic Acid	585	121	79
Propionic Acid	524	73	86
Isobutyric Acid	211	Nil	100
Butyric Acid	280	34	88
Isovaleric Acid	368	Nil	100
Valeric Acid	312	Nil	100

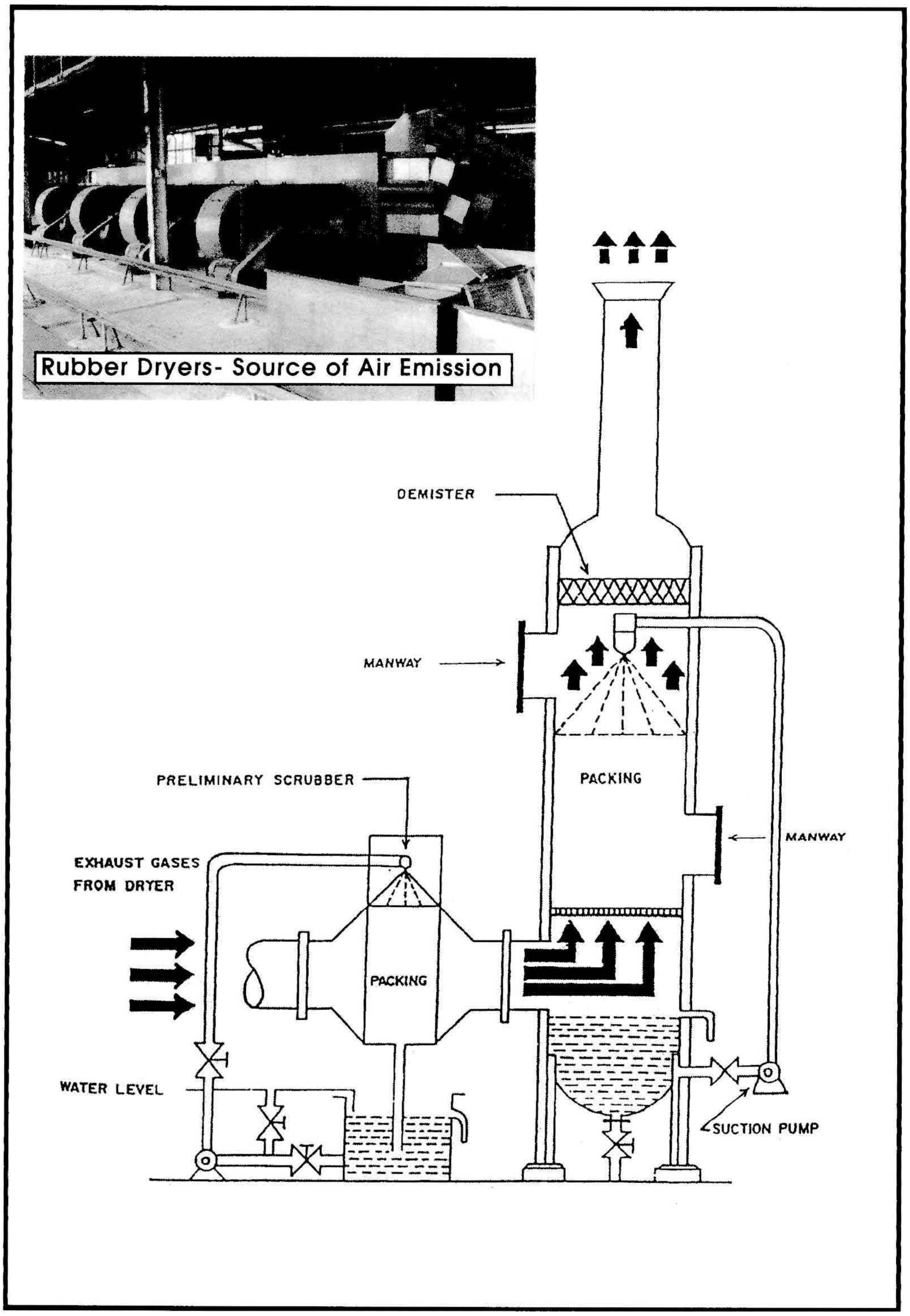


Figure 13: A Wet Scrubber System for Cleaning Exhaust Air from a Crumb Rubber Dryers

7.0 POLLUTION PREVENTION AND THE CLEANER PRODUCTION APPROACH

7.1 INTRODUCTION

It is inevitable that some waste is generated by all human activities. However, the quantity and the toxicity of the waste released into the environment can be reduced. End-of-pipe waste treatment, which has been the emphasis until quite recently, requires additional input of materials, energy and activities that result in residual waste and hence additional disposal cost. It is therefore a much better strategy to minimise the amount of waste generated at source so that the end-of-pipe treatment cost, as well as the cost of ultimate disposal of residual waste can be reduced. In many cases the waste can be recycled or valuable materials reclaimed for reuse. In general, pollution prevention and cleaner production refer to:

- Reduction of waste generation at source through in-plant control and housekeeping measures;
- Resource recovery and reuse;
- Recycling of water and waste constituents;
- Substitution of toxic materials and processes; and
- Use of cleaner technologies.

7.2 CLEANER PRODUCTION IN THE RAW NATURAL RUBBER INDUSTRY

7.2.1 The Cleaner Production Approach

Since the implementation of regulatory environmental control of the raw natural rubber industry in the late 70's, the industry has endeavored to progressively introduce in-plant control and housekeeping measures to minimise waste generation and the cost of waste management. The specific cleaner production measures that have been successfully introduced into the raw natural rubber industry may be summarised as follows:

- Control of water usage;
- Control of chemical usage;
- Proper handling and storage of process chemicals;
- De-ammoniation of skim latex in latex concentrate factories;
- Proper design and operation of rubber traps;

- Separation of effluent and stormwater drainage systems
- Product substitution;
- Process substitution; and
- Waste utilisation.

7.2.2 Control of Water Usage

Water usage is a critical parameter that influences the quantity of effluent generation. In rubber processing, it has been generally determined that the total quantity of effluent generated by the factory is almost equal to the total quantity of water used in the various process operations. In order to limit the overall size, and therefore the construction and operation cost for the effluent treatment facility, it is necessary to control water usage to the optimum rates that are recommended as follows:

- Water usage in centrifuged latex factories should ordinarily not exceed 20 m^3/tonne DRC of latex processed;
- Water usage in crumb (latex crumb combined with up to 20% lower grade crumb), pale crepe and sheet factories should not exceed about 25 m^3/tonne DRC of rubber processed; and
- Water usage in factories processing lower grade crumb or crepe (i.e. from field coagula materials) should not exceed 35 m^3/tonne DRC of rubber processed.

The measures for controlling water usage in rubber factories include:

- Flow metering of water consumption and effluent discharge;
- Adequate supervision to ensure timely shutting-off of valves, water faucets and water hoses; this may be augmented with the implementation of spring-loaded, self-shutting water hoses and faucets;
- Control of tank overflows by installing appropriate float valves, cut-off switches (level controllers) and proper tank sizing;
- Timely replacement or repair of leaking pipe joints, valves and faucets;
- Training of the factory operators in good housekeeping measures;
- Recycling of wash waters in remiller factories; and
- Use of treated wastewaters for factory washdown and other appropriate uses.

7.2.3 Control of Chemical Usage

Excessive use of process chemicals not only results in wastage, but also leads to difficulties in effluent treatment as these chemicals often end up in the effluent.

Excessive use of ammonia and other preservatives in the field latex leads to higher usage of acids during the subsequent coagulation of the latex. The excess ammonia and/or other preservatives are carried-over into the latex serum which becomes part of the effluent stream. These preservatives or their constituents are pollutants that can adversely affect the water quality of the waste-receiving stream, and therefore need to be removed through treatment to acceptable levels as in the case of ammonia.

In the case of latex concentrate factories, excessive usage of ammonia and TMTD-zinc oxide should be avoided as they will eventually be carried over into the effluent in significant concentrations. Excessive use of ammonia will also lead to higher use of sulphuric acid during the coagulation of skim latex to produce skim rubber. The resulting skim serum, which is a highly polluting component of the final effluent, will also have extremely high residual concentrations of sulphate. High concentrations of sulphate adversely effect the biological treatability of the final effluent.

It is important to control the use of process chemicals in accordance with the recommended technical ratios. As a guideline, the chemical usage for processing of centrifuged latex should be based on the following technical ratios:

- Ammonia usage for preservation of the field latex should be within a range of 20 to 25 kilograms/tonne DRC of field latex; and
- Sulphuric acid usage for coagulation of skim latex should be controlled by performing the coagulation at a pH of not less than 4.0.

In a recent Malaysian survey, the final effluent discharge from latex concentrate factories varied from pH 2.0 to 6.7. The low effluent pH indicates excessive acid usage for coagulation of skim latex. Sulphuric acid is relatively cheap and this leads to indiscriminate use of acid in the factory.

7.2.4 Proper Handling and Storage of Process Chemicals

The proper handling and storage of chemicals, especially in bulk, are important to prevent or minimise their accidental access into effluent and stormwater drains. Proper handling practices are also essential for the occupational safety and health of workers. The general measures to be observed include:

- Bulk storage of toxic and hazardous chemicals should preferably be in a separate room or building, away from processing areas;
- The quantities of chemicals for daily use may be stored in a designated chemical preparation area within easy access of the rubber processing area; and
- The chemical preparation area should have appropriate spill containment barriers, such as periphery drains or low level bunds leading to a collection pit or sump for recovery of the spilled chemicals.

7.2.5 De-ammoniation of Skim Latex in Centrifuged Latex Factories

Centrifuged latex factories should reduce the ammonia content of the skim latex prior to acid coagulation to produce skim rubber; this will reduce the sulphuric acid needed for coagulation (minimum pH of 4.5). Typical de-ammoniation facilities include:

- A de-ammoniation tower as shown in *Figure 14*;
- A short-retention holding tank with continuous agitation; and
- A shallow cascading drain to enhance release of ammonia to the atmosphere.

The ammonia content of the skim latex should be reduced to about 0.1% by weight or less, prior to its coagulation. De-ammoniation of skim latex is particularly essential when the ammonia content exceeds about 0.2% by weight.

7.2.6 Proper Design and Operation of Rubber Traps

A properly designed rubber trap is essential for recovery of particulate rubber and uncoagulated latex, and to reduce the suspended solids load reaching the effluent treatment facility. The Rubber Research Institute of Malaysia has developed a simple, but effective rubber trap design, which has been widely adopted in Malaysia. A schematic diagram of the rubber trap showing the principal design features is presented in *Figure 15*.

The essential design and operational features of the rubber trap are:

- A minimum hydraulic retention time (HRT) of 12 hours for factories processing field latex;
- A minimum hydraulic retention time (HRT) of 6 hours for factories processing only field coagula materials;
- Up-and-down configuration of baffles to ensure adequate mixing of the effluent and effective release of particulate rubber to the effluent surface; and
- Regular removal of the floating rubber particles (daily basis), as well as bottom sediment (once every 2 or 3 months.)

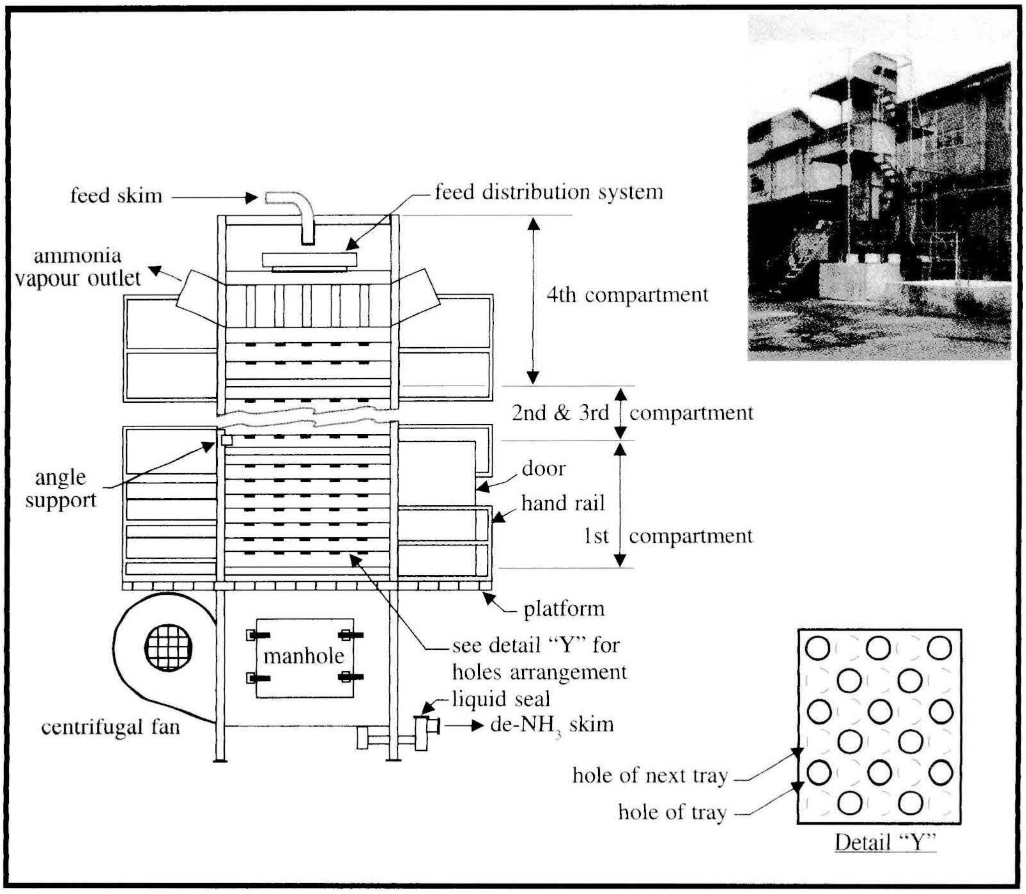


Figure 14: Typical De-ammoniation Tower for De-ammoniation of Skim Latex

7.2.7 Separation of Effluent and Stormwater Drainage Systems

There must be a complete separation of the stormwater and effluent drainage systems. The entry of stormwater into effluent drains is detrimental to the performance of a treatment facility as it may cause sudden and excessive dilution of the effluent in the treatment facility and washout of essential active biomass. This can grossly reduce the effectiveness of the treatment system.

7.2.8 Product Substitution

A product that is inherently hazardous to health or the environment, or which involves a highly polluting production process, is best replaced by a less harmful alternative.

In the production of certain specialty raw rubbers, chemicals such as hydroxyl amine hydrochloride and oxalic acid which are both suspected carcinogens have been replaced by much safer, but equally effective materials.

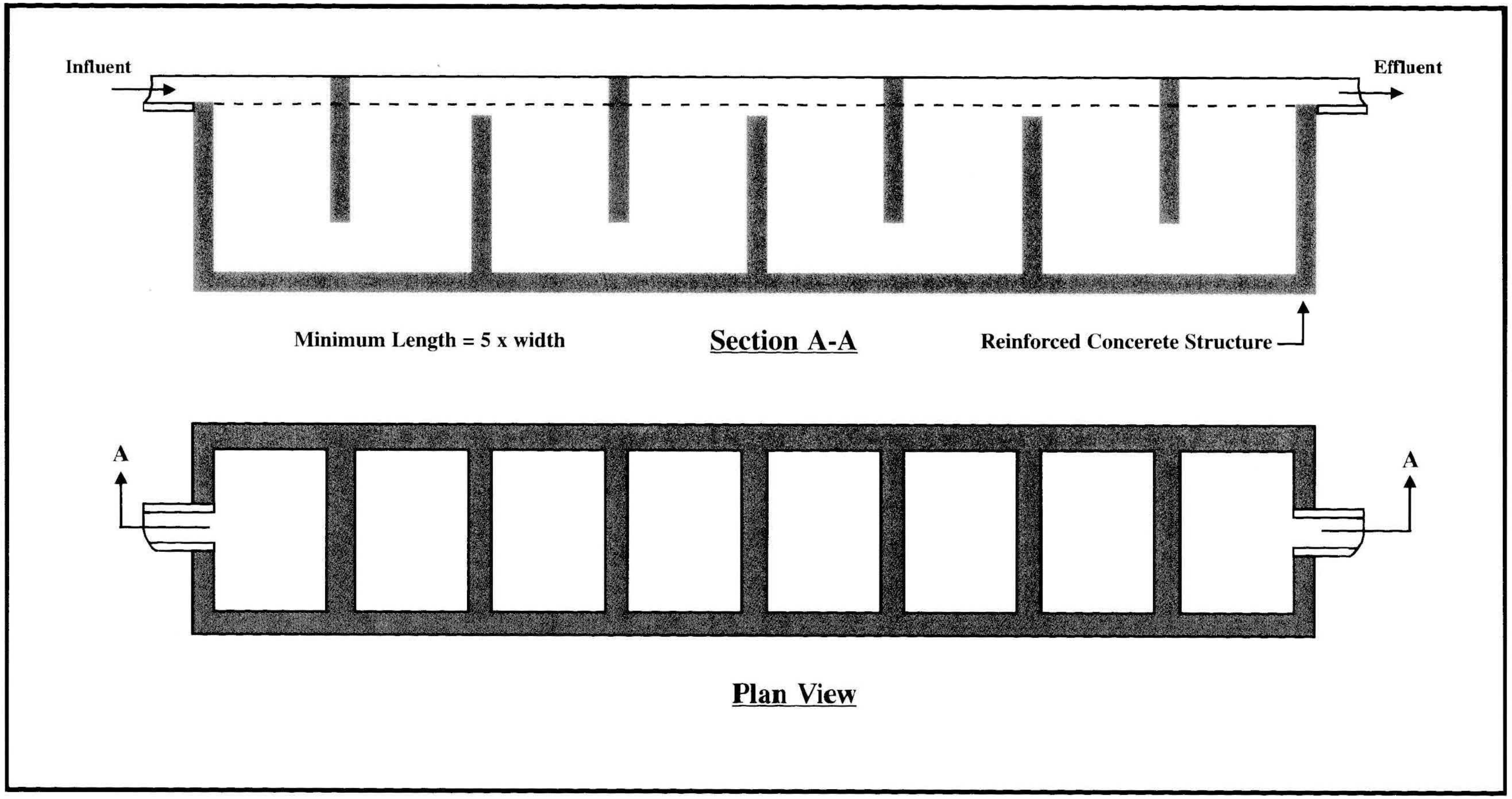


Figure 15 : Principal Design Features of a Typical Rubber Trap

Another good example is the reduction in the use of ammonia to preserve the latex. Field latex has to be treated with high concentration of ammonia to keep the latex preserved without microbial activity. But a high level of ammonia is hazardous to the health of workers who are constantly exposed to it. The level of ammonia is markedly reduced by the addition of safer and cheaper chemicals like zinc oxide and TMTD. A large part of the latex concentrate produced in Malaysia is with a low level of ammonia and very small concentration of zinc oxide and TMTD.

7.2.9 Process Substitution

Process substitution involves replacing a highly polluting or potentially hazardous process with a different process that is safer or less offensive to the environment. A case in point is the elimination of mastication in production of rubber product. Natural rubber contains appreciable amounts of non-rubber components such as protein, lipids, glycerides, etc., which when masticated produce volatile gases that cause offensive odours. Premastication can be eliminated by mixing the materials with viscosity stabilised latex instead of the solid rubber, thus reducing the levels of odour. Eliminating this step also reduces consumption of energy, estimated to be about 270 kW/tonne of rubber.

7.2.10 Waste Utilisation

As previously discussed rubber factory effluents contain substantial amount of plant nutrients, particularly nitrogen and potassium. The fertiliser-equivalent of the effluent produced by a 20-Tonne/Day Latex Concentrate Factory, expressed in terms of the content of essential elements such as nitrogen (N), phosphorus (P), potassium (K) and magnesium (Mg) is as follows:

- N : 203,500 kg;
- P : 13,000 kg;
- K : 48,800 kg; and
- Mg : 13,200 kg.

Similar fertiliser-equivalent information for a 20-Tonne/day Crumb Rubber Factory is as follows:

- N : 63,900 kg;
- P : 7,800 kg;
- K : 10,900 kg; and
- Mg : 7,200 kg.

Rubber factory effluents have shown no adverse effects on the receiving soil. Their application to certain crops has been shown to increase production yields by as much as 20%.

7.2.11 ISO 9000 and ISO 14000

The raw natural rubber industry should strive to accomplish certification under ISO 9000 and ISO 14000, within a reasonable time-frame, in order to enhance product quality while meeting the desired environmental performance objectives.

7.3 RELATIVE COSTS OF IMPLEMENTING CLEANER PRODUCTION

Although, there are obvious benefits in implementing cleaner production which include optimum use of resources, reduced wastage and waste generation, reduced production and waste management costs, etc., it must be realised that cleaner production does entail some cost investments. Some elements of cleaner production are relatively low cost, while others may involve high capital investments. Nonetheless, aside from considering the benefits that accrue, one should also look at the pay-back period for investments in the course of decision-making.

Figure 16 is a graphical representation of the relative costs of various elements of cleaner production. It is seen that elements such as rational use of resources, housekeeping and recycling may not involve high costs, while equipment and process modifications do involve high investment costs. Even if one is to adopt the cleaner production elements involving significant costs, the assessed benefits and savings which contribute to a reasonable pay-back period on investments should be able to justify the investments involved.

In order to identify the opportunities for cleaner production and waste minimisation, it is necessary to conduct a comprehensive environmental audit of the processes by suitably qualified people. This can be done by the company's own personnel if they are appropriately trained to do so. If there is no internal lead auditor available, then the facility operator may be encouraged to seek the assistance of an external lead auditor to work along with the company's personnel as a team.

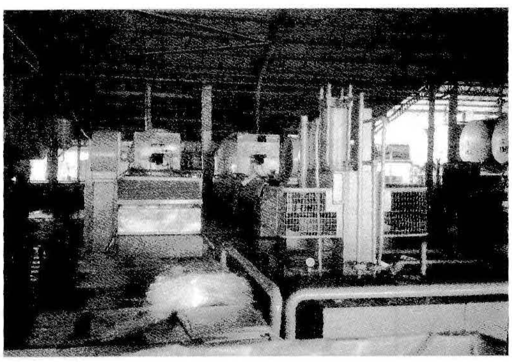
As previously indicated in this and other sections of the Handbook, there is certainly room for the application of pollution prevention and cleaner production in the raw natural rubber industry; the pay-back periods on investments are ordinarily reasonable and invariably favour implementation.

7.4 ADDRESSING FACTORY CONSTRAINTS

It is a common perception that factories are faced with various constraints in wanting to practise pollution control. In view of the significant production-cost savings and other potential benefits that can accrue from introducing the cleaner production measures described in the foregoing, it is apparent that the factory constraints often cited are the consequence of a lack of knowledge of these available measures. Many of the perceived factory constraints can be addressed using the arguments presented in *Table 14*.

Table 14 : Addressing Factory Constraints

Factory Constraints	Counter Arguments
No profit in pollution control	Profit margin can be expected to increase due to reduced costs on consumption of water and chemicals, and fee for disposal of hazardous wastes
	Market potential may be enhanced due to improved product quality
Space limitation for installing CP measures and/or wastewater treatment plants	In general, improved cleaning and maintenance procedures do not require separate dedicated space
High cost of land and factory space for the treatment equipment	In-plant measures require limited space, e.g. control of water and chemical usage, and recycling of process water
	Highly mechanised treatment systems require less space, but involve higher investment cost
High treatment equipment cost and recurrent operating cost of treatment	The investment cost can be justified by the cost-savings from reduced production costs
Poor pay-back period	Prices of water and electricity can be expected to increase in the future and thereby the pay-back time may be more attractive - normally can be brought down to below 2 years
Difficulty to access financing	Banks responding to the government's prompting are giving end-financing of up to 90%. Many incentive schemes are available to SMIs
Lack of access to technology	Information guidelines are available from DOE, RRIM and private consultants
Inadequate waste management skills	Available from RRIM, SIRIM and CP consultants
	Some CP measures do not require specific waste management skills, but only technical skills to do proper maintenance and modifications of process lines

⬆ Potential for Cleaner Production ⬆

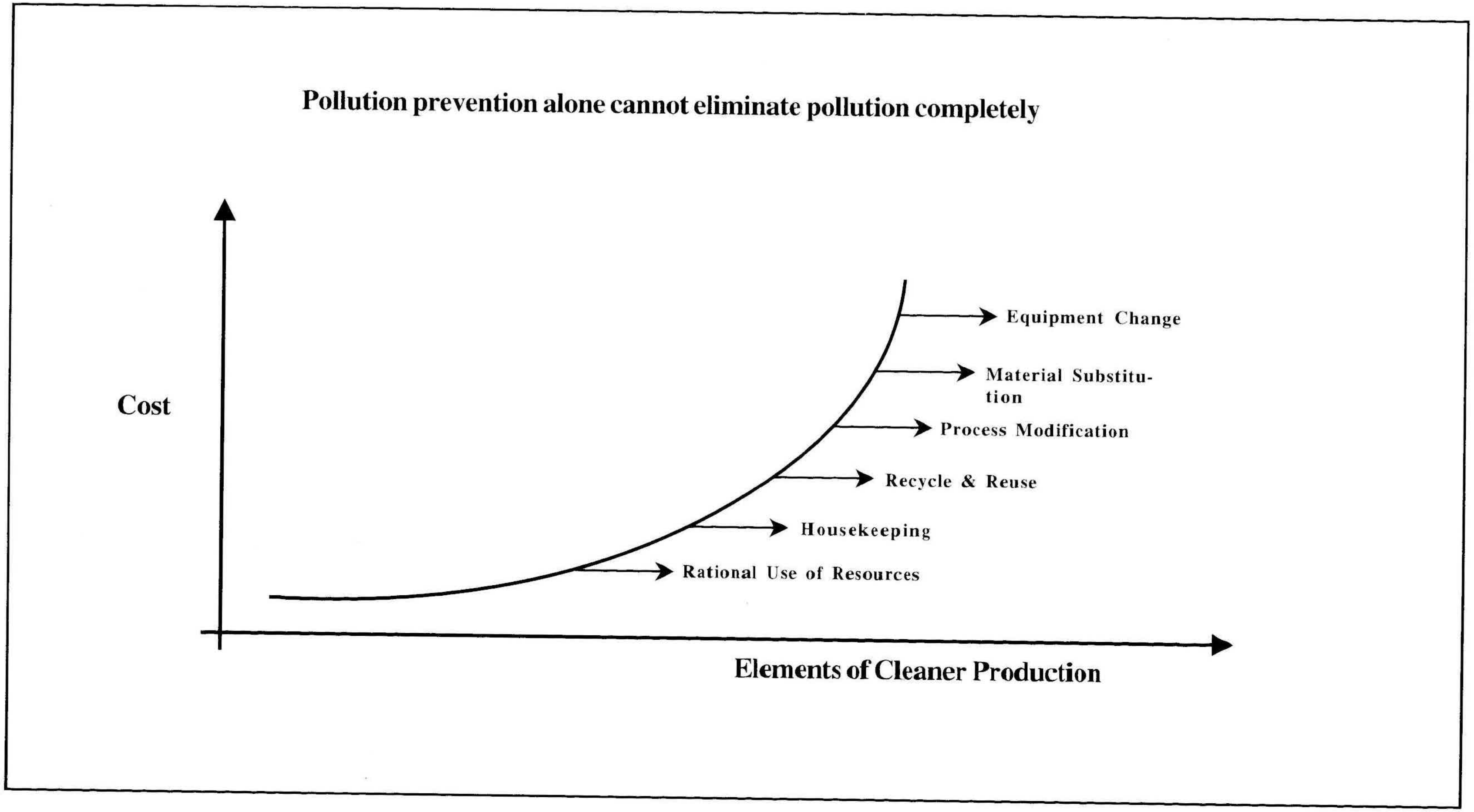


Figure 16 : Relative Costs of Various Elements of Cleaner Production

8.0 INSPECTION FOCUS

8.1 INTRODUCTION

This is a very important Section of the Handbook as it covers the necessary inputs to guide the DOE Officers in performing the inspections as effectively and efficiently as possible.

A manual on Practical Enforcement dealing with the general procedures for pre-inspection preparation, comprehensive inspection, and follow-up of inspection visits has been developed separately to assist DOE Officers in carrying-out their enforcement activities.

This Section on Inspection Focus is industry-specific for factories processing raw natural rubber and serves as a supplement to the above mentioned Practical Enforcement Manual.

The main purpose of this Section on Inspection Focus is to provide guidance on:

- Essential background information that must be obtained before the inspection;
- Preparation of inspection checklists that enlist essential inspection issues;
- Preparation of recording worksheets to be used during the inspection; and
- Preparation for the closing meeting with the factory management.

8.2 KEY ENVIRONMENTAL ISSUES

The environmental issues related to raw natural rubber processing are generally less consequential than those of other industries such as that of the metal finishing industry, or chemical industries. The raw natural rubber industry essentially processes a natural raw material, namely rubber latex and field coagula materials, and uses process chemicals that are not considered highly toxic or hazardous under normal conditions of use. The latex preservatives and process chemicals used are also relatively safe to handle.

The only exception is the concentrated ammonia used in latex concentrate factories which causes eye-irritation and asphyxiation; however, even this does not present a serious problem as the factories are usually designed with processing areas that are relatively open to ensure good natural ventilation. Where necessary, fans are also placed at strategic locations to disperse fugitive emissions and maintain an acceptable working environment.

As a result, the only key environmental issues in raw natural rubber processing relate to:

- Inadequate housekeeping in some factories;
- Highly polluting effluents due to high organic content, ammonia and other nitrogenous compounds;
- Objectionable odours; and
- Air emissions.

8.3 INSPECTION OBJECTIVES

The main objectives of a 'multi-media' environment-based industrial inspection are:

- To monitor and ensure compliance with the regulatory requirements of environmental legislation;
- To observe the conditions of housekeeping and assess the potential for cleaner production;
- To identify the potential areas for improved waste management and pollution control;
- To identify obvious areas for improved waste treatment and waste utilisation, if any;
- To investigate sources of public or any other type of complaints;
- To draw the attention of the management to the possible environmental performance improvements and cleaner production possibilities; and
- To demonstrate DOE's commitment to enhance and protect the environment and ensure fulfillment of the EQA.

8.4 INSPECTION PROCEDURE AND STEPS

With the above objectives in mind, the main steps associated with a rubber factory inspection visit are:

- Pre-inspection planning and gathering of factory background information;
- Factory inspection;
- Closing meeting with the factory management; and
- Reporting and follow-up action.

8.4.1 Pre-inspection Planning and Information Review

It is preferable to conduct the review of the relevant documents before the site inspection. In general, the Inspector should review the available documents to gain a better understanding of the key issues involved.

(a) Identification, Location and Environmental Status

The DOE Officers would need to familiarise themselves with, among other things, the following background information on the factory to be visited:

- Factory identification, location and immediate surrounding landuse with the aid of a map;
- Terms and conditions in the Schedule of Compliance attached to the DOE "prescribed premises" licence issued under Section 18 of the EQA;
- Status of effluent discharge for at least two preceding quarters based on the Quarterly Return Forms from the factory;
- Findings of previous inspection visits and recommendations, if any.

(b) Factory Production Process

This will include, among other things, the following:

- The type of rubber factory:
    - Whether it is a latex concentrate, block rubber, sheet, crepe, mixed production, or any other type of factory.
- The production capacity and rate for the various products and by-products, if any:
    - If it is a latex concentrate factory the main product is liquid latex concentrate, while the skim rubber is a by-product.
- The raw materials and quantities used in the factory:
    - Field latex in latex concentrate factories; and in the case of block rubber factory the raw materials may be a combination of field latex and cup lumps, scrap rubber, tree lace, pre-coagulated lumps, etc.
- Process chemicals and quantities used in the factory:
    - The number of chemicals used in the rubber factory is limited; mainly, formic or acetic acid in crumb rubber factories; and dilute sulphuric acid, ammonia and TMTD-zinc oxide in latex concentrate factories.

- Process flow chart:

    - This is highly essential, as it gives all the inputs and outputs, including the effluent discharges. This and the other information referred to above will help the inspector to assess the mass balance himself, if the factory has not already worked-out one for him.

(c) Waste Management Systems

- Drawings of the drainage system of the factory:

    - This is essential to make sure that the factory has separate drainage systems for the storm water management. If the factory has not got a separate drainage system for storm water, it is likely that this storm water will join the effluent discharge and thus reduce the HRT of the treatment system;

- Water-supply and effluent discharge:

    - Information on the water-supply, including facilities for metering, and the information on the type of waste-receiving watercourse and their downstream beneficial uses;

- Engineering drawings and plans of the effluent treatment and other waste management systems:

    - These would be useful to verify the principal design features of the systems and any observed deficiencies needing rectification;

- Air emissions:

    - Information is needed on whether the factory operates any air emission control system to reduce the odour problem and, if any, analytical data to establish the efficiency of the system.

Much of the needed information may be available in the industry source files maintained by the DOE, particularly in the quarterly reports that the factory submits to the DOE. If the relevant information is not available in the files, then it should be obtained through the usual mechanisms employed by the DOE.

8.4.2 Factory Inspection

While the factory inspection primarily aims at compliance-monitoring, waste auditing of the facility should also be performed. The good thing about the rubber factory inspection is that the process is not complicated, highly toxic chemicals are not used in the process line and the factory operation does not generate any significantly hazardous or toxic wastes. The other aspect is that the size of the facility operation is such that there are hardly any small operators. Even the smallholder's latex, cup-lump or other materials are co-operatively collected and processed in centralised factories, wherein qualified and experienced operators and supervisors are available to carry-out the various activities.

The only exception are the group processing centres (GPCs) where a small number of small-holders come to coagulate the latex and process it into sheets and take the sheets back to their houses for drying. The GPC operations are so small that it seldom creates any serious environmental problems. Thus, the rubber factory inspection is a relatively simple activity and involves the following:

- Opening meeting
- Document review
- Inspection of the factory premises
- Use of inspection checklists and inspection worksheets
- Effluent sampling and analysis

(a) Opening Meeting

An opening meeting is an important element of the inspection visit. The meeting should be held with the factory management to explain the purpose of the visit and how the inspection will be carried out. In some cases, it may address specific concerns that the DOE Officers may have (e.g. as a result of a complaint the DOE may have received), regarding certain adverse environmental impacts of the factory's operation.

(b) Interview and Document Review

The interview phase of the inspection visit can be an important aspect of the process as the DOE Officer can obtain details not found in records, as well as to familiarise with the factory operation. The success of the interviews will depend on the inter-personal skill of the DOE Officer as well as his technical knowledge.

The interview should be such as to convey the message to the facility management and operators that the DOE Officer has not come as a prosecutor or a judge, but to jointly review the whole operation from an environmental perspective, and to provide guidance to the management on how to improve the operation to achieve greater success in managing the environmental aspects and issues and facilitate compliance with the conditions of licence.

The findings of the interviews should be verified through record checks, site inspection and further interviews, if necessary. Such a step will help the DOE Officer avoid drawing conclusions of certain matters based on mere hearsay.

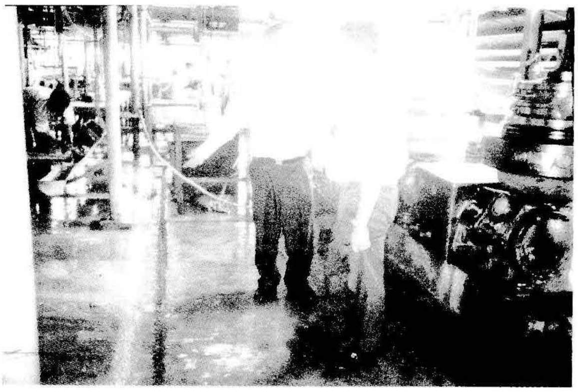
During the interviews, documents to be reviewed should include:

- Quarterly returns earlier submitted to the DOE;
- Records of monthly data which were used in preparing the quarterly returns including production data, water consumption, effluent discharge data, etc.;
- Relevant analytical data, i.e. the effluent analysis and air emission analysis;
- Records of complaints, if any, and how the factory management resolved the issues involved; and
- Process flow and the treatment plant diagrams, if not already done so as part of the pre-inspection activities.

(c) Inspection of Premises

This is the most important aspect of the factory inspection. There are many ways of conducting a factory site-inspection. But the most commonly practised method is the general planned walk-through inspection. The DOE Officer examines everything from the raw material reception area to the dispatch of finished products, using the process flow chart obtained earlier. The DOE Officer should:

- Evaluate housekeeping and in-plant process control.
- Examine the process line, and where possible:
    - inspect all areas, including remote areas;
    - observe operations during times of effluent discharge; and
    - observe sampling and monitoring procedures.



Inpection of premises is the most important aspect of factory inspection.

The process line inspection is mainly to ensure that the effluent generation and discharge points are the same as those shown in the process flow diagram.

Inspect the treatment plant, and observe for the following:

- type of treatment system;
- adequacy of basic design;
- status of operation and maintenance;
- regularity of sludge removal and sludge return (if any);
- status of compliance with effluent discharge standards;
- any special features of improved design or operation.

The DOE Officer should review the pre-treatment and treatment plant operations by visiting the plants. In some cases, the treatment plants could be far away from the factory, depending on the availability of suitable land for the treatment plant. In some cases, the factory effluent may be utilised for land application in which case the DOE Officer should visit the field to check on the system to see that the operation complies with the general DOE requirements.

(d) Use of Inspection Checklists and Worksheets

To carry-out the inspection of the factory premises effectively, the use of checklists are essential for providing guidance, and worksheets to systematically record the observation and findings.

For this purpose, two checklists and two worksheets have been developed.

These are:

- Checklist on status of good housekeeping and cleaner production;
- Checklist on status of regulatory compliance;
- Recording worksheet on status of good housekeeping and cleaner production; and
- Recording worksheet on status of regulatory compliance.

(i) *Inspection Checklist on Status of Good Housekeeping and Cleaner Production:*

An inspection checklist on good housekeeping is highly necessary to provide guidance and a reminder on what to look for in this area. A comprehensive list is provided in the attached *Appendix 3*. It highlights the production flow sequence and inspection items for each station, including the cleaner production opportunities.

(ii) *Recording Worksheet on Status of Good Housekeeping and Cleaner Production:*

The detailed worksheet is provided in *Appendix 4*. It covers the inspection area, observations, evidences taken and findings based on three(3) qualifiers – satisfactory, unsatisfactory and further investigation.

(iii) *Checklist on Status of Regulatory Compliance:*

This checklist is attached as *Appendix 5* and it contains the final discharge status, regulatory requirements and inspection focus.

(iv) *Recording Worksheet on Status of Regulatory Compliance:*

This recording worksheet is attached as *Appendix 6* and is for documenting information and data on the status of the final effluent discharge, inspection focus, evidences and findings.

(e) Sampling and Analysis of Rubber Effluents

The main characteristics of rubber effluents are determined by the following parameters:

- pH
- Total Solids (TS)
- Suspended Solids (SS)

- Chemical Oxygen Demand (COD)
- Biochemical Oxygen Demand (BOD; 3-Day, 30°C)
- Total Nitrogen (TN)
- Ammoniacal Nitrogen (AN)

(i) *Sampling of Rubber Factory Effluents:*

The basic objectives of representative effluent sampling are:

- To obtain a sample whose concentrations of determinants are representative of those in the effluent at the time of sampling; and
- To ensure that the concentrations of the determinants in the samples do not change between sampling and laboratory-based analysis.

If these objectives are not achieved, the analytical results may be partially or completely invalid for their intended purposes.

(ii) *Sampling Apparatus:*

The type of sampling equipment and apparatus required to obtain representative effluent samples depends on the sampling technique to be employed. Representative sampling techniques include:

- Flow-proportional sampling and compositing of effluent; and
- Time-composite sampling.

Sampling may be performed manually, semi-manually or with the use of automatic sampling equipment consisting of flow monitors and flow proportional samplers. Time-composite samples may be taken manually or with the use of automatic samplers. The apparatus used for sampling may therefore range from simple hand-operated vessels, such as beakers and buckets, to sophisticated automatic devices which take constant volume samples at specified time intervals or, which take sample volumes proportional to the effluent flow rate.

Sample containers should be of material that will not contaminate the sample. Chemical- resistant glass and polyethylene are suitable materials for containers.

Coloured bottles are preferred for BOD test samples as they limit light penetration and consequently inhibit microbial activity which can otherwise change the effluent characteristics prior to testing.

All sample containers should be provided with stoppers, caps or plugs of suitable material that can resist the attack by the vessel's contents. Containers should be carefully cleaned before use to remove all extraneous surface dirt. Before filling, the sample container should be rinsed out two or three times with the effluent to be sampled.

(iii) *Sampling Techniques:*

The chemical analysis is generally intended to reveal the composition of the effluent at the time of sampling. As the composition of effluent varies with time, it is recommended thata time-composite sample be taken for chemical analysis in order to represent an average condition of the total effluent discharged for the day of production.

In order to get a time-composite sample, a minimum of six individual samples should be collected at regular time intervals over a minimum period of one 8-hour shift during the operation of the factory. The individual samples taken should be refrigerated immediately to 4°C and kept at this temperature during the compositing period. At the end of the compositing period, the composite sample should be mixed thoroughly and a suitably-sized portion taken for performance of the chemical analysis. Usually a 1-litre portion of the composite sample is sufficient for a complete effluent analysis.

The sampling point for the factory effluent should be carefully chosen to ensure that the total combined factory effluent which is finally discharged from the factory premises is being sampled. This is the point at which the effluent emerges from the premises or treatment plant or the point prior to the discharge of effluent into a watercourse or any soil or surface of land. The sampling point must be acceptable to the DOE. The sampling point(s) shall be as approved by the DOE.

A record should be made of every sample collected and each sample should be identified by a proper label. The record should contain sufficient information to provide positive identification of the sample as well as the name of the sample collector, the date, time and exact sample location, the weather condition and any other data which may help in the interpretation of the analytical results.

(iv) *Sample Preservation:*

Because of likely changes which take place on standing, it is desirable that analyses be made as soon as possible after collection of samples. However, this is not always feasible as factories are usually located far from effluent laboratories. In order to prevent, or at least to minimise the changes in their properties, the effluent samples should be preserved according to the techniques given in *Table 15*. However, rubber effluent samples are usually preserved by refrigeration at 4°C, or by adding acid to bring down the pH of the sample to about 2.0 to minimise microbial activities of the sample.

Table15: Parameter-Based Preservation Techniques for Effluent Samples

Parameter	Preservation Technique	Maximum Holding Period
Acidity	Refrigeration at 4 °C	24 hours
Alkalinity	Refrigeration at 4 °C	24 hours
BOD	Refrigeration at 4 °C	6 hours
COD	Add 2 ml H_2SO_4/litre sample	7 days
Solids	None available	7 days
Total Kjeldahl Nitrogen	Add 40 mg $HgCl_2$/litre sample at 40 °C	Unstable
Ammoniacal Nitrogen	Add 40 mg $HgCl_2$/litre sample at 40 °C	7 days
Nitrate	Add 40 mg $HgCl_2$/litre sample at 40 °C	7 days
Nitrite	Add 40 mg $HgCl_2$/litre sample at 40 °C	7 days
Sulphate	Refrigeration at 4 °C	7 days
Sulphide	Add 2 ml Zinc acetate 1N/litre sample	7 days
Phosphate	Add 40 mg $HgCl_2$/litre sample at 4 °C	7 days
Metals	Add 5 ml HNO_3/litre sample	6 months

8.4.3 Closing Meeting

The closing meeting should be held with the factory management following the inspection of the factory premises and the treatment plant, and after the DOE Officer has had time to note the main points for presentation and discussion.

The closing meeting should aim at accomplishing the following:

- Sum up the observations and findings;
- Ensure a common understanding on the findings to avoid any misunderstanding;
- Enhance the environmental awareness of the factory personnel;
- Explain and issue compounds, if necessary;

- Inform the management of any needed follow-up action in response to areas of non-compliance;
- Arrange for a follow-up visit, if necessary;
- Discuss possible improvements of the factory's good housekeeping, treatment system, etc.;
- Clarify and confirm any agreement recorded;and
- Discuss any other matters of mutual interest or concern.

8.4.4 Reporting and Follow-up Action

The main purposes of reporting and follow-up action are to ensure that:

- All information and data collected are well-documented, registered, filed and used appropriately;
- Suggestions on further actions are taken to enhance compliance;
- The facility operator and the management are aware of the requirements for any needed improvement of their environmental performance; and
- DOE's general commitment to enforcement of the EQA is well demonstrated.

Further information on reporting and follow-up action can be found in the *Practical Enforcement Manual*.

Greening of Effluent Treatment System

APPENDIX 1

ENVIRONMENTAL QUALITY (CLEAN AIR) REGULATIONS 1978

AIR EMISSION STANDARDS

	SUBSTANCES EMITTED	STANDARDS		
1.	Solid particle concentration in the heating of metals	Standard A : 0.3 gm/Nm^3 Standard B : 0.25 gm/Nm^3 Standard C : 0.2 gm/Nm^3		
2.	Solid particle concentration in other operations	Standard A : 0.6 gm/Nm^3 Standard B : 0.5 gm/Nm^3 Standard C : 0.4 gm/Nm^3		
3.	Metals and metallic compounds:	Std. A gm/Nm3	Std. B gm/Nm3	Std. C gm/Nm3
	Mercury	0.02	0.01	0.01
	Cadmium	0.025	0.015	0.015
	Lead	0.04	0.025	0.025
	Antimony	0.04	0.025	0.025
	Arsenic	0.04	0.025	0.025
	Zinc	0.15	0.1	0.1
	Copper	0.15	0.1	0.1

	Substances Emitted	Sources of Emission	Standards
4.	Acid Gases	Manufacture of sulphuric acid	1. Equivalent of: Standard A : 7.5 Standard B : 6.0 Standard C : 3.5 gram of sulphur trioxide/Nm^3 of effluent gas 2. Effluent gas free from persistent mist
5.	Sulphuric acid mist or sulphur trioxide or both	Any source other than combustion process and plant for manufacture of sulphuric acid as in (a) above	1. Equivalent of : Standard A : 0.3 Standard B : 0.25 Standard C : 0.2 trioxide/Nm^3 of effluent gas 2. Effluent gas free from persistent mist
6.	Chlorine gas	Any source	Standard A : 0.3 Standard B : 0.025 Standard C : 0.2 gram of hydrogen chloride/Nm^3

	Substances Emitted	Sources of Emission	Standards		
(d)	Hydrogen chloride	Any source	Standard A : 0.6 Standard B : 0.5 Standard C : 0.4 gram of hydrogen chloride/Nm^3		
(e)	Fluorine, hydrofluoric acid or inorganic fluorine compound	Manufacture of aluminium from alumina	Equivalent of: Standard C : 0.02 gram of hydrofluoric acid/Nm^3 of effluent gas		
(f)	Fluorine, hydrofluoric acid or inorganic fluorine compound	Any source other than manufacture of aluminium from alumina as in (e) above	Equivalent of: Standard A : 0.15 Standard B: 0.125 Standard C : 0.100 gram of hyrofluoric acid//Nm^3 of effluent gas		
(g)	Hydrogen sulphide	Any source	Standard A : 6.25 Standard B : 5.00 Standard C : 5.00 parts per million volume for volume		
(h)	Oxides of nitrogen	Manufacture of nitric acid	Equivalent of: Standard A : 4.60 Standard B : 4.60 Standard C : 1.7 and effluent gas substantially colourless gram of sulphur trioxide/Nm^3		
(i)	Oxides of nitrogen	Any source other than combustion process and manufacture of nitric acid	Standard A : 3.0 Standard B : 2.5 Standard C : 2.0 gram of sulphur trioxide/Nm^3		
5.	Dust and solid particles		Std. A gm/Nm^3	Std. B gm/Nm^3	Std. C gm/Nm^3
	ASPHALT CONCRETE PLANT Stationary Plant Mobile Plant		0.5 0.7	0.4 0.7	0.3 0.4
	PORTLAND CEMENT PLANT Kiln Clinker, cooler finish, grinding and others		0.4 0.4	0.2 0.2	0.2 0.1
6.	Asbestos and free silica		0.4	0.2	0.12

APPENDIX 2

ENVIRONMENTAL QUALITY (CLEAN AIR) REGULATIONS 1978 THIRD SCHEDULE

NOXIOUS AND OFFENSIVE SUBSTANCES
[Regulation 32]

Muriatic acid

Sulphuric acid and sulphuric anhydride

Sulphurous acid and sulphuruos anhydride

Nitric acid and acid forming ozides of nitrogen

Chlorine and its acid compounds

Bromine and its acid compounds

Iodine and its acid compounds

Fluorine and its compounds

Arsenic and its compounds

Ammonia and its compounds

Cyanogen and its compounds

Pyridine

Bisulphide of carbon

Chloride of sulphur

Acetylene

Sulphuretted hydrogen

Volatile organic sulphur compounds

Fumes from benzene works

Fumes from cement works

Fumes from fish manure works

Fumes from pesticides formulating and manufacturing works

Fumes from asbestos product works

Fumes from tar works

Fumes from paraffin oil works

Fumes containing copper, lead, antimony, arsenic, mercury, zinc, aluminium, iron, silicon, calcium or their compounds

Smoke, grit and dust

Fumes containing uranium, beryllium, cadmium, selenium, sodium, potassium or their compounds

Carbon monoxide

Acetic anhydride and acetic acid

Aldehydes

Amines

Fumes containing chromium, magnesium, manganese, molybdenum, phosphorus, titanium, tungsten, vanadium or their compounds

Maleic anhydride, maleic acid and fumaric acid

Products containing hydrogen from the partial oxidation of hydrocarbons

Phthalic anhydride and phthalic acid

Picolines

Fumes from petroleum works

Acrylates

Di-isocyanates

Fumes containing chlorine or its compounds

APPENDIX 3

Inspection Checklist on Status of Good Housekeeping and Cleaner Production

No.	Production Flow Sequence	Model Situation	Inspection Focus
1.	Raw materials reception areasfor field latex and field coagula materials (cuplumps, tree lace, earth scrap, etc.)	• Areas clean, tidy and free of spillages of latex and field coagula materials.	<u>**Look-out for:**</u> • Spillages of field latex • Careless parking of raw material transport vehicles • Tankers washings after discharging of latex directed to effluent drainage system <u>**Cleaner Production Opportunities:**</u> • Cleaning of reception areas after unloading raw material with pressure hose. • No running valves, water taps, or hoses when not in use.

No.	Production Flow Sequence	Model Situation	Inspection Focus
2.	Storage of raw materials, including field latex and field coagula materials, and chemicals	• Clean and tidy area • Leak-proof containers for latex storage • Leak-proof containers for chemical storage • Provision for spillage containment and material recovery • Proper storage and handling of cuplump-type materials using first come/first use system • Free movement of forklifts.	**<u>Look-out for:</u>** • Spillage of latex • Excessive use of ammonia to preserve latex • Odour from cup lump storage area • Mixing of dry cup lump and wet latex coagulant – provide separate areas • Improper containment areas for spillages **<u>Cleaner Production Opportunities:</u>** • Proper storage of field latex • Covered storage of cup lump and field coagula materials • Floor of storage sloping towards a drain and sump to collect serum • Clear labeling of cup lump materials with the date of arrival.

No.	Production Flow Sequence	Model Situation	Inspection Focus
3.	Control of water usage	• Latex Concentrate Factory : 20 m^3/tonne DRC processes • Crumb Rubber Factory : 25 m^3/tonne DRC processed • Sheet Rubber Factory : 25 m^3/tonne DRC processes • Rubber Remilling Factory : 35 m^3/tonne DRC	**Look out for:** • Water faucets and hoses kept open when not in use • Leaking pipe joints, valves and faucets **Cleaner Production Opportunities:** • Flow metering of water consumption and effluent discharge • Installing float valves/ cut-off switch for water tanks. • Training of factory operators in good housekeeping
4.	Control of chemical usage	• NH_3 for field latex not to exceed 20-25 kg /tonne DRC • Skim latex coagulation pH to be not less than 4.5	**Look-out for:** • Excessive use of NH_3 and other preservative in the field latex • Excessive use of acid in field latex and skim latex coagulation; sometimes these coagulations take place at unnecessarily low pH levels **Cleaner Production Opportunities:** • Apply strict control over the use of preservatives in latex. • Supervise acid use and pH of coagulation.

No.	Production Flow Sequence	Model Situation	Inspection Focus
5.	Deammoniation of skim latex in latex concentrate factories	• Availability of deammoniation facilities such as deammoniation tower, cascading system etc.	**Look-out for:** • Excessive NH_3 in the skim latex before coagulation • Excessive usage of sulphuric acid or spent acid to coagulate skim latex. **Cleaner Production Opportunities:** • Encourage production of low ammonia latex • Install efficient deammoniation system (ammonia level in skim to around 0.1% w/w) , if necessary try re-circulation through the deammoniation system.

No.	Production Flow Sequence	Model Situation	Inspection Focus
6.	Handling and storage of chemicals	• Storage of chemicals away from processing areas in a special room	**Look-out for:** • Possible access of chemicals into effluent/stormwater drains. • Stored chemicals are to be under lock and key • Storage of bulk chemicals in the process area **Cleaner Production Opportunities:** • Provide adequate training to workers on handling and storage of chemicals • Chemicals for daily use may be stored in a designated area, within easy reach of the processing area, but secure with appropriate spill containment barriers

No.	Production Flow Sequence	Model Situation	Inspection Focus
7.	Operation of rubber trap	• A properly designed rubber trap with at least 12 hrs HRT • Recovery of rubber on a regular basis	**Look-out for:** • Poorly designed rubber trap • Poorly operated rubber trap which is an indication of improper coagulation of latex • Milky serum in rubber trap **Cleaner Production Opportunities:** • A good rubber trap and its operation is essential . The capital cost can be recovered in less than 12 months. It is income-generating and enhances effluent treatment
8.	Storm water and effluent drainage systems	• The two drainage systems working independently • Both systems at a satisfactory level.	**Look-out for:** • Mixed drainage system • Maintenance of this drainage system • Clogging of the drains **Cleaner Production Opportunities:** • Maintenance of a good drainage system reflects good housekeeping being practised in the factory.

No.	Production Flow Sequence	Model Situation	Inspection Focus
9.	Acid usage to coagulate field and skim latex (skim latex is only re: LC factories)	• Use of minimum acid in latex coagulation particularly for skim latex	**<u>Look-out for:</u>** • Corrosion of the factory floor and processing machinery • The pH of coagulation – it must not be less than 4.5 for field latex and 4.0 for skim latex • Supervision of operators by a supervisor during addition of acid. • Excessive malodour coming from anaerobic treatment ponds – an indication of excessive use of acid. **<u>Cleaner Production Opportunities:</u>** • Avoiding the use of excessive acid is good in many ways. • Less cost • The biological treatment system are not inhibited • Less malodour from the anaerobic treatment ponds.

No.	Production Flow Sequence	Model Situation	Inspection Focus
10.	Stabilisation (compositing) of effluent	• The provision for a stabilisation (compositing) tank/pond with 1-day HRT, after the rubber trap is ideal.	**Look-out for:** • Absence of a stabilisation (compositing) pond/tank due to lack of space or cost-saving intentions. • Minimum HRT of 12 hours and preferably 24 hours • Rubber build-up in stablisation (compositing) pond is an indication of poor operation of the coagulation system and/or rubber trap. **Cleaner Production Opportunities:** • A stabilisation (compositing) pond/tank helps to prevent the shock-loading of the treatment system. • Under emergency situation, it provides temporary storage facility. • If liming is necessary to improve the pH of effluent before the treatment, it provides a homogeneous input.

No.	Production Flow Sequence	Model Situation	Inspection Focus
11.	Disposal of solid wastes as follows: - Sludge from rubber trap and sumps - Sludge from latex reception area - Sludge from the storage tanks - Coagulated materials recovered from the drains - Packing materials - Melted rubber recovered from the dryer	• Provision for the proper interim storage and disposal of solid wastes generated in the factory	**Look-out for:** • Sludge in the raw material reception areas and interim waste storage areas finding access into the drains. • Sludge and other materials recovered from the drain but left beside the drain, which are likely to fall back into the drain. • In block rubber factory packing materials being thrown around • Melted rubber recovered from the dryer accumulates beside the dryer. • Sludge from the rubber trap not being disposed properly **Cleaner Production Opportunities:** • Waste containing recovered rubber must be recycled into the processing system • Make provision for the satisfactory disposal of sludge materials from all parts of the factory • In block rubber factory a system must be developed for the disposal of packing materials, especially damaged crates • Open burning is prohibited. • If malodour from the treatment plant is a problem, use an enclosed anaerobic system or use an aerating system.

APPENDIX 4

Recording Worksheet on Status of Good Housekeeping And Cleaner Production

Name of Factory : ______________________________

Address : ______________________________

____

____

Date of Inspection : ______________________________

Time of Inspection : ______________________________

Legend:

Evidence
- Photos (P)
- Factory Records (FR)
- Samples (S)

Findings
- S : Satisfactory
- US : Unsatisfactory
- F : Further Investigation

Please tick [✔] where applicable.

Inspection Area	Observation	Evidence Taken	Findings
1. Raw material reception areas: field latex, field coagula materials, etc.		☐ P ☐ FR	☐ S ☐ US ☐ F
2. Storage of raw materials and chemicals: liquid, solid		☐ P ☐ FR	☐ S ☐ US ☐ F
3. Control of water usage		☐ P ☐ FR	☐ S ☐ US ☐ F
4. Control of chemical usage		☐ P ☐ FR	☐ S ☐ US ☐ F
5. Deammoniation of skim latex		☐ P ☐ FR ☐ S	☐ S ☐ US ☐ F
6. Handling and storage of chemicals		☐ P ☐ FR	☐ S ☐ US ☐ F

Inspection Area	Observation	Evidence Taken	Findings
7. Operation of rubber trap		□ P □ FR □ S	□ S □ US □ F
8. Effluent and stormwater drainage system		□ P □ FR	□ S □ US □ F
9. Acid usage (a) Field latex coagulation		□ FR □ S	□ S □ US □ F
(b) Skim latex		□ FR □ S	□ S □ US □ F
10. Compositing of effluent		□ P □ FR	□ S □ US □ F
11. Solid waste disposal		□ P □ FR	□ S □ US □ F
12. Liquid waste disposal	□ Treated	□ P □ FR	□ S □ US □ F
	□ Untreated	□ P □ FR	□ S □ US □ F
13. Air emission	□ Treated	□ P □ FR	□ S □ US □ F
	□ Untreated	□ P □ FR (Complaints)	□ S □ US □ F

DOE Officer

Name : ______________________________

Designation : ______________________________

Date : ______________________________

APPENDIX 5

Inspection Checklist on Status of Regulatory Compliance

Final Discharge Status	Regulatory Requirement	Inspection Focus
1. Effluent discharge	Compliance with prevailing Regulatory standards presented in Table 8 in Section 5, and/or other effluent parameter limits imposed as conditions of license in accordance with the Environmental Quality (Prescribed Premises) (Raw Natural Rubber) Regulations, 1978.	- Evidence based on monitoring and analysis of effluent - Sampling location and frequency - Analytical results - Public complainants
2. Air emission	Compliance with the relevant provisions of the Environmental Quality (Clean Air) Regulations, 1978, if any.	- Factory records - Public complainants

APPENDIX 6

Recording Worksheet on Status of Regulatory Compliance

Name of the Factory : ______________________________

Address : ______________________________

____

____

Legend:

C : Compliance

NC : Non-compliance

F : Further Investigation

Please tick [✔] where applicable.

Final Discharge Status	Inspection Focus	Evidence	Findings
1. Effluent discharge	- pH - BOD - COD - Total Solids - Suspended Solids - Total Nitrogen - Ammoniacal Nitrogen - Sulphate (where applicable)	☐ Factory records ☐ Samples ☐ Photos	☐ C ☐ NC ☐ F
2. Air emission		☐ Available ☐ Not Available	☐ Satisfactory ☐ Unsatisfactory
3. Solid waste		☐ Visual inspection ☐ Photos	☐ Satisfactory ☐ Unsatisfactory

DOE Officer

Name : ______________________________

Designation : ______________________________

Date : ______________________________

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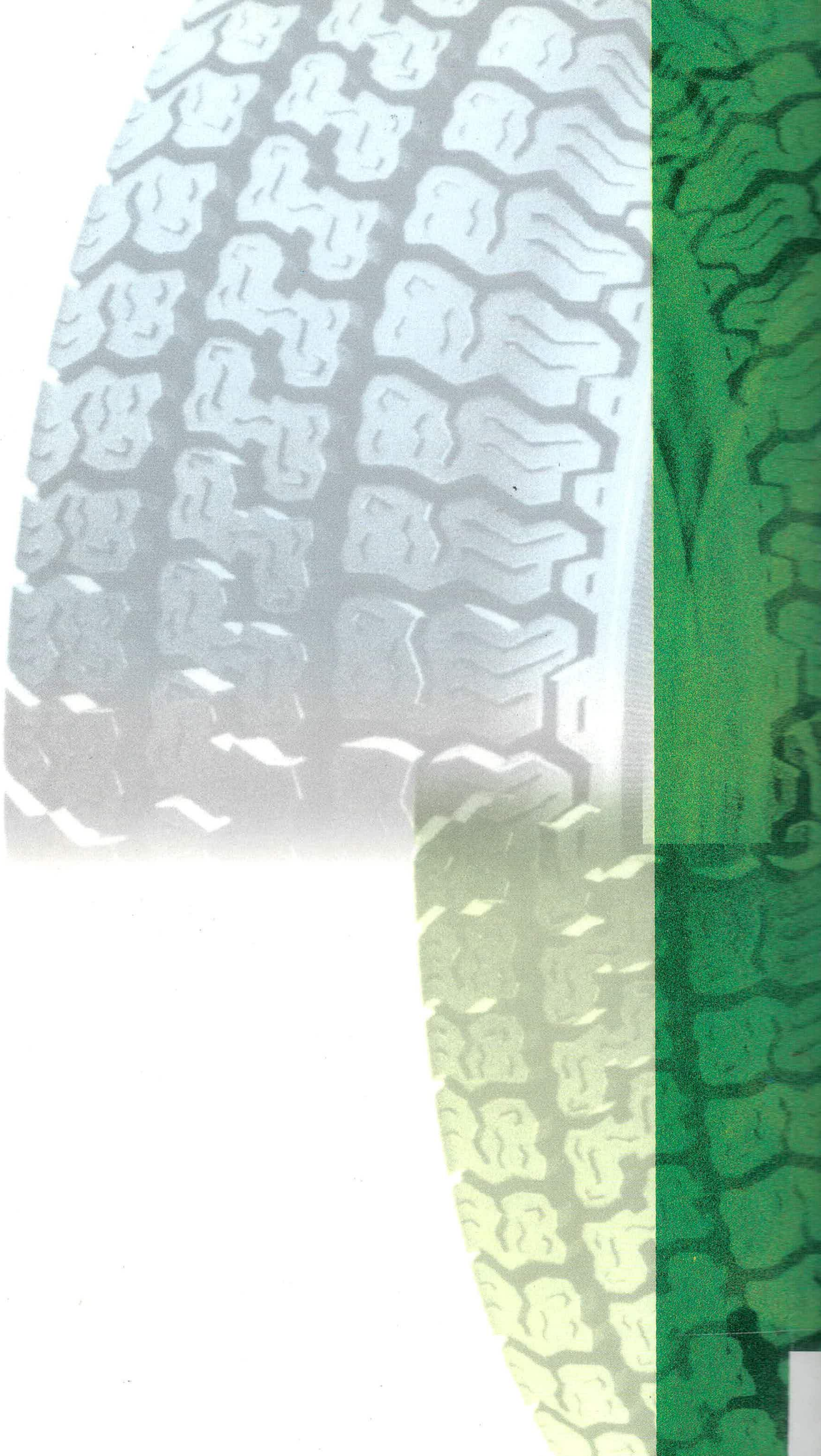

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