INDUSTRIAL POLLUTION CONTROL GUIDELINES

No. 1 — Natural Rubber Industry
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Prepared by the
Central Environmental Authority
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PREFACE

The Government of Sri Lanka is promoting rapid industrialization in order to create better employment opportunities for the growing work force of the country, and to increase the income level of the people. At the same time the Government is conscious of the fact that some of the existing industries significantly contribute to the deterioration of the quality of the environment in the country, especially in the urbanised and industrialized areas. Ill-planned industrialization will no doubt accelerate the process of environmental degradation.

The Government has, therefore, introduced environmental legislation to enhance environmental protection and pollution control. The Central Environmental Authority (CEA) is the lead agency in the implementation and enforcement of the environmental legislation. It has initiated various programmes for the protection of the environment, with special attention on industrial pollution control.

The CEA has requested technical and financial assistance from the Government of The Netherlands for a number of projects in this field.

As a result technical assistance for a programme which consist of the following projects was provided by the Government of The Netherlands:-

1. Development of environmental quality standards on the basis of designated uses.
2. Development and updating of emission/discharge standards and pollution control guidelines for selected priority industries
3. Feasibility studies on pollution control for priority industries or industrial sectors
4. Study tour to The Netherlands for Sri Lankan officers involved in compliance procedures in the Environmental Protection Licensing Scheme (enforcement)

Under project No 2 above, industrial pollution control guidelines, were prepared for the following eight(8) industrial sectors, considered as major polluters in Sri Lanka:-

1. Natural Rubber Industry
2. Concentrated Latex Industry
3. Desiccated Coconut Industry
4. Leather Industry
5. Dairy Industry
6. Textile Processing Industry
7. Pesticide Formulating Industry
8. Metal Finishing Industry
The main objective of the preparation of these guidelines was to assist the Central Environmental Authority in industrial pollution control with special reference to the introduction of the Environmental Protection Licensing Scheme.

In the preparation of these guidelines attention was focused on the generation of liquid, gaseous and solid wastes and their impacts on the environment. In the process aspects of industrial counselling, including in-plant measures to prevent and reduce waste generation and measures to improve occupational safety and health were also considered. Alternative methods were discussed for end-of-pipe treatment of liquid, gaseous and solid wastes.

Existing wastewater discharge quality standards were considered and intermediate standards (with respect to the phased installation of treatment systems) were proposed in these guidelines.

The guidelines were mainly prepared on the basis of data available on industrial pollution and its abatement in Sri Lanka, from studies and reviews carried out in the past and from missions to Sri Lanka specifically carried out for preparation of these guidelines.

The project was directed by Mr K G D Bandaratilake, Director of the Environmental Protection Division of the CEA, and coordinated by Mr W A D D Wijesooriya, Senior Environmental Scientist of the CEA. The CEA project team consisted of Mr C K Amaratunga and Mr S Seneviratne, Environmental Officers.

Technical assistance was given by a team of BKH Consulting Engineers, Comprises Dr I van der Putte (team leader), Mr J G Bruins and Mr H J F Creemers.

This document contains pollution control guidelines for Natural Rubber Industry.

G K Amaratunga
Chairman
Central Environmental Authority
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INTRODUCTION

Natural rubber is the third agricultural export product of Sri Lanka after tea and coconuts. Approximately 80% of the total natural rubber production is exported. The annual production of natural rubber is around 110,000 tonnes. The area cultivated with rubber trees is about 200,000 ha mainly in the south-western part of the country (1990 data).

Natural rubber is manufactured in 145 state-owned factories, in 84 private industries and by several thousands of small holders. The production plants are located mainly in rural areas. The industry can be divided into manufacturers of concentrated latex and manufacturers of dry rubber.

This document describes guidelines for the dry rubber industry only. A separate document for the concentrated latex industry has been prepared.

The various types of dry natural rubber, such as Crepe, Ribbed Smoked Sheet (RSS) and Technically Specified Rubber (TSR) are used as raw materials in the dry rubber-based industries. About 20% of the total natural rubber production is processed domestically into dry rubber-based products such as tires, tubes, garden hoses, rubberised fibres, sheets, shoes (soles), valves, etc.

In the latex-based industries concentrated latex is used for the manufacture of thin, simple profile, high elastic products such as gloves, elastic thread, mattresses, cushions and carpet backings. The production of concentrated latex is about 6% of the total natural rubber production. 80% of the concentrated latex is processed locally into latex products (1990 data).

These pollution control guidelines concern only the manufacturing of Ribbed Smoked Sheet and all types of Crepe rubber. These two account for 85% of the total natural rubber production in Sri Lanka (1990). The production of TSR rubber or "Block rubber" is not included in these guidelines. Only a few factories produce TSR (one factory is responsible for about 70% of the total TSR production) and the pollution caused by TSR factories is only slightly different from the pollution caused by RSS and Crepe rubber manufacturing. For this reason the guidelines for crepe rubber manufacture can also be applied for TSR production.

The rubber industry generates relatively large quantities of wastewater. The pollutional load of wastewater discharge in the rubber cultivation area is equivalent to that of a town with about 350,000 people. In addition to organic pollutants, rubber factory wastewater contains various types of chemicals which are used in the rubber manufacturing process. Some of these process chemicals are potentially toxic for man and the ecosystem in general.

Production units and factories generally discharge their wastewater into the nearest stream or low-lying land. In most cases the wastewater ends up in a river or in a paddy field. Some of the rivers are sources for urban water supply schemes and most surface waters in rural areas are used for washing and bathing. A hazardous situation is therefore being created by such polluted waters which has resulted in numerous complaints. At the same time public awareness on environmental issues has increased and legislation on water pollution control has been introduced.
The primary objective of these pollution control guidelines is to describe and assess methods of pollution control and to provide a pollution control programme which could allow the phased fulfilment of the wastewater discharge quality standards, introduced for the rubber industry. In this document methods of pollution control are discussed regarding prevention and in-plant reduction of waste generation, improvement of occupational safety and health, and wastewater treatment. Intermediate wastewater discharge quality standards are proposed to be complied with in a phased programme.
2. PRODUCTION OF NATURAL RUBBER

2.1 Production data

In Sri Lanka the following types of rubber are produced in the natural rubber industry:

- ribbed smoked sheet rubber (RSS)
- crepe rubber
- sole crepe rubber
- scrap crepe rubber
- concentrated latex
- technically specified rubber (TSR) or block rubber

Data on production of the various types of rubber are summarized below (see also Table 2.1).

a) **Ribbed smoked sheet rubber (RSS)**

Most RSS rubber is produced by small holders (56,900 t in 1990). In 1990 the state-owned factories produced about 2000 t. The production process is simple in comparison to other types of rubber production processes. Rubber is coagulated from the latex in a flat aluminium tray. The coagulum is then pressed into a sheet by a roller mill and the sheets dried by smoking. Liquid wastes, serum and washing water are discharged directly.

b) **Crepe rubber**

The majority of the state owned factories produce crepe rubber. Total production of crepe rubber in 1990 was about 37,800 t, of which about 95% was produced by the state owned factories.

Rubber is coagulated from the latex in tanks. The coagulum then passes through a series of rollers until thin rubber sheets or laces are formed. These laces are dried in drying towers. The dry laces are cut into a regular shape and folded and then spindled into bundles of 50 kg. Alternatively layers of laces are processed into blankets packaged in 50 kg lots.

c) **Sole crepe rubber**

Sole crepe rubber is a type of crepe rubber, specially produced for the shoe industry. The production process is basically the same as for crepe rubber, but for sole rubber the laces are laminated into sheets of a specified thickness.

In 1990, about 3,700 t of sole crepe rubber were produced. The Sri Lankan rubber industry is virtually the only producer of crepe and sole crepe rubber in the world.

d) **Scrap crepe rubber**

Scrap crepe rubber is produced out of solid pieces of latex, which precoagulates on the trees and in the collection cups. The pieces are passed through the roller mills and milled into laces, which are then dried. After drying,
the laces are pressed into blankets. In 1990, 5,000 t of scrap crepe rubber were produced.

e) Concentrated latex

Concentrated latex is used for the production of dipped products such as gloves and balloons. Concentrated latex has a dry rubber concentration of 60-70% which is achieved by centrifugation. A very concentrated wastewater is generated by this process. In 1990 about 6,700 t of concentrated latex was produced, of which 10% came from the state owned factories. The liquid remaining after centrifugation is further treated by the addition of concentrated sulphuric acid as a coagulant producing skim rubber.

f) Technically specified rubber (block rubber)

Technically specified rubber (TSR) is produced for special purposes. The production process depends on the purpose for which the rubber is made. In 1990 about 9,900 t of TSR were produced, all by privately owned factories.

A summary of the rubber producers, the types and quantities of rubber produced, is shown in Table 2.1.

Table 2.1 Rubber production by state factories, private factories and smallholders (1990)

<table>
<thead>
<tr>
<th>Producer</th>
<th>Rubber production (tonnes of dry rubber)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RSS</td>
</tr>
<tr>
<td>State-owned factories</td>
<td>1,750</td>
</tr>
<tr>
<td>(145 plants)</td>
<td></td>
</tr>
<tr>
<td>Private factories</td>
<td>-</td>
</tr>
<tr>
<td>(84 plants)</td>
<td></td>
</tr>
<tr>
<td>Smallholders</td>
<td>56,900</td>
</tr>
<tr>
<td>(several thousand units)</td>
<td></td>
</tr>
</tbody>
</table>

2.2 Production processes

The production processes of crepe rubber, sole crepe and scrap crepe rubber are basically the same. RSS rubber is mostly produced in small units. For production of one tonne RSS rubber less water and chemicals are used than for production of the other types. The wastewater from the smallholders and RSS rubber production units can in most cases be disposed of in nearby agricultural lands without environmental problems.
The production processes of RSS, crepe, sole crepe and scrap crepe rubber are described below. In Figures 2.1, 2.2, 2.3 and 2.4 the respective process diagrams for each rubber type are shown.

Crepe rubber production (Figure 2.1)

Crepe rubber is manufactured in the following steps:

a) Initial processing

   Latex collection
   After tapping the latex is strained. Sometimes Na₂SO₄·7 H₂O is added to the latex (0.5 g per litre of latex) to prevent pre-coagulation. The latex is then transported by bowser or buckets to the factory.

   Latex bulking
   The latex is led into the bulking tank, after it has been strained and after its dry rubber content has been determined. The latex is mixed in the bulking tank with water to produce a standardized dry rubber content of 125 kg per m³ of latex. Sodium metabisulphite (Na₂S₂O₅) is then added to the bulking tank at a concentration of 500 g per 100 kg of rubber, to prevent enzymatic discoloration. The bulking tank contents are then mixed for 2-3 hours until a yellow and a white fraction are formed.

   The yellow fraction contains all the non-rubber substances in the latex. Grade I and II crepe rubber is produced from the white fraction. Grade III and IV crepe rubber from the yellow fraction.

   Coagulation of latex (white fraction)
   The white fraction is removed from the bulking tank, strained and led into the coagulation tanks. A solution of Nexobleach (C₇H₈S) is added at a concentration of 125 g per 100 kg rubber, to remove the carotenoid pigments. A solution of formic acid (H₂CO₂) is then added at a concentration of 450 g per 100 kg of rubber and the latex is mixed thoroughly. A coagulum is formed after 1.5-2 hours.

   Milling
   The coagulum is taken out of the tank and fed into the horizontal grooved mill to produce rubber mats, with a thickness of 9-12 mm. It is then passed through a diamond grooved mill which reduces the thickness to between 2.1 and 2.5 mm.

   The thickness of the mat is further reduced to between 1.1 and 1.4 mm by passing it through the smooth mill. These thin mats are called laces.
Drying
After milling the laces are placed in the drying tower in which a temperature of 34°C is maintained. Heat is provided by wood-fired furnaces which heat water that circulates through radiators at the bottom of the drying towers. The laces are dry after 4-5 days.

Finishing
The dry laces are processed into bundles of thin pale crepe or into blanket crepe:

Thin pale crepe
The dry laces are cut into a rectangular shape and then wound on to spindles to long sheets that are baled into bundles of 50 kg.

Blanket crepe
The dry laces are folded into mats 1.8 m long by 0.9 wide, a mat consisting of a layer of 12-15 laces. The mats are compressed (blanketed) by passing them through a horizontal grooved mill. The compressed mats (blankets) have a thickness of 2 cm and are cut to a size of 59 x 43 cm. The blankets are packed into bundles of 50 kg.

c) Grade III and IV crepe rubber
The yellow coagulum fraction from the bulking tank is processed into low grade crepe rubber. Grade III crepe rubber has a beige colour, Grade IV a brown colour. Production is in the following steps.

- Milling into laces
The yellow coagulum is passed three times through a horizontal grooved mill, four times through a diamond grooved mill and once through a smooth mill.

- Drying
The laces are dried naturally in the loft of the factory. Drying time is about five days.

- Folding
The dry laces are folded into sheets.

- Blanketing, cutting and packing
The sheets are passed twice through blanketing mills to form blankets which are cut into pieces of 58 x 43 cm, and packed into bundles of 50 kg.

Grade I sole crepe rubber production (Figure 2.2)
The initial processing of sole crepe rubber (latex collection and bulking) is similar to that of crepe rubber. The subsequent process steps differ somewhat and are described below:
a) **Coagulation**

The white fraction is strained, removed from the bulking tanks and brought into the coagulation tanks. A solution of Nexobleach ($\text{C}_7\text{H}_6\text{S}$) is added to remove carotenoid pigments at a concentration of 125 g of Nexobleach per 100 kg of rubber. Formic acid and oxalic acid are added as coagulants. 250 g of formic acid and 375 g of oxalic acid are added per 100 kg of rubber.

Both acids are added as solutions. The acid is mixed with the latex by vigorously stirring for some minutes. A coagulum is formed after 1.5 to 2 hours.

b) **Milling**

The coagulum is taken out of the tank and passed three times through a horizontal grooved mill, which squeezes out serum water and rubber mats are formed. These rubber mats are then passed three times through a spiral mill which reduces the thickness. They are then passed four times through a diamond grooved mill which reduces the thickness of the mat to about 2 mm. The mats are finally passed three times through smooth mills to produce rubber laces with a thickness of 0.53 mm.

c) **Drying**

The rubber laces are dried in drying towers in which a temperature of 34°C is maintained. Heat is provided by wood-fired furnaces with heated water which circulates through radiators at the bottom of the towers. Air is heated by the radiators and rises upwards through the tower. The laces are dry after 3 days.

d) **Lamination**

The laces are laid on a table forming a sheet of specified thickness. These sheets are pressed together by passing them through a roller mill. This process is called lamination. The sheets are passed three times through the laminating mills resulting in sheets of sole crepe rubber.

e) **Cutting**

The sheets of sole crepe rubber are cut into pieces of 91 x 33 cm which are packed in wooden boxes, each box containing 83 kg of sole crepe rubber.

**Scrap rubber production (Figure 2.3)**

Pre-coagulated latex (scrap) is collected in the field and taken to the factory where sand and dirt is removed by washing. The scrap is then milled into laces.

It is passed four times through a horizontal grooved mill, six times through a diamond grooved mill and once through a smooth mill. The laces are then processed into blankets in the same way as Grade III and IV rubber. Scrap rubber blankets have a dark brown colour.
Ribbed Smoked Sheet (RSS) production (Figure 2.4)

a) Initial processing

After tapping the field latex is collected in bowsers or buckets. Sodium sulphite ($\text{Na}_2\text{SO}_3\cdot7\text{H}_2\text{O}$) and ammonia or formalin are sometimes added for preservation to prevent pre-coagulation.

The latex is led into a bulking tank, where the dry rubber content is determined. Sodium bisulphite is added to prevent enzymatic discolourization. Water is added to dilute the latex to a standard dry rubber content.

b) Coagulation of latex

The rubber is coagulated from the latex in a flat aluminium tray of about 30 x 50 cm after addition of the coagulant formic acid. The soft rubber mass is removed from the tray and further processed. The remaining serum water is discharged.

c) Milling and draining

The coagulum is pressed into a sheet by a roller mill while washing water is added continuously. Subsequently the sheets are drained. The wash and drain water is discharged.

d) Smoking

The RSS sheets are dried by smoking them in the smoke house. The rubber is also preserved by smoking.

e) Packing

The RSS rubber sheets are packed into bales and transported to factories which further process the ribbed smoked sheets into rubber products.
Figure 2.1 - Processing of latex into crepe rubber
Sodium sulphite → Field latex

Sodium bisulphite
Water → Bulking

washing water → discharge

Fractionation

Yellow Fraction → Milling → Drying

Cutting, baling, packing

Crepe rubber
Grade III and IV

White Fraction

Nexo bleach → Formic acid

Coagulation

serum water → discharge

milling

washing water → discharge

Drying

Cleaning, cutting, Lamination, packing

Sole crepe rubber
Grade I and II

Figure 2.2 - Processing of latex into sole crepe rubber
Field coagula
(cuplump, tree laces)

Milling

Drying

Cutting, baling, packing

Scrap rubber

Figure 2.3 - Processing of field coagulated latex into scrap rubber
**Anticoagulants** (sodium sulphite, ammonia)

Sodium bisulphite*

Water**

Formic acid

Field latex

Bulking

Coagulation

Milling

Draining

Smoking

Packing

washing water → discharge

serum water → discharge

washing water → discharge

drain water → discharge

* Sodium bisulphite is added to prevent enzymatic discolorization

** Water is added to dilute the latex to a standard dry rubber content

Figure 2.4 - Processing of latex into Ribbed Smoked Sheet rubber (RSS)
3. WASTE PRODUCTION AND ENVIRONMENTAL IMPACTS

3.1 Water use and wastewater production

The average water use per tonne crepe rubber produced is as follows:

- Bulking: 5 m³ (depends on rubber content of latex)
- Milling: 14 m³
- Washing: 10 m³

Total: 29 m³ per t rubber produced

The average wastewater production including serum water is 32 m³ per tonne crepe rubber produced.

The composition of the combined wastewaters from crepe rubber manufacture is mainly determined by the composition of the serum. Major constituents of serum are proteins, sugars, organic acids (coagulant), sulphites (preservatives), mercaptans (used for bleaching), nitrogen, phosphorus and potassium. Rubber factory wastewater has an acidic pH.

The average wastewater characteristics for the manufacturing of crepe and sole crepe rubber are given in Table 3.1. The waste loads from sole crepe rubber production are approximately identical, but the concentrations of the wastewater from sole crepe production are lower, due to the higher water consumption for this production process.

Table 3.1 Wastewater characteristics of crepe rubber manufacturing

<table>
<thead>
<tr>
<th>Wastewater parameter</th>
<th>Waste load (kg/t rubber)</th>
<th>Concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td></td>
<td>5.5</td>
</tr>
<tr>
<td>COD</td>
<td>180</td>
<td>5600 mg/l</td>
</tr>
<tr>
<td>BOD</td>
<td>60</td>
<td>1900 mg/l</td>
</tr>
<tr>
<td>N total</td>
<td>7.2</td>
<td>225 mg/l</td>
</tr>
<tr>
<td>Total solids</td>
<td>180</td>
<td>5600 mg/l</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>5</td>
<td>150 mg/l</td>
</tr>
<tr>
<td>Sulphide</td>
<td>0.5</td>
<td>15 mg/l</td>
</tr>
<tr>
<td>Sulphite</td>
<td>6</td>
<td>190 mg/l</td>
</tr>
</tbody>
</table>

The waste loads from RSS manufacture are basically similar to those from crepe rubber manufacture, but the wastewater volume from RSS production is much lower.
3.2 Solid wastes

Rubber production generates no solid process wastes, since all cuttings and rejected rubber pieces are processed into lower grade rubber types. The only solid waste consists of packing materials of process chemicals.

3.3 Air pollution

Rubber production, except for some types of TSR, causes no emission of gaseous pollutants. Some emission of smoke and flue gases is caused by the woodstoves, which are used for heating the drying towers.

3.4 Environmental impacts

Rubber factories are mostly situated in rural areas near the rubber cultivation areas, which produce the latex. Most factories discharge their wastewater directly into the nearest stream. In most cases the wastewater ends up in a river or in a paddy field.

Some of these rivers are sources for urban water supply schemes and most surface waters in rural areas are used for washing and bathing.

In the dry season rivers may become polluted by the rubber wastewater discharges, resulting in low dissolved oxygen concentrations and bad odours caused by anaerobic degradation of organic substances.

The number of complaints about nuisance, caused by pollution, increases annually. The discharge of rubber factory wastewater into paddy fields in some cases causes crop damage, due to the low pH of the wastewater.

According to a survey, carried out in 1986 in the State plantation sector, approximately 30% (38) of the state factories have received complaints about water pollution and bad odours.
4. INDUSTRIAL COUNSELLING

4.1 Introduction

The industrial counselling procedures are directed towards the introduction of environmentally sound technology ("clean technology"). Clean technologies contribute to more efficient production methods by saving energy and raw materials and reducing emissions to air, water and soil. They include good housekeeping measures, modification of production processes and raw materials use, as well as recycling of waste and process waters.

Industrial counselling aims at environmentally sustainable industrial development by promoting a combination of in-plant pollution control and end-of-pipe treatment in order to protect the environment and to optimize the conservation of energy and raw materials.

Additional advantages of the application of cleaner production processes are the reduction of safety hazards and the improvement of occupational health. Therefore, initial investments aimed at pollution control become more cost effective.

In this chapter in-plant pollution control measures and methods to improve occupational safety and health are proposed.

4.2 In-plant pollution control

The liquid waste load could be reduced by reducing the wastage of product and the use of chemicals and water, by reusing process chemicals and water and by good housekeeping methods.

However, in crepe rubber very little rubber from the latex is wasted. The wastewater contains only the non rubber components from the latex. The quantities of process chemicals, used in the manufacturing process, have been standardized. Accurate pH control during the coagulation process is required for optimal chemical use.

Some of the milling water might be recycled, but only after treatment, since crepe rubber is very sensitive to contamination by impurities. Wastewater from smooth mills, however, can be recycled and used for the grooved mills. Water use might be reduced to some degree by good housekeeping methods but the waste load per tonne rubber produced will not be affected by this, since all the latex, without the rubber components, has to be discharged.

Waste products can be recovered and reused. For example, Quebrachitol is a serum constituent which can be recovered and used as a raw material for the production of certain medicines. The serum can also serve as a fertilizer for rubber trees, because of its relatively high concentration of nutrients (Nitrogen, Phosphorus, Potassium). In Malaysia an annual dosage of 3 x 30 l serum per rubber tree has been recommended.
Improvement of occupational safety and health

Occupational safety and health aspects concern physical, chemical, biological and mental hazards and stresses present in the working environment. The improvement of occupational safety and health aims at the protection of workers at the workplace and its immediate surroundings against hazards such as heat, dust, noise, vibration, toxic chemicals, airborne pollutants, mechanical hazards, explosions and radiation. It also includes the adaptation of installations and processes to the physical and mental capacity of the workers.

At present the operations in rubber factories are such that factory workers have frequent contact with dissolved process chemicals, particularly in handling the coagulum. The manufacturing system should be modified in order to avoid physical contact with the process materials as much as possible. Workers should wear protective clothing when physical contact cannot be avoided. Working conditions and safety can be improved by providing appropriate drainage for discharge of wastewaters and by adequate ventilation of the factory buildings.
5. **POLLUTION ABATEMENT MEASURES**

5.1 **Introduction**

Pollution abatement methods usually consist of end-of-pipe treatment methods for treatment of the wastewater and the gaseous emissions, and for appropriate disposal of the solid wastes, generated by the industries. Since the natural rubber industry produces negligible quantities of gaseous and solid wastes, only wastewater treatment methods are discussed in this chapter.

Wastewater from the natural rubber industry can be treated by biological wastewater treatment methods, such as pond systems, activated sludge systems and rotating biological contactors. The organic substances in rubber wastewater have a good bio-degradability.

Rubber factory wastewater may also be used for irrigation of rubber plantations. Because of the relatively high concentrations of nutrients in the rubber factory wastewater the fertilizer requirements of the rubber trees could be reduced by irrigation (see also Section 4.2).

For small production units (smallholders) methods could be used, such as overland flow/irrigation, septic tanks, infiltration beds and small ponds. These methods are briefly discussed in Section 5.3.

Before the wastewater is treated biologically or used for irrigation, it must be pre-treated to remove rubber particles, to correct the pH and to add any necessary nutrients.

The pre-treatment system and some biological treatment methods for crepe rubber factories are described below. Wastewater treatment methods for small production units in particular are discussed in Section 5.3.

5.2 **Wastewater treatment for crepe rubber factories**

5.2.1 **Pretreatment system**

The same type of pretreatment system may be used for the treatment methods described below.

The pretreatment systems consists of:

- equalization tank
- rubber trap
- pH correction

In the equalization tank the wastewater is stored and mixed to create an equal flow to the other treatment plant components. The volume of the equalization tank is equal to the volume of wastewater generated from factory production during one day.
From the equalization tank, the wastewater is pumped to the rubber trap. Rubber particles are forced to float on the water surface by means of baffles. The rubber particles are removed from the water surface and are remilled in the factory. The retention time in the rubber trap is 2 hours. After the rubber trap, lime is added to the wastewater to raise the pH to 7-8.

5.2.2 Biological wastewater treatment methods

1. Pond system

In this system the wastewater flows through a series of ponds which usually consists of an anaerobic pond followed by a facultative pond or an aerated pond.

The pretreatment system may be omitted in the pond system because of its large buffer capacity. pH correction, however, may be required.

a) Anaerobic pond

In the anaerobic pond the organic matter in the wastewater is bio-degraded by anaerobic bacteria into gases, such as methane, hydrogen sulphide, ammonia and carbon dioxide. Solids settle into a sludge layer at the bottom of the pond and are periodically removed.

The most important design parameters are, for Sri Lankan conditions with an average temperature of 27°C:
- organic volume loading rate 300 g BOD/m³d
- retention time 1-5 d
- depth 2.5-4 m
- BOD removal efficiency 70%

Anaerobic ponds may cause odour nuisance. Therefore these ponds should be located at sufficient distance from residential areas (at least 500 m).

b) Facultative pond

The effluent of the anaerobic pond can be led into a facultative pond. Organic matter is biodegraded aerobically in the upper layers of the pond.

Oxygen for this process is mainly supplied by algae. Some anaerobic biodegradation of settled organic material takes place at the bottom of the facultative pond. The most important design parameters for facultative ponds treating anaerobic pond effluent are:
- organic surface loading rate 330 kg BOD/ha.d
- depth 1.2 m
- BOD removal efficiency 90%

c) Mechanically aerated pond

An alternative for the facultative pond is a mechanically aerated pond. In this type of pond oxygen for aerobic biodegradation is supplied by
mechanical aerators. There are two types of aerated ponds, the completely mixed aerated pond and the facultative aerated pond.

c.1 In the completely mixed aerated pond the contents are completely mixed, and the whole system is aerobic. The effluent from this pond is led into a sedimentation tank or pond, in which solids settle into a sludge. The most important design parameters for completely mixed aerated ponds are:

- required power input: 6 W/m³ pond volume
- BOD removal efficiency: 85 %
- depth: 2 - 4 m

c.2 In a facultative aerated pond only the top layers are kept aerobic by means of mechanical aerators. Suspended solids settle to the bottom of the pond, where anaerobic biodegradation takes place. The most important design parameters for facultative aerated ponds are:

- required power input: 1.75 W/m³ pond volume
- BOD removal efficiency: 90 %
- depth: 2.5 - 4 m

2. Activated sludge system

In the activated sludge system the wastewater is led into an aeration tank, where it is mixed with flocs of aerobic micro-organisms (activated sludge). The mixture of activated sludge and wastewater is aerated vigorously.

Organic substances in the wastewater are absorbed by the active micro-organisms, which biodegrade the organic matter, utilizing the breakdown products as a substrate for growth and formation of new cells. As a result the sludge quantity in the aeration tank is increased. Micro-organisms die-off in the aeration tank, the dead cells being oxidized into inert material (mineralization).

The mixture is led from the aeration tank into a sedimentation tank where the flocs settle into a sludge. Part of this sludge is returned to the aeration tank in order to maintain a constant concentration of activated sludge therein. The remainder of the sludge (surplus sludge) must then be removed. The surplus sludge is often de-watered in a sludge drying bed to decrease its volume.

Controlled disposal of the wet sludge in rubber or coconut plantations is also possible.

High-load activated sludge systems with a high loading rate of organic matter per quantity activated sludge (kg BOD per kg sludge solids per day) and low load activated sludge systems are used in wastewater treatment.

The advantages of low load systems in comparison with high load systems are higher reliability, better BOD removal, production of a mineralized sludge and simpler operation. One type of low load activated sludge system is the oxidation system, which is frequently used in Malaysia for rubber industry wastewater treatment.
The most important design parameters for low load activated sludge systems (oxidation ditch) are:

- organic sludge loading rate \( 0.15 \text{ kg BOD/kg sludge dry solids} \)
- sludge dry solids content in aeration tank \( 4 \text{ kg/m}^3 \)
- oxygen requirement \( 2.5 \text{ kg O}_2/\text{kg BOD} \)
- BOD removal efficiency \( 97 \% \)
- depth \( 1.5 - 2.5 \text{ m} \)
  (depends on aerator type)

3. Rotating Biological Contactors System

The Rotating Biological Contactors (RBC) system consists of a series of biorotors, a biorotor being a central horizontal shaft to which a contact surface has been attached. The biorotor is fitted into the tank, into which the wastewater, after pretreatment, is led. The submersion depth of the biorotor in the tank is 40% of the biorotor diameter. The biorotor rotates slowly, about 1-2 rotations per minute, and a film of sludge, containing aerobic micro-organisms develops on the contact surface of the biorotor. While rotating in the tank the biorotor lifts up a quantity of wastewater, causing intensive contact between wastewater, micro-organisms and oxygen from the air.

The sludge film absorbs organic matter, which is biodegraded aerobically in the process of substrate utilization by the micro-organisms for growth and formation of new cells. The excess sludge is washed off from the contact surface.

The effluent of the biorotor tanks is led into a sedimentation tank in which the excess sludge settles.

Important design parameters for the RBC system are:

- biorotor surface loading rate \( 10 \text{ g BOD/m}^2\text{d} \)
- peripheral rotation speed \( 12.5 \text{ m/min} \)
- biorotor submersion depth \( 25 - 40 \% \text{ of diameter} \)
- BOD removal efficiency \( 95 \% \)

4. Irrigation

After pretreatment the rubber factory wastewater can be used for irrigation of rubber trees. The organic substances are then absorbed in the top layers of the soil and subsequently biodegraded. Rubber factory wastewater is to some extent also a fertilizer because of its nutrients content (N, P and K).

In Malaysia, where irrigation with serum water is applied, it is recommended that 30 l of serum water is applied to a rubber tree, three times per year. Currently no irrigation is applied in the rubber estates in Sri Lanka. If the serum water were to be used for irrigation, a special irrigation network would need to be installed. In most estates, however, the installation of such a system would be very difficult to realize and would be very costly, because of the following reasons:
- the estates cover large areas;
- the factories are often located at the lowest point of the estates;
- most plantations are situated in hilly lands with short steep slopes.

For this reason the best method is to transport the serum water by bowser to the sites to be irrigated.

With an irrigation rate of 90 l per tree per year, nearly 50,000 trees could be irrigated, with the serum water production of a rubber factory of an average size (500 t rubber per year). That number of trees is generally not available in an estate. Therefore higher rates would have to be applied.

This could be carried out without adverse effects on the trees and the soil, but operation of an irrigation system requires extensive control and supervision and it is very labour intensive.

For these reasons the irrigation system seems presently not a feasible system for most estates. The costs are difficult to estimate and will vary greatly from estate to estate.

5.2.3 Preliminary design of wastewater treatment systems

In the following, preliminary designs of a number of alternative wastewater treatment systems are described.

The designs have been made for a factory with a production capacity of 2000 kg rubber per day.

The wastewater from such a factory has the following characteristics:

| Flow       | 64 m³/d |
| COD        | 5600 mg/l |
| BOD        | 1900 mg/l |
| pH         | 5.5     |

**Pretreatment system**

- equalization tank volume 64 m³
- pump capacity 3 m³/h
- rubber trap volume 5 m³
- chemical addition
  - * lime for pH correction to pH = 7
  - * nutrients to BOD : N : P = 100 : 5 : 1

**Pond system (no pretreatment required, with exception of chemicals addition)**

a) Anaerobic pond

| Volume | 400 m³ |
| Depth  | 4 m     |
| Area (excl. embankments) | 100 m² |
| Effluent BOD | 570 mg/l |
b1) Facultative pond

<table>
<thead>
<tr>
<th>Volume</th>
<th>1400 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>1.2 m</td>
</tr>
<tr>
<td>Area (excl. embankments)</td>
<td>1170 m²</td>
</tr>
<tr>
<td>Effluent BOD</td>
<td>60 mg/l</td>
</tr>
</tbody>
</table>

b2) Completely mixed aerated pond

<table>
<thead>
<tr>
<th>Volume</th>
<th>260 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>3 m</td>
</tr>
<tr>
<td>Area (excl. embankments)</td>
<td>85 m²</td>
</tr>
<tr>
<td>Power input</td>
<td>1.5 kW</td>
</tr>
<tr>
<td>Effluent BOD</td>
<td>80 mg/l</td>
</tr>
</tbody>
</table>

b3) Facultative aerated pond

<table>
<thead>
<tr>
<th>Volume</th>
<th>640 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>4 m</td>
</tr>
<tr>
<td>Area (excl. embankments)</td>
<td>160 m²</td>
</tr>
<tr>
<td>Power input</td>
<td>1 kW</td>
</tr>
<tr>
<td>Effluent BOD</td>
<td>60 mg/l</td>
</tr>
</tbody>
</table>

**Oxidation ditch system (pretreatment required, excluding equalization)**

a) Oxidation ditch

<table>
<thead>
<tr>
<th>Volume</th>
<th>200 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>1.5 m</td>
</tr>
<tr>
<td>Area</td>
<td>135 m²</td>
</tr>
<tr>
<td>Power input</td>
<td>12 kW</td>
</tr>
</tbody>
</table>

b) Sedimentation tank

<table>
<thead>
<tr>
<th>Volume</th>
<th>14 m³</th>
</tr>
</thead>
<tbody>
<tr>
<td>Depth</td>
<td>2.5 m</td>
</tr>
<tr>
<td>Area</td>
<td>5 m²</td>
</tr>
<tr>
<td>Sludge recirculation pump capacity</td>
<td>3 m³/h</td>
</tr>
<tr>
<td>Excess sludge production</td>
<td>70 kg dry solids/d (8 m³/d)</td>
</tr>
<tr>
<td>Effluent BOD</td>
<td>60 mg/l</td>
</tr>
</tbody>
</table>

c) Disposal of wet sludge in the estate

<table>
<thead>
<tr>
<th>Sludge volume</th>
<th>8 m³/d</th>
</tr>
</thead>
<tbody>
<tr>
<td>Storage tank volume</td>
<td>25 m³</td>
</tr>
</tbody>
</table>
Rotating Biological Contactors System (pretreatment required)

a) Rotating Biological Contactors

- Contact area surface: 12,160 m²
- Contactor diameter: 2.5 m
- Shaft length: 4 m
- Contact area per unit: 3,040 m²
- Number of units: 4
- Tank volume: 78 m³
- Power input: 2 kW

b) Sedimentation tank

- Volume: 14 m³
- Depth: 2.5 m
- Area: 5 m
- Effluent recirculation: 6 m³/h
- Pump for influent dilution
- Sludge production: 80 kg dry solids/d (6 m³/d)
- Effluent BOD: 95 mg/l

c) Disposal of wet sludge in the estate

- Sludge volume: 6 m³/d
- Storage tank volume: 20 m³

5.2.4 Evaluation and comparison of wastewater treatment systems

In the following a number of the aforementioned wastewater treatment systems are briefly described, and evaluated as to costs (investment and operation/maintenance), treatment efficiency, process reliability and need for labour and skilled operators or supervisors.

The investment costs include costs of an operators building, site work, piping, fencing, engineering and construction supervision but exclude land purchase costs.

A summary of the evaluation is given in Table 5.1.

1. Anaerobic/facultative ponds

This system consists of chemicals addition, an anaerobic pond and a facultative pond.

Land requirement is 3,800 m².
Investment costs are medium; the costs of electro-mechanical equipment are low.
Annual maintenance costs are very low; the operational costs are low.
This system requires little skilled operation. It is reasonable efficient and reliable, but it may cause odour nuisance. An area of flat land is required for the installation of pond systems.
2. Anaerobic/completely mixed aerated ponds

This system consists of chemicals addition, an anaerobic pond, a completely mixed aerated pond and a settling pond.

Land requirement is 800 m². Investment costs and the costs of electro-mechanical equipment are medium. Annual maintenance costs are very low; the operational costs are low.

This system has the same advantages and disadvantages as an anaerobic/facultative ponds system, but it is more reliable and requires less land area.

3. Anaerobic/facultative aerated ponds system

This system consists of chemicals addition an anaerobic pond and a facultative aerated pond.

Land requirement is 1,100 m². Investment costs are medium; the costs of electro-mechanical equipment are low. Annual maintenance and operational costs are respectively very low and low.

This system has the same advantages and disadvantages as the anaerobic/completely mixed ponds system.

4. Oxidation ditch system

The oxidation ditch system consists of pretreatment, an oxidation ditch, a sedimentation tank and a sludge storage tank for disposal of sludge onto rubber lands. Sludge drying beds are not further considered due to the large land area they require.

Land requirement is 300 m². The investment costs and the costs of electro-mechanical equipment are both high. Annual maintenance costs are low, while the operational costs are high.

The oxidation ditch system is very efficient and reliable, but it requires more skilled labour input than the pond systems. The costs are high.

5. Rotating Biological Contactors system

The RBC system consists of pretreatment, a tank with 4 biorotors, a sedimentation tank and a sludge storage tank.

Land requirement of this system 200 m². The investment costs and the costs of electro-mechanical equipment are both high. Annual maintenance costs are low and operational costs are medium. The RBC system requires little land area. The costs are relatively low if the equipment is manufactured locally. On the basis of prices of imported equipment the costs are high.

The effluent quality of the RBC system is less than of the other systems.
5.2.5 System selection

The most important data for selection of a wastewater treatment system are given in Table 5.1, for each of the previously described systems.

Table 5.1 Comparison of wastewater treatment systems

<table>
<thead>
<tr>
<th>Treatment system</th>
<th>Anaerobic/ facultative ponds</th>
<th>Anaerobic/ complete mix ponds</th>
<th>Anaerobic/ facultative aerated ponds</th>
<th>Oxidation ditch</th>
<th>RBC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Investment costs</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Civil</td>
<td>medium</td>
<td>medium</td>
<td>medium</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>- E/M</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Operation costs</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
<td>high</td>
<td>high</td>
</tr>
<tr>
<td>Maintenance costs</td>
<td>very low</td>
<td>low</td>
<td>low</td>
<td>medium</td>
<td>medium</td>
</tr>
<tr>
<td>Land area (m²)</td>
<td>3,800</td>
<td>800</td>
<td>1,100</td>
<td>300</td>
<td>200</td>
</tr>
<tr>
<td>Environmental impact</td>
<td>yes</td>
<td>yes</td>
<td>yes</td>
<td>little</td>
<td>little</td>
</tr>
<tr>
<td>Effluent BOD (mg/1)</td>
<td>60</td>
<td>80</td>
<td>60</td>
<td>60</td>
<td>95</td>
</tr>
<tr>
<td>Quality standard:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BOD (mg/1)</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
<td>50</td>
</tr>
<tr>
<td>Need for skilled operators</td>
<td>little</td>
<td>little</td>
<td>little</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Process reliability</td>
<td>+ / -</td>
<td>+</td>
<td>+</td>
<td>++</td>
<td>+</td>
</tr>
</tbody>
</table>

From Table 5.1 may be concluded that the anaerobic/facultative aerated ponds system is the most appropriate system for treatment of rubber factory wastewater, because of the low costs, the good effluent quality and the relatively simple operation.

The major disadvantage of this system is that it should be located at an adequate distance from the factory and from housing, to avoid odour nuisance. A survey of the plantation rubber industry has shown that such a location is not readily available at most factories. The oxidation ditch system is a good system, but the investment and operation costs are very high. However the investment costs could be reduced significantly, if locally manufactured equipment could be used.

The BOD of the effluent of the RBC system is higher than the BOD according to the quality standard. The effluent BOD could be reduced, by further biological treatment. The costs of the RBC system could be reduced by using locally manufactured equipment: such equipment is not yet manufactured in Sri Lanka. At this moment however the RBC system is considered the most feasible system, because of little land requirement, simple operation and relatively low operational costs.
5.3 Wastewater treatment for small production units

The discharges of wastewater from small rubber production units (small holders), manufacturing RSS rubber generally cause less environmental problems than the discharges from larger crepe rubber factories. Pollution problems may, however, occur in areas with a high concentration of small holders. A recent development in the Sri Lanka rubber industry is the foundation of Group Processing Centres (GPC's). In the GPC's the latex from varying numbers of small holders (up to 100) is processed into RSS rubber.

These GPC's discharge a relatively large volume of wastewater with a high concentration of organics, which may cause water pollution and related environmental problems. Treatment of the wastewaters from small production units and GPC's may be required in the near future due to the increasing water pollution problems, the development of stricter wastewater discharge quality standards and the increasing awareness of the public regarding environmental issues.

Alternative wastewater treatment or disposal methods can be applied for the relatively small wastewater volumes from small production units and GPC's.

These methods are irrigation, overland flow, septic tanks, infiltration beds and small ponds. The design parameters for these methods are briefly discussed hereafter.

1. **Irrigation**

Irrigation has been discussed also in Section 5.2. The wastewater is stored and neutralized, and rubber particles are removed from it. Subsequently, the wastewater is transported to rubber or coconut lands to be irrigated.

2. **Overland flow**

In an overland flow system the wastewater is applied to the land. It subsequently flows over the land, in which process pollutants are removed by adsorption by the soil and plants and by aerobic biodegradation. Most important design criteria are the land slope, the application rate, and the type of soil and vegetation. Overland flow systems are often operated intermittently.

A typical land slope is 4% and a typical hydraulic application rate is 0.025 m/d.

3. **Septic tanks**

The septic tank is an anaerobic wastewater treatment system which is generally applied for pretreatment of domestic wastewater. In can also be used for small flows of industrial wastewaters, containing high concentrations of suspended solids and biodegradable organics.

In a septic tank the solids and floating material are separated from the wastewater and organic material is biodegraded anaerobically.

The septic tank has to be desludged periodically. The design loading rate is approximately 50 g BOD/m² tank per day.
4. **Infiltration beds or -channels**

This wastewater treatment method can only be used for pre-treated wastewater from which suspended solids and coarse materials have been removed. Effluent from septic tanks is often further treated in infiltration beds or -channels.

An infiltration bed consists of some layers of filter material (usually sand and gravel). The wastewater is applied to the surface of the bed. In the infiltration bed the pollutants are adsorbed and bio-degraded.

The filtered wastewater disperses into the subsoil or can be collected in a drainage system under the infiltration bed. The design depends highly on the local soil properties. Generally a land area of $3 \cdot 6 \text{ m}^2$ per 50 g BOD$_5$ is required.

The infiltration channel system consists of a number of drainage pipes, usually surrounded by filter material, to which the wastewater is fed. The wastewater percolates from the pipes into the filter and the subsoil, where adsorption and biodegradation take place.

**Discussion**

The above discussed methods are all suitable for disposal of wastewater from small rubber manufacture units. If the infiltration system is chosen the wastewater should be pre-treated, e.g. in septic tanks.
6. DISCHARGE AND EMISSION STANDARDS

Since the natural rubber industry causes no atmospheric pollution, specific emission standards are not relevant for this type of industry.

The Sri Lankan Government has set specific quality standards for the discharge of natural rubber industry wastewater into inland surface waters.

These standards are given in Table 6.1.

Table 6.1 Sri Lankan standards for discharge of natural rubber industry wastewater into inland surface waters

<table>
<thead>
<tr>
<th>Component</th>
<th>Maximum allowable concentration</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>6.5 - 8.5</td>
</tr>
<tr>
<td>Suspended solids</td>
<td>100 mg/l</td>
</tr>
<tr>
<td>Total solids</td>
<td>1000 mg/l</td>
</tr>
<tr>
<td>BOD</td>
<td>50 mg/l</td>
</tr>
<tr>
<td>COD</td>
<td>400 mg/l</td>
</tr>
<tr>
<td>Total Nitrogen (as N)</td>
<td>60 mg/l</td>
</tr>
<tr>
<td>Ammonium Nitrogen (as N)</td>
<td>40 mg/l</td>
</tr>
<tr>
<td>Sulphide</td>
<td>2 mg/l</td>
</tr>
</tbody>
</table>

From the previous chapter it can be concluded that an effluent BOD of 50 mg/l cannot be achieved by the described biological systems. Evaluation of these systems has indicated that pond systems are hard to be applied because of land shortage and possible odour nuisance, and that the oxidation ditch system has very high operational costs.

Rotating Biological Contactors are considered the most feasible system, but an effluent BOD concentration below 100 mg/l is difficult to achieve with this system.

Therefore, for practical and economic reasons, it is proposed that an intermediate effluent quality standard with an allowable effluent BOD of 100 mg/l is introduced.

In a later stage the effluent quality could be improved by installation of a second step treatment system, which could consist of a maturation pond, an aeration unit or additional Rotating Biological Contactors.

It is also possible that the Rotating Biological Contactors are preceded by preliminary treatment in an anaerobic reactor. This would depend, however, on the results of experiments regarding anaerobic treatment of rubber factory wastewater.

The waste stream standard for natural rubber production should be based on a raw wasteload of 60 kg BOD per t rubber produced.
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