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STUDY ON SYNTHETIC VERSUS NATURAL PRODUCTS:

Pilot Project on the Rubber Industry and its Impact on the Environment.

A case study in India and the United Kingdom of Great Britain and Northern Ireland prepared under the joint UNIDO/UNEP Environmental Programme

by

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id. 75-6162

We regret that some of the pages in the microfiche copy of this report may not be up to the proper legibility standards even though the best possible copy was used for preparing the master fiche

Explanatory notes

Reference to "tons" indicates metric tons.

Reference to "dollars" ($) indicates United States dollars.

The term "billion" is used to signify a thousand million.

Use of a hyphen (-) between dates representing years signifies the full period involved, including the beginning and end years, e.g. 1971-1973.

A slash (/) between dates representing years indicates one year that is not a calendar year.

The unit of currency in India is the rupee (Rs). During the period of the project, the operational rate of exchange was Rs 7.50 = $1.00.

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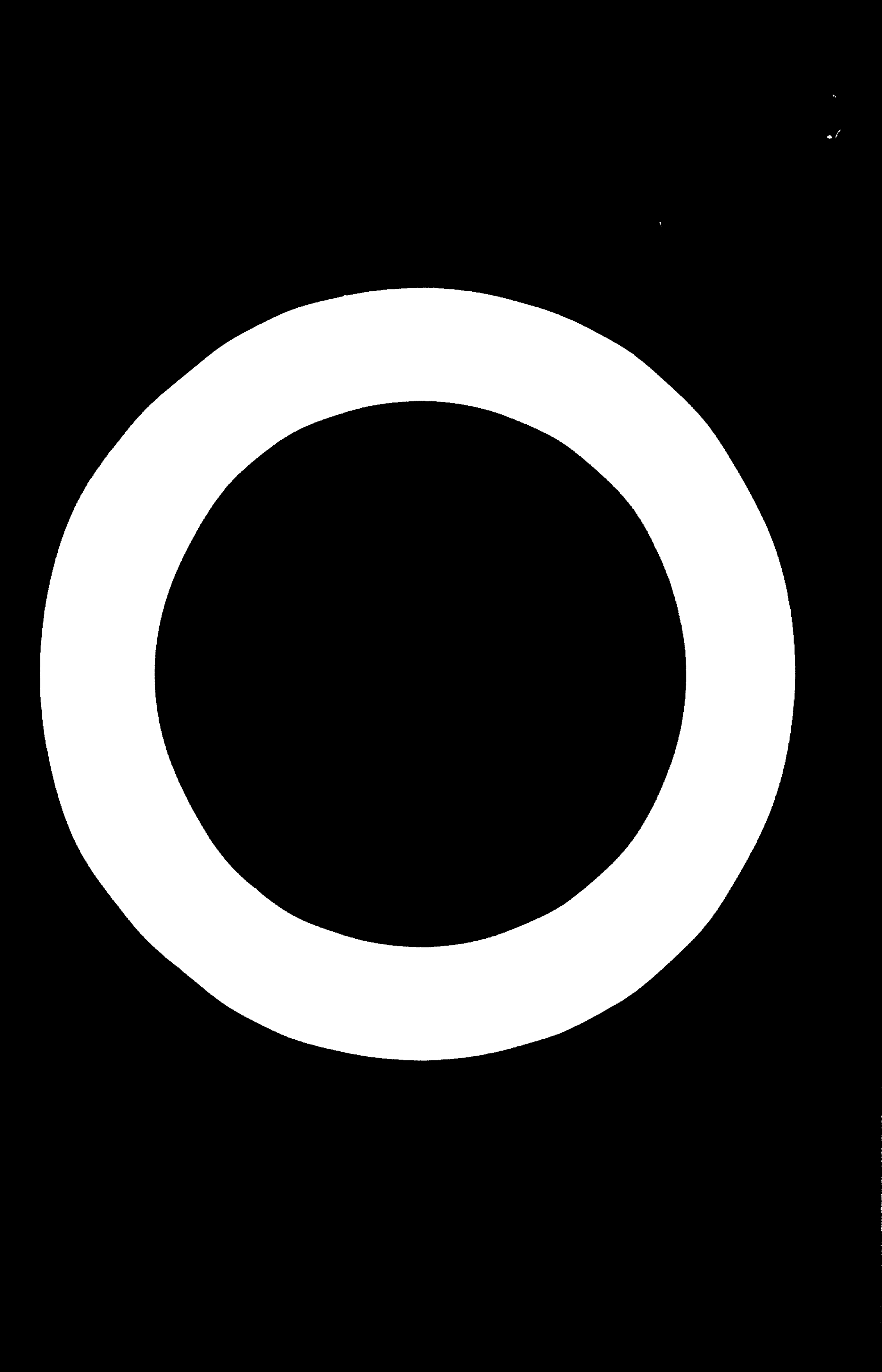


INTRODUCTION

Following the United Nations Conference on the Human Environment, held at Stockholm in 1972, the United Nations established the United Nations Environmental Programme (UNEP). The United Nations Industrial Development Organization (UNIDO) and UNEP are now collaborating on a programme concerned with the effects of industry on the environment in developing countries.

One of the projects being undertaken jointly by UNIDO and UNEP is a "Study on synthetic versus natural products: pilot project on the rubber industry and its impact on the environment". The purpose of the project is to study the environmental impact of the rubber industry, to determine the extent to which environmental considerations should influence the choice between natural and synthetic rubber production, and to examine manufacturing processes and the disposal or recycling of wastes. Detailed studies were made by consultants on specific aspects of the subject, and these were examined by an Expert Group that met in Vienna in September 1974. One of the recommendations of the Expert Group was that a detailed study of the environmental impact of the rubber industry in one or two limited areas be undertaken, since the reports of the consultants represented only a general survey of the environmental problem.

Consequently, it was decided to send a team of two experts to undertake the study in two countries, namely, India, a developing country in which both natural rubber and synthetic rubber are produced and rubber products are manufactured on a large scale, and the United Kingdom of Great Britain and Northern Ireland, a developed country in which synthetic rubber production is well established.

The team spent approximately a month (13 February - 20 March 1975) in India studying the production of the following:

Natural rubber
Synthetic rubber
Rubber products
Retreaded tires
Reclaimed rubber

The team also visited the government departments responsible for environmental controls.

In the United Kingdom, the team spent a week (31 March - 3 April 1975) studying synthetic rubber production, discussing problems with pollution-control officers and studying the work of the Department of the Environment.

The team also studied existing and proposed legislation in both countries.

With only a limited amount of time and money available, the team was able to make only a qualitative survey. The team had to rely on the analyses of effluents provided by the factories visited except in one case where it was able to obtain the services of the National Environmental Engineering Institute (NEERI) in India to carry out an analysis of effluents.

This report is based on the findings of the team of experts. It is one of a series of case studies being carried out under the UNIDO/UNEP programme. Others in the series deal with the chemical industry in Turkey, the textile industry in Thailand, the cement industry in Iran, an integrated iron and steel mill in Brazil and the chemical industry in India.

Acknowledgement is made to the Department of Science and Technology of the Government of India for the assistance it extended to the team while it was in India and to the British Association of Synthetic Rubber Manufacturers for arranging the visit to one of the well-known synthetic rubber plants in the United Kingdom.

I. PRODUCTION OF NATURAL RUBBER IN INDIA

General survey of rubber cultivation on plantations

Natural rubber is produced from the latex of the rubber tree (Hevea brasiliensis) and latex is synthesized by nature within the tree. The tree has to be planted and cultivated for about six years before it starts yielding the product. The latex is extracted by cutting a "V" notch on the bark about 1 m above the ground.

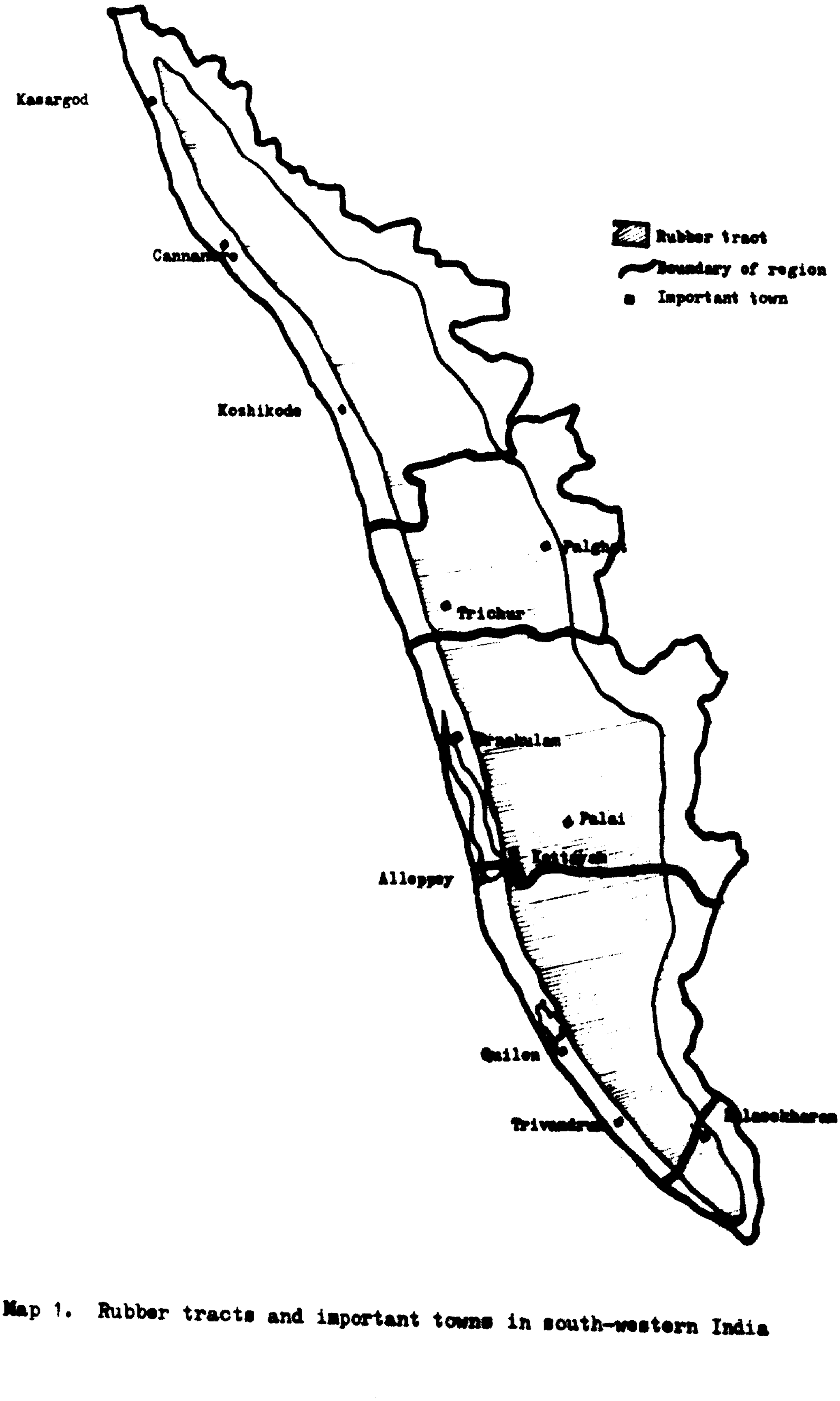
Rubber cultivation in India is confined largely to the south-western region of the country, mainly in the State of Kerala and partly in the States of Tamil Nadu and Karnataka. The rubber plantations are mainly situated in the midland region between the low coastal areas and the high mountain areas in a narrow belt approximately 400 km in length running parallel to the Western Ghats mountains. The region receives a heavy annual rainfall and the weather is warm and humid. Map 1 shows the rubber-growing areas in south-western India.

Small holdings occupy 69 per cent of the total area in which rubber is grown. Recently a co-operative marketing federation was formed to strengthen the organization of co-operatives for the benefit of the small holders.

The Indian Rubber Board plays an active role in developing rubber cultivation. Subsidies for replanting, loans for new planting, distribution of fertilizers and fungicides at concessional rates, distribution of high-yielding planting materials and assistance to rubber- marketing co-operatives are some of the measures implemented by the Board.

The research and development activities of the Board are financed by the tax collected at the rate of 30 paise (Rs 0.3,$0.04) per kg of all rubber produced in India and deposited with the Central Government. The annual tax collected amounts to about Rs 35 million. The Rubber Research Institute of India (RRII), which was established in 1955, has done some commendable work in evolving high-yielding clones, in experimenting on yields and in formulating cheaper fungicides. It has also made recommendations on manuring. One of the clones developed, RRII 208, appears to be most promising, with a yield potential of about 4,000 kg/hectare as against the average yield of 730 kg/hectare.

RRII has also undertaken the breeding of clones with objectives other than high yield, e.g. disease resistance, drought tolerance, wind resistance, desirable



Map 1. Rubber tracts and important towns in south-western India

canopy. The Institute has helped to make a start in the production of technically specified rubber to assist small growers to improve the quality of the rubber they produce.

Employment and conditions of labour

The population of Kerala was 22.75 million in 1974, of which the number of persons employed in cultivating rubber on plantations - owners, workers and members of their families - is estimated at 1.45 million, or 6.37 per cent.

One of the objectives of the Rubber Board is to achieve better working conditions for the workers. The natural rubber industry is an important source of employment in Kerala, which is not highly industrialized.

Well over 150,000 persons are employed in rubber cultivation. Men, women and adolescents are employed in the plantations. Earlier, children were also employed, but now the use of child labour has been prohibited by statute. The percentage of men employed is 69; women, 30; and adolescents, 1. They are distributed among three main occupational groups of tappers, general workers and factory workers in the ratio of 50, 40 and 10, respectively.

Some of the benefits for workers on plantations are described below.

In 1957/58, a scheme for granting stipends to children of workers on the plantations was launched. In that year 128 students received stipends; in 1972/73, 1,185. The amount disbursed under the scheme rose from Rs 1,428 in 1957/58 to Rs 177,353 in 1972/73.

The Board gives grants to hospitals to construct wards for the benefit of rubber plantation workers. So far eight hospitals have availed themselves of these grants, and a total of Rs 287,486 has been paid out up to 1974. Under the Plantations Labour Act of 1951 it is the responsibility of the employer to grant medical facilities to workers in the plantations. The Act applies to rubber plantations having an area of 10.1 hectares or more, but 97 per cent of the plantations are too small to come under the scheme. The Board has consequently formulated a scheme to grant relief to workers in cases of distress and prolonged illness.

The Board is working out plans to provide homes for orphans and destitute adults.

The Board has set up a school to train tappers. So far around 600 persons have been trained. The training lasts for eight weeks, during which period the trainee receives free lodging and a small stipend per day.

The relations between employer and employee on the rubber plantations have been good compared with those in manufacturing industries in India. Joint consultation machinery works quite satisfactorily. Apart from being assured of a minimum wage, the plantation workers are paid according to an incentive scheme. The plantation labour has been the first in India to receive the payment of an annual bonus, and also a lump-sum retirement benefit.

The growing tendency of fragmentation of the estates into small units is likely to affect living conditions of the workers, particularly with regard to housing, hygiene and health.

Another problem will be the existence of educated, unemployed dependants of plantation workers in the future, who may not wish to take up work on plantations; even if they were willing to, there may not be enough work for them.

Effect on the national economy

In 1972/73, production of natural rubber in Kerala, amounted to 106,000 tons, valued at Rs 500 million. The net domestic product of Kerala in that year was Rs 14,460 million at current prices. Rubber formed 3.5 per cent of the net domestic product of the State in that year.

During the last 25 years the area under rubber cultivation has increased from 63,000 to 212,000 hectares, a phenomenal increase of 236 per cent. Production of rubber has increased from 15,000 to 112,000 tons, an increase of 647 per cent. Productivity in terms of yield per hectare has increased from 320 kg/ha to 730 kg/ha, an increase of 128 per cent. Natural rubber is no longer imported.

Effect on the environment

Agro-climatic conditions suitable for successful rubber growing exist in the centre of the south-western region of India. The land in this area consists of low hills and hillocks of varying sizes and heights and the resulting valleys. Though rubber is the main crop at present, large-scale planting of new rubber in the non-rubber areas should be considered ecologically sound for the following reasons, even though it is recognized that large-scale new planting will adversely affect production of food crops, particularly tapioca, which is the second staple food (next to rice) grown in the area

(a) Scientific rubber cultivation in which a legume ground cover is also grown in association with rubber stabilizes the soil;

(b) Food crops cannot be cultivated permanently in this area without soil erosion;

(c) Rubber cultivated according to latest scientific methods, in which importance is given to soil-conservation techniques, can serve as a better reforestation crop than some of the forest crops which are usually planted in the region;

(d) Rubber trees purify the atmosphere by absorbing carbon dioxide and releasing oxygen;

(e) The only non-renewable resources consumed in the cultivation of rubber are fertilizers and the chemicals used to stimulate growth.

Processing of natural rubber

Latex is generally processed in the following forms:

Preserved latex in various concentrations

Ribbed smoke sheets

Crumb rubber or block rubber

Crepe in different qualities

Preserved latex in various concentrations

The team visited two factories of a private company owned almost entirely by one family in Kerala. One factory is at Kodimatha and the other at Chenappady. The latter factory has its own plantation of about 300 acres. The factories process rubber mostly as concentrated latex. The combined yearly production capacity of the two factories is 6.5 million litres of 60 per cent concentrated latex by the centrifuge process. The two factories employ 213 persons.

Process and production

Fresh latex collected from the rubber tree usually contains 30-40 per cent dry rubber, 3 per cent non-rubber constituents and the rest water. Like milk, it is an excellent medium for the growth of bacteria and therefore coagulates on keeping, owing to bacterial action. Preservatives are added to prevent bacterial action and stabilise the latex. The most commonly used latex preservative is 0.7 per cent of ammonia. A variety of chemicals with a low level of ammonia of about 0.2 per cent can also be used.

Although a few latex rubber goods can be manufactured from preserved field latex, it is uneconomical to pack and transport over long distances at the low level of concentration. Therefore, preserved field latex is produced and marketed only to meet local demand. But when part of the water has been removed for economy in packing and transporting, concentrated latex is an important form in which to market natural rubber.

In the centrifuge process, latex is subjected to centrifugal force in the separator and split into two fractions, the cream, with dry rubber content (drc) of 60 per cent and skim, drc, 5-10 per cent. The non-rubber constituents of the skim will be more than those of the cream.

Figure I gives a flow chart for the production of concentrated latex.

Daily production data for each of the two factories is as follows:

Input - 110 drums each containing 205 litres of ammoniated and settled field latex

Output - 50 drums, or 10 tons, of 60 per cent concentrated latex, and 60 drums of skim latex, a by-product containing approximately 10 per cent dry rubber

Consumption of water - 20,000 gallons for washing and processing of skim latex into the skim crepes

The Chenappadi factory obtains about 15 drums of latex from its own plantation. The other 95 are purchased from other plantations in the Iddikki and Kottayam districts at the normal concentrations of 30-40 per cent dry rubber. Figure II gives a diagram for the layout for the centrifuging process in the first factory.

The equipment, De Laval-type centrifuging machines, is identical in both plants. The only difference is that at the first factory the latex is air-lifted from the settling tanks to feeding tanks and from the cream-reception tank to the storage tank, but in the second factory the entire operation is done by gravity feeding making use of the natural slope of the land on which the factory is situated.

It is proposed to manufacture master batches of carbon black with natural rubber. This material is not at present manufactured in India. Use of this material will be advantageous to the tire manufacturers. The master batch can be added direct to the mix, which reduces the time required for the mixing and

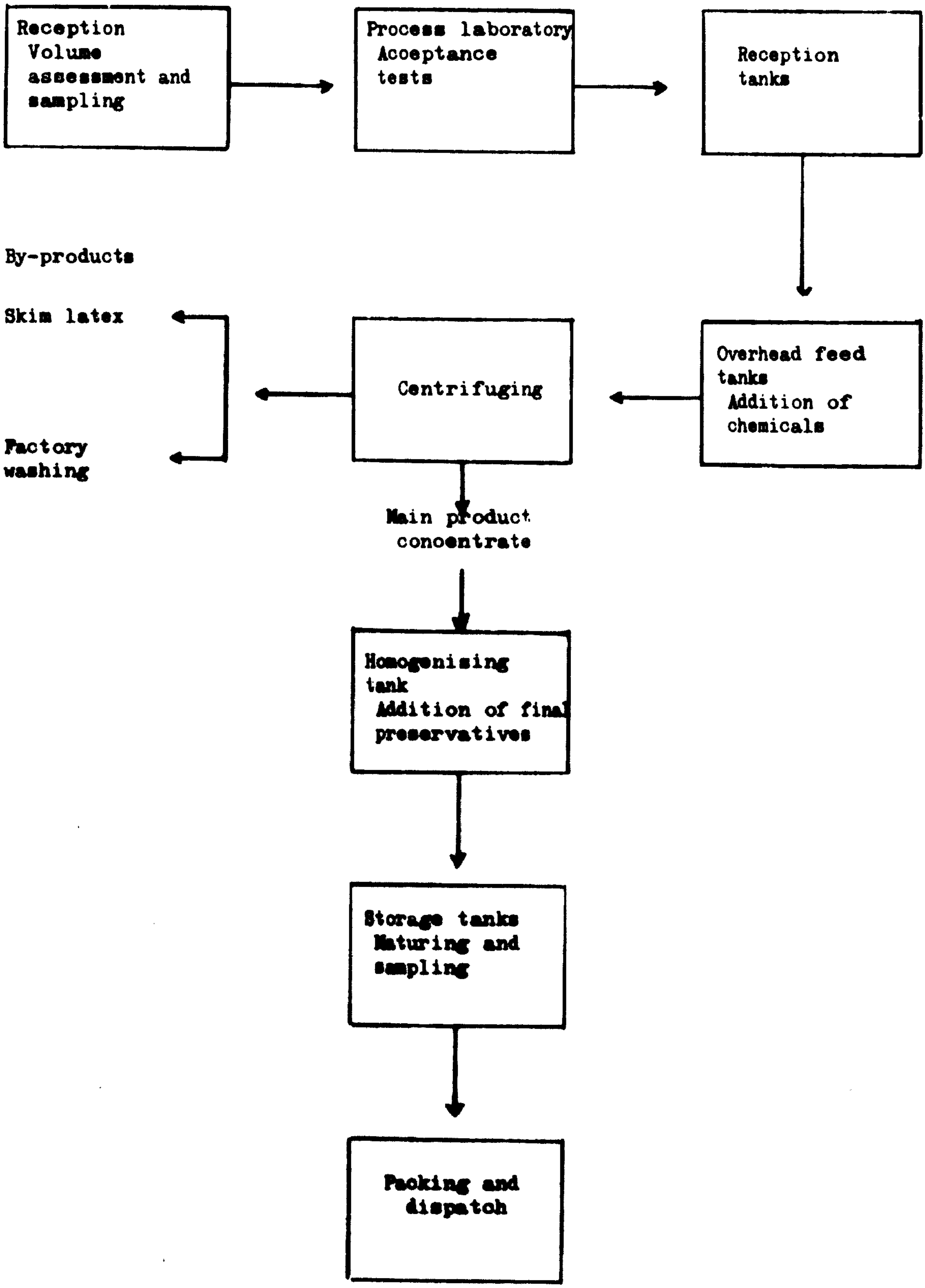


Figure I. Latex concentration by centrifuge process

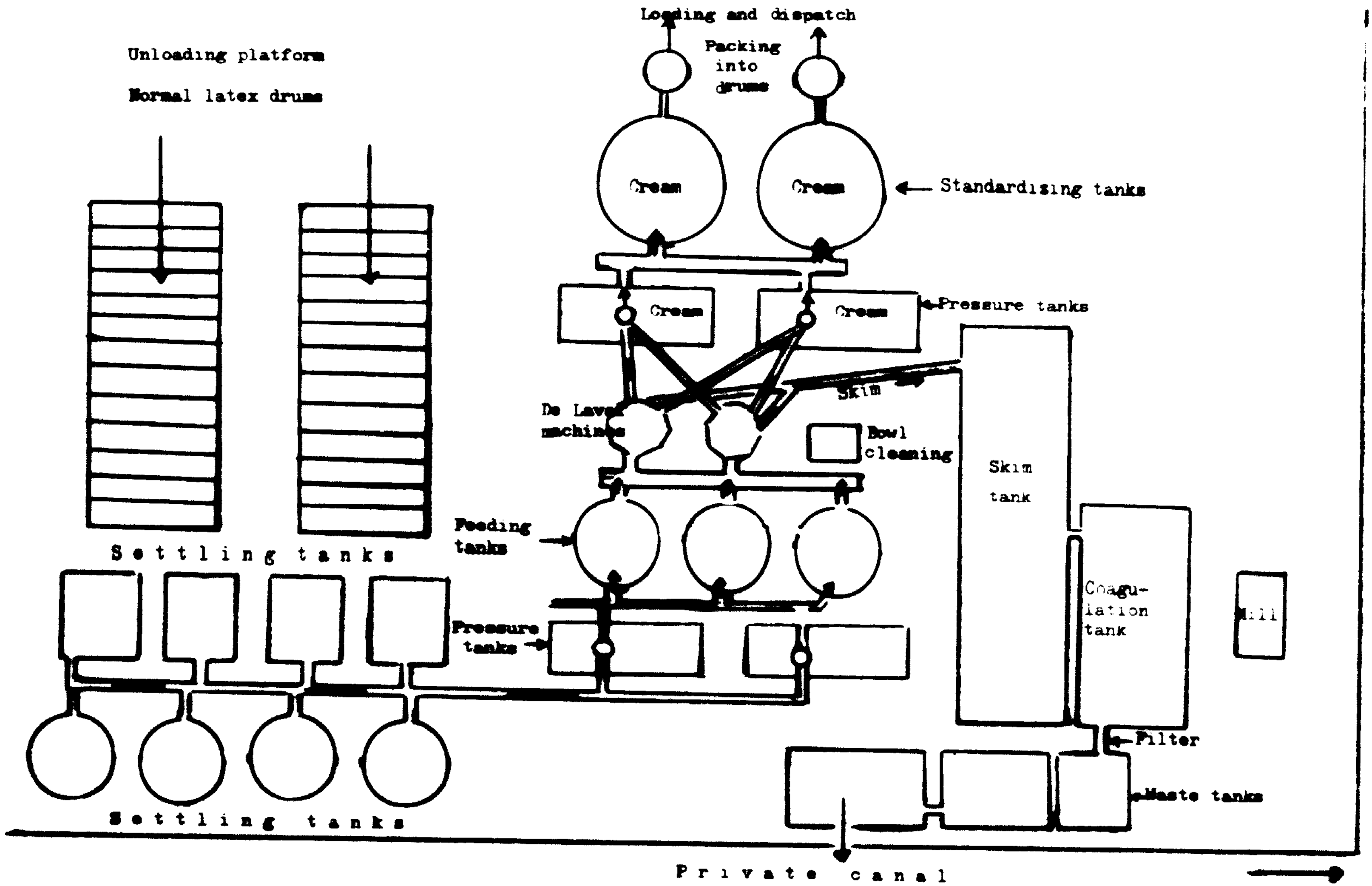


Figure II. Layout diagram of latex concentration plant

consequently increases the capacity of the mixing plant. Also, electricity consumption in the tire plants can be reduced. By eliminating the messy handling of free carbon black, pollution problems, as well as housekeeping problems, will be solved in the tire plants.

Effect on the environment

Gaseous emissions

The smell caused by the putrefaction of protein and other non-rubber constituents in the skim latex is one of the main problems. The odour emanating from the Kodimatha factory is smelled even at a distance from the factory. People who pass over the bridge on the main central road adjacent to the factory get the full impact of the odour. The odour inside the factory is stronger when the factory is not operating, since the ammonia used in processing helps to counteract it. The effect of ammonia on the human system is well known. No adverse effects were reported.

Effluents

The effluent problem starts with the skim latex separated from the centrifuging machine as a by-product of the concentrated latex. The route it takes is as follows:

Skim latex reception tank
↓
Coagulation tank
↓
Waste tanks ⟶ discharge into a river or stream

Skim latex from the centrifuging machines is collected in tanks and released into the coagulation tank, where dilute sulphuric acid is added to effect coagulation. The liquid waste after coagulation flows into waste tanks.

There are three waste tanks at the same level in the first factory, whereas in the second factory they are at different levels, and the waste flows from one tank into another through filters by gravity. In both cases the waste tanks are outside the main building and are exposed to the open air.

In the factory at Kodimatha the effluent from the waste tanks after natural aeration is released into the private canal that runs in the company's own land, which in turn flows into the the Kadoor River. The river is full of water all year round and feeds into Lake Vempanad at a distance of 3-4 miles. From May to October the monsoon floods merge the river with the adjoining paddy fields. The level of concentration during the monsoon is not significant, but during other times the position has to be watched. Table 1 gives an analysis of the effluent. No complaints from outsiders were reported.

Table 1 A. Analysis of effluent from factory at Kodimatha on 17 May 1975

Test	Results
Colour	Creamy white
Odour	Musty odour
Appearance	Turbid viscous liquid
Reaction	Highly acidic - 10 ml of the sample consumed 1.6 ml of 1 N NaOH to become neutral
Total solids	5.1595 g/100 ml
Ammoniacal N	4.404 mg/ml
Total N	4.732 mg/ml
Reducing sugar	0.52 mg/ml
BOD	7681 ppm

B. Microbial population

Only rod-shaped yeasts and a few coccoid bacteria were observed.

When neutralized with lime, white precipitation took place and the liquid turned brown.

In the factory at Chenappadi, the effluent from the waste tanks is let out through drains into shallow pits dug in the company's plantation. The Manimalai River, which is only partially full in the summer months, runs adjacent to the plantation and factory site, and some quantities of the effluent seep through the earth and find their way into the river. During the monsoon months the river is flooded and seepage has no appreciable effect. There have been no complaints from the villagers using the river water for bathing, agriculture and for watering cattle. The seepage into the soil is considered to enrich the soil in the adjacent areas of the rubber plantation. (See photograph.)

One of the settling tanks with the partially dry
river in the background

Pollution is caused by the discharge of effluents from the processing factories, and analysis results published indicate that the effluents from factories producing concentrated latex contain the highest concentration of undesirable oxygen-absorbing materials.

Studies indicate that the processing factory effluents can be sufficiently purified so that they can be discharged without any harm to rivers and streams by subjecting the effluent to aeration and sun and then seeding with an appropriat algal culture, preferably an inoculum containing chlorella as the dominant species

Solid waste

The coagulated latex obtained from the coagulating tanks is used for making crepe rubber. At the Kcdimatha factory, the creping is done in a unit on the opposite side of the river, whereas in the Chenappadi factory it is done on the same premises. Equipment required for creping consists of a battery of marceratora crepers and smooth rollers.

Sludge containing mostly magnesium ammonium phosphate and rubber particles is removed from the latex reception and settling tanks periodically. If it is dried and passed through a specially designed granulator, the magnesium ammonium phosphate can be removed from the rubber particles. In actual practice the sludge is sold to small traders who recover the rubber from it.

Sludge is also collected periodically from the centrifuge bowls when they are cleaned. Usually 10-15 kg of bowl sludge per day is obtained from each of the two factories.

Recommendations

Use of closed chutes from the centrifuge to the cream-collection tanks will reduce the emission of ammonia into the air. Besides causing less pollution, it will reduce the loss of ammonia.

Use of Formalin can reduce the foul smell by reducing putrifaction, but it should be pointed out that the smell gives a warning that the BOD level of discharge into the river is high.

The Dunlop method of treating the skim latex with an enzyme (trypsin) has been reported to reduce the foul smell and also give a better-quality rubber. Besides, the BOD level of the discharge will also be reduced. This method, unfortunately, is costly.

Assisted biological coagulation (ABC method) has been recommended in some quarters as a means of recovering better-quality rubber from skim latex and also as a cheaper method. Sugary materials like molasses or pineapple waste are introduced into the skim latex to encourage fermentation leading to coagulation. The smell will be worse as a consequence. The process, however, has not been widely adopted.

<u>Ribbed smoke sheets</u>

Brief description of process

Most natural rubber produced in India at present is marketed as sheet rubber. Sheeting is the only process practicable for small growers. The following are the important steps in this process:

- Reception of field latex
- Straining of field latex
- Standardisation by dilution with water to 12.5 per cent drc after measurement of drc of the sample and allowing fine sand particles to settle
- Addition of dilute formic acid or acetic acid to standard containers (placing partition boards if tanks are big) and allowing complete coagulation
- Flooding of containers with water after coagulation
- Removal of coagulum and sheet in a sheeting battery, the simplest consisting of two small mills, one having a pair of smooth rolls and the other a pair of grooved rolls

Washing the sheets in a washing tank

Drying the sheets for three to four hours in the shade

Drying the sheets in the smoke house at a temperature of 49°-60°C for four to five days or in an air drying shed

Removal, grading and packing

The smallest grower can carry out all the operations in his house using small aluminium containers for coagulation, a set of hand rollers for sheeting, and the house kitchen for smoking. High-quality sheet cannot be produced by this method. First, the small grower has no facilities for standardizing properly the latex and its bulking. Secondly, the sheet can become dirty or contaminated, and the smoking or drying in the kitchen is without proper control. The low-quality sheets produced fetch a low price. It is estimated that there are about 60,000 holdings of less than one hectare. For a large estate, sheeting is not considered economic.

The production and marketing of ribbed sheets have many disadvantages. The ribbed sheets permit only visual grading, which leaves ample scope for faulty and indiscriminate grading. The sheets lack uniformity; dirt, sand and other foreign matter are often found in them. The cost of production is high. To dry the sheets properly takes a long time. They are difficult to store for long periods owing to existence of moisture etc. The costs of transport, handling and storage are high. The packaging is unattractive.

Effect on the environment

Water from washing is spilt all over the premises of the small growers who use the method described above. The serum is usually poured outside the house, causing a smell around it. As compared with the skim from the centrifuge plant, the serum from coagulation is in a dilute form as far as non-rubber constituents are concerned.

Smoke from the smoking chamber, a mixture of smoke, water vapour and air, is released at a height. No problems were reported.

Cleanings from the bulking tank, scrap from the collecting cups as well as from the trees are sold as scrap to smal. ers, who sell it to crepe factories or manufacturers.

Figure III shows a flow chart for the production of sheet rubber.

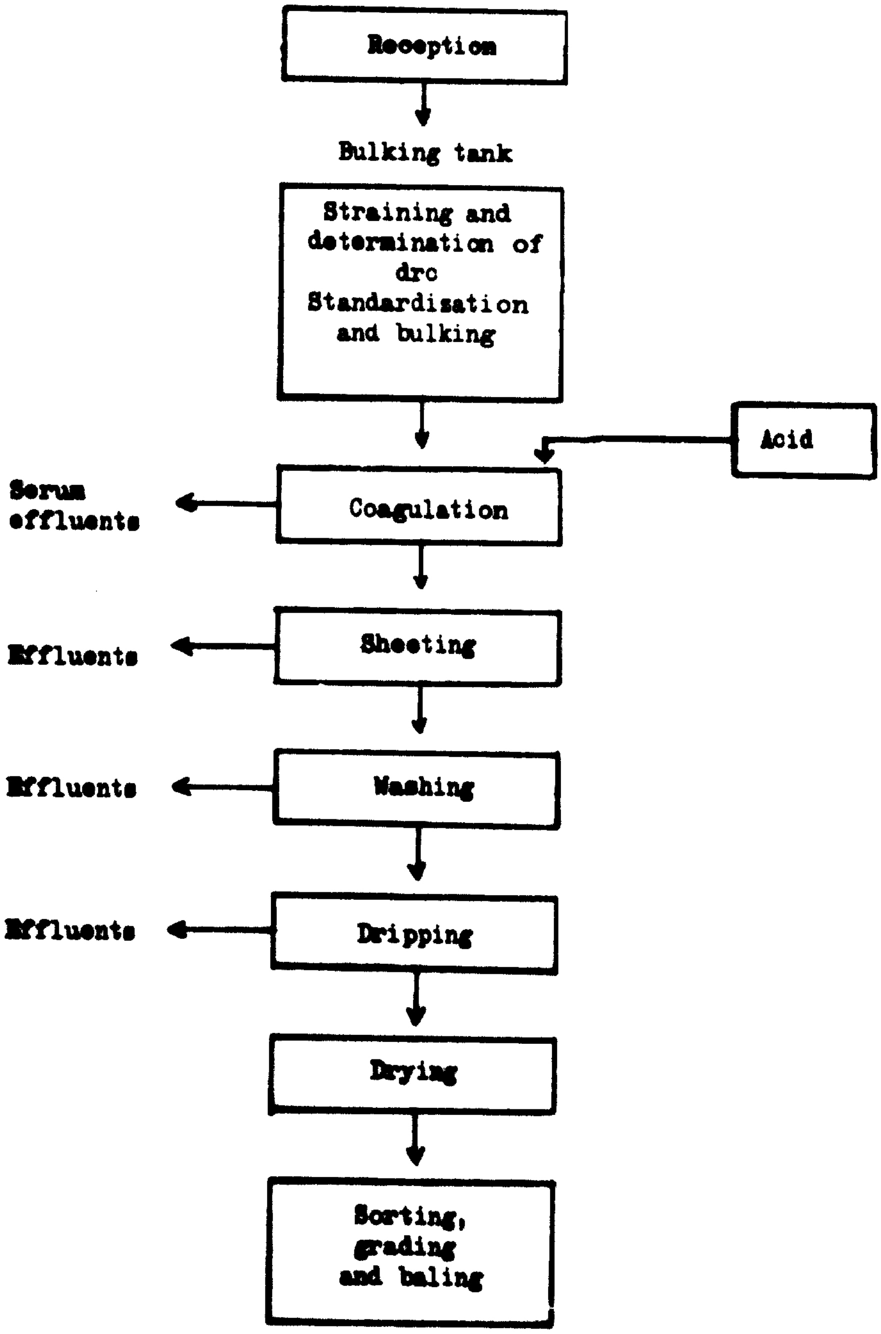


Figure III. Flow chart for production of sheet rubber

Solid block rubber

Processing of natural rubber in solid block form is a most important development since it enables natural rubber to be marketed in a manner similar to that of synthetic rubber and it does not have the disadvantages of ribbed smoke sheets.

Brief description of process

The team visited the factory operated by the Palai Marketing Society, a co-operative society at Palai, Kerala. The Society purchases field latex and scrap rubber from small growers on a commission basis. In its coagulation tanks, the latex is collected and processed into coagulum. The coagulum is transported to the factory for further processing into solid block rubber.

The method of processing involves essentially the following operations: (a) size reduction; (b) de-watering; (c) dirt removal; (d) drying; (e) pressing and baling; and (f) grading. The first three operations are accomplished togethe A set of machines, namely, the macerator rollers and the hammer mill, disintegrat the coagulum or scrap into granules and at the same time remove the dirt and water. The processed granules are then passed on to driers, the temperature of which is kept at about 100°C. The drying time depends upon the size of the particles. Usually four to eight hours is required for the drying. The dried granules are pressed when they are warm (60°C) with a hydraulic press. Bales containing 25 or 50 kg are prepared. Samples are then cut from a few representative bales and tested for technical specification. Grading is based on the test results. The bales are then wrapped in polythene film, packed and marketed.

Figure IV gives a flow chart for this process.

The advantages of the process are:

- Standard quality and uniformity of product
- Improved appearance of product
- Ease in transporting, storing and handling
- Adaptability for using up all the crop material, e.g. latex coagulum, low-grade scrap
- Reduced labour and power costs

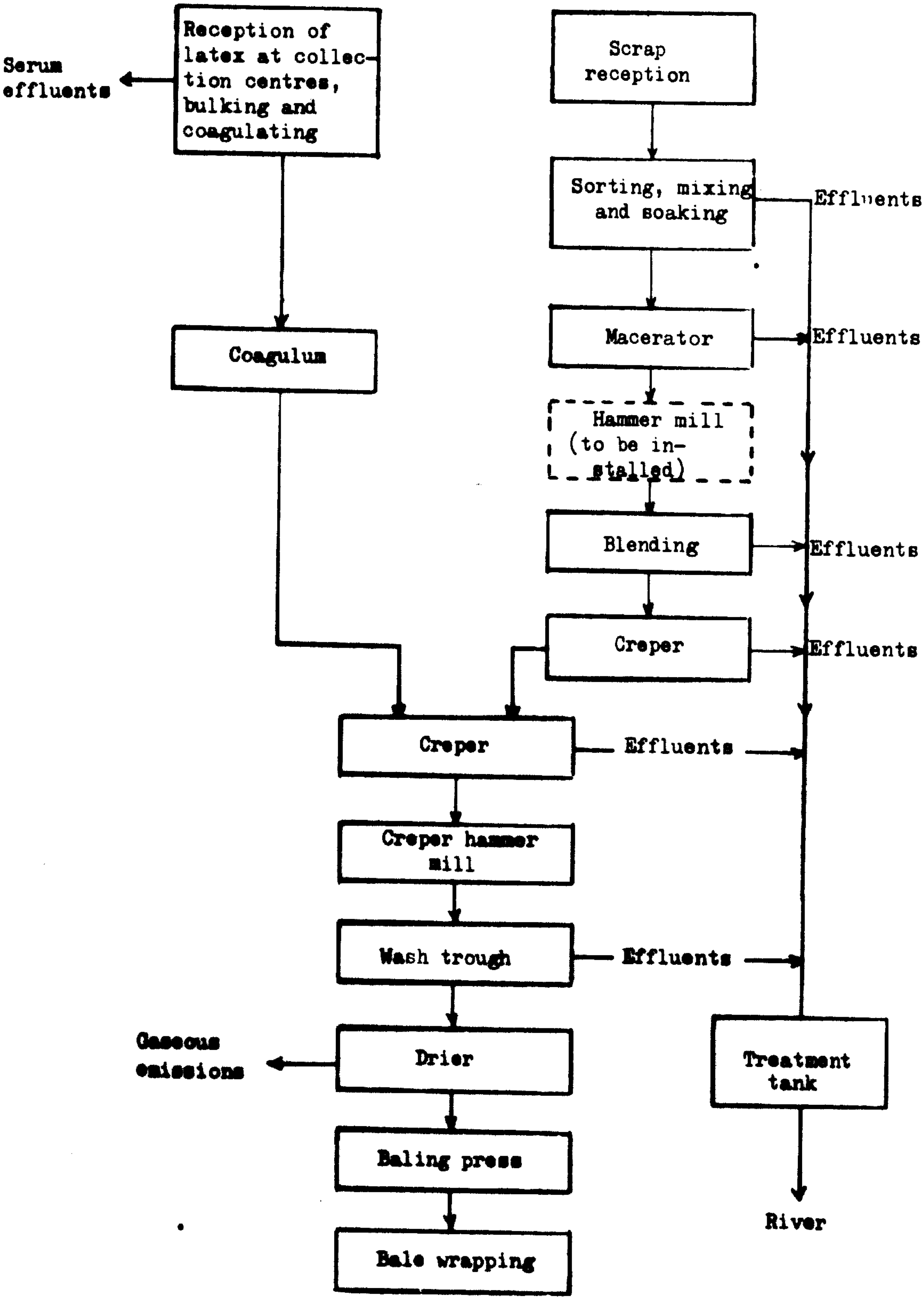


Figure IV. Flow chart for production of solid block rubber at Palai Marketing Society

Effect on the environment

The factory stands in a low-lying area where the water table is high. The effluents are collected in a treatment tank from which the water slowly seeps through the soil into the adjacent river. Table 2 gives an analysis of the effluents.

Table 2. Analysis of tank water and effluents from the crumb rubber factory at Palai, Kerala (Date of receipt of sample 7 January 1974)

Characteristic or component	Tank water	Effluent
Physical		
Appearance	Clear, brown sediments present	Turbid sediments present
pH	6.1	6.0
Electrical conductivity (mho)	100.1	700.0
Chemical	Parts per million	
Alkalinity	44.0	248.0
Chlorides	10.0	26.0
Nitrites	Nil	Nil
Nitrates	Nil	Nil
Sulphates	Nil	15.0
Oxygen absorbed	1.1	157.0
Ammonia free and saline	0.2	15.0
Ammonia albuminoid	Trace	22.5
Total solids	80.0	780.0
Hardness - total	40.0	130.0
Iron	1.4	14.0
Suspended solids	6.0	105.0
Settleable solids		5.0
Sulphides		25.0
BOD for 5 days at 20°C		720
COD		868.0

The public and particularly the rice cultivators objected when the BOD was originally about 700 ppm. With aeration and an algal culture containing chlorella, the co-operative society claims to have brought down the BOD level to 25 ppm.

In summer when the level of water in the river is low, it is proposed to pump the effluents into the nursery for rubber plants. During the monsoons when the river is flooded, the effluents can be discharged into the river without any appreciable effects.

No occupational hazards have been reported.

Crepe processing

Brief description of process

Latex for crepe rubber is coagulated in the same way as for sheet, but for crepe, the coagulum is passed through heavy rollers revolving at different speeds to produce a creping effect. Crepe thus obtained is air-dried, usually in the upper floor at 35°C and not smoked. There are various types of crepe rubber. Superior grades are prepared from field latex under controlled conditions to meet exact specifications, whereas inferior grades are made from all types of scrap rubber.

Effect on the environment

The effect on the environment is similar to that of crumb processing.

Ancillary industries

Several small industries, some of them cottage industries, produce dipped goods from concentrated latex. Such production could be developed further, since it has many advantages, e.g. low capital requirement, a simple process, availability of raw materials and a ready market for the products. Some of the items produced are rubber bands, teats, toy balloons and gloves.

Role of co-operative societies

Co-operative societies that have been established in recent years have helped the small grower immensely by distributing fertilisers, pesticides, acids and other items required, e.g. coagulation dishes, tapping knives at wholesale rates; giving information on methods of planting, manuring etc.; and processing from latex supplied by the member at half of what it would cost him if he were to do it himself, quite apart from the capital expenditure he would have to incur.

The investment in each collection depot run by the co-operative society is only about Rs 15,000 ($2,000). The collection depot is provided with the necessary equipment for processing and testing, equipment that is superior to any the individual member could acquire. There is one collection depot in every 4 sq km of plantation area. (See photograph.)

The society markets the sheets at favourable prices, stocking and selling at the right time. It pays cash for the latex immediately on delivery or on a weekly basis.

The society extends credit to each member up to a certain amount at reasonable interest.

The small grower is spared the time required for processing and selling his produce. He is able to concentrate on replanting or new planting and to look after manuring and other important tasks.

A co-operative collection depot

II. PRODUCTION OF SYNTHETIC RUBBER: FACTORY AT BAREILLY, INDIA

Background

The synthetic rubber factory the team visited in India is located in the centre of the sugar and fermentation alcohol industry in Uttar Pradesh State at Fatehganj-West, 231 km from Delhi and 12 km from the town of Bareilly. The site was selected because of:

(a) Availability of raw materials, i.e. alcohol from molasses, a by-product in sugar manufacture from sugar-cane;

(b) A plentiful supply of water from the river nearby and tube wells, the requirement being 2,000 gal/min for the capacity of 30,000 t/a;

(c) Proximity to waste land and to the river for disposal of effluents;

(d) Easy access to trunk rail and roads;

(e) Availability of land for expansion.

Map 2 shows the location of the plant.

The idea of producing styrene butadiene rubber (SBR) at the time at which the plant was commissioned, 1961, was prompted by the inadequate supply of natural rubber production in India to meet the growing demand for rubber, particularly for tires. India was trying to conserve foreign exchange, which was badly needed for the import of heavy machinery and equipment. At the same time a small SBR factory was readily available from a company in the United States of America at a reasonable cost.

Description of process and production

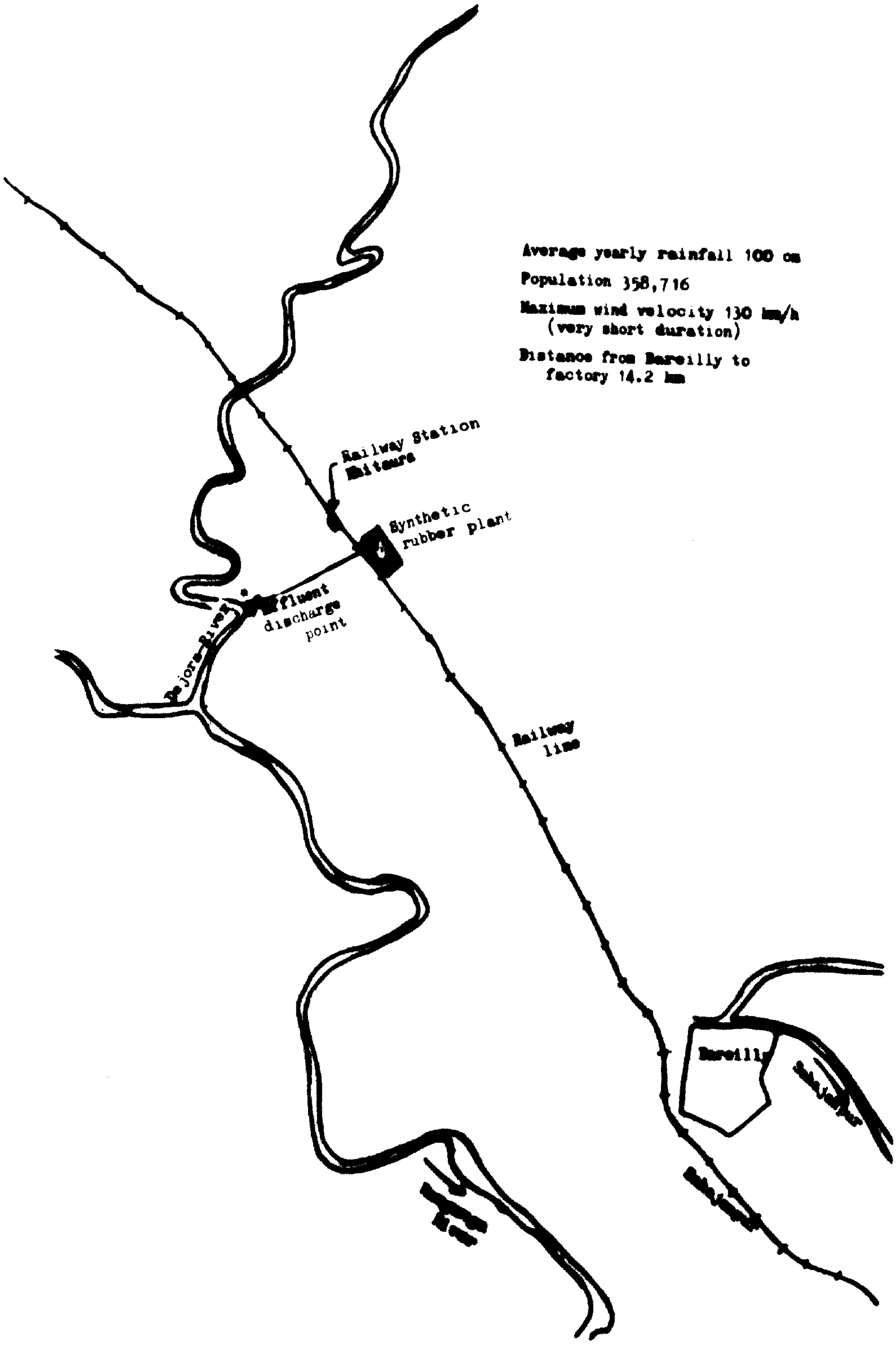
The synthetic rubber factory at Bareilly is divided into the production area, tank farm area, and the utilities, workshop and stores areas.

Production area

The units in this area are designed to make 30,000 t/a of latices and synthetic rubber. The four main processing units are the ethylene and styrene unit, butadiene unit, latex unit and the rubber unit.

Ethylene-styrene unit

In the ethylene-styrene unit, the manufacture of styrene from alcohol and benzene is effected in five major steps.



Map 2. Location of synthetic rubber plant at Bareilly, India

Step 1. Ethylene is produced from ethyl alcohol as represented by the following chemical equation, using a dehydration type of catalyst at high temperatures:

$$C_2H_5OH \longrightarrow C_2H_4 + H_2O$$

Vapours of ethyl alcohol	passed over a catalyst for dehydration	make ethylene and water

Step 2. Crude ethylbenzene, called "alkylate", is produced from ethylene and benzene using aluminium chloride as catalyst as represented by the following equation:

$$C_2H_4 + C_6H_6 \xrightarrow[\text{Chloride}]{\text{Aluminium}} C_6H_5C_2H_5$$

Ethylene	Benzene	Ethylbenzene and by-products

This reaction is carried out in a special type of reactor called an "alkylator". The product, alkylate, consists of ethylbenzene, diethylbenzene, unreacted benzene and some residues.

Step 3. Crude alkylate is purified and separated by distillation into ethylbenzene and other side products.

Step 4. Crude styrene is produced from ethylbenzene using a special dehydrogenation catalyst at high temperature as shown in the equation:

$$C_6H_5C_2H_5 \longrightarrow C_6H_5C_2H_3 + H_2$$

Vapours of ethylbenzene	passed over a dehydrogenation catalyst	make styrene and hydrogen

Step 5. Crude styrene is purified and separated by vacuum distillation to yield pure styrene.

Butadiene unit

In the butadiene unit, a closely integrated, continous operation takes place in three steps.

Step 1. Crude acetaldehyde is produced from ethyl alcohol using a dehydrogenation catalyst at high temperature as shown in the equation:

$$C_2H_5OH \longrightarrow CH_3CHO + H_2$$

Vapour of ethyl alcohol	passed over a dehydrogenation catalyst	make acetaldehyde and hydrogen

Step 2. Crude butadiene is produced from ethyl alcohol and acetaldehyde using a dehydration catalyst at high temperature as shown below:

C_2H_5OH	+	CH_3CHO	$\longrightarrow$	C_4H_6 + $2H_2O$
Vapours of ethyl alcohol	and	vapours of acetaldehyde	passed over a dehydration catalyst	make butadiene, water and by-products

Step 3. In addition to butadiene, gases and oils are also formed in step 2. Hence, elaborate separation and purification steps by distillation listed below are adopted:

(a) Acetaldehyde is recovered, purified and distilled for reuse;

(b) Butadiene is recovered, separated and purified by absorption and distillation;

(c) Gases and oils are separated for use in the plant furnaces;

(d) Alcohol is recovered and purified for reuse.

Latex unit

In the latex unit, copolymerization of butadiene and styrene into copolymer particles, in aqueous suspension, known as latex, is done. Three steps are involved in preparing latex.

Step 1-feed blending. Butadiene and styrene are blended at high precision and emulsified activator, modifier and catalyst are added before the blend is fed to reactors.

Step 2-emulsion polymerization. This reaction is carried out in a series of reactors. The mechanism of reaction is represented by the following equations:

(a) Generation of free radicals

ROOH	+	Fe^{++}	$\longrightarrow$	RO^{*}	+	Fe^{+++}
Hydroperoxide catalyst		Ferrous ion		Peroxyl free radical (* denotes free radical)		Ferric ion

(b) Initiation

The free radical attaches to a monomer molecule, which itself then becomes a free radical.

$$RO^{*} + \underset{\text{Butadiene}}{CH_2{=}CH{-}CH{=}CH_2} \longrightarrow ROCH_2CH{=}CHCH_2^{*}$$

(c) Propagation

The charged monomer molecule adds to other monomer molecules. The addition of styrene and butadiene molecules takes place at random.

$$ROCH_2CH{=}CHCH_2^* + n(CH_2{=}CHCH{=}CH_2) + m(C_6H_5CH{=}CH_2) \longrightarrow$$

Butadiene Styrene

$$RO(CH_2CH{=}CHCH_2)(CH_2CH{=}CHCH_2)_n[C_6H_5(CH{-}CH_2)]_m^*$$

When the desired conversion of monomers is reached, polymerization is stopped by addition of a chemical called "short stop". Figure V gives a flow chart for this process.

Step 3-Feed recovery. Crude latex is further processed by successive flashing and stripping to recover unreacted butadiene and styrene for recycling. The stripped latex is then stored for further processing.

Rubber unit

In the rubber unit, latex is coagulated into large rubber particles, washed, dried, baled and packed. Several solutions needed for various units are also prepared. Effluent treatment and disposal facilities are provided here.

Tank farm area

In the tank farm area, bulk storage facilities are provided for raw materials, benzene and alcohol and for intermediates such as ethylbenzene and reactor oil. This area also includes facilities to handle railway tank wagons and road tank trucks bringing in alcohol from the distilleries of Uttar Pradesh and benzene from the steel plants of Hindustan Steel Ltd.

Utilities, workshop and stores area

The facilities in the utilities, workshop and stores are listed below.

Steam generation and distribution

Two boilers, each with 150,000 lb/h capacity, produce steam at 600 psig pressure. This area also includes coal- and ash-handling facilities. Coal is used as fuel.

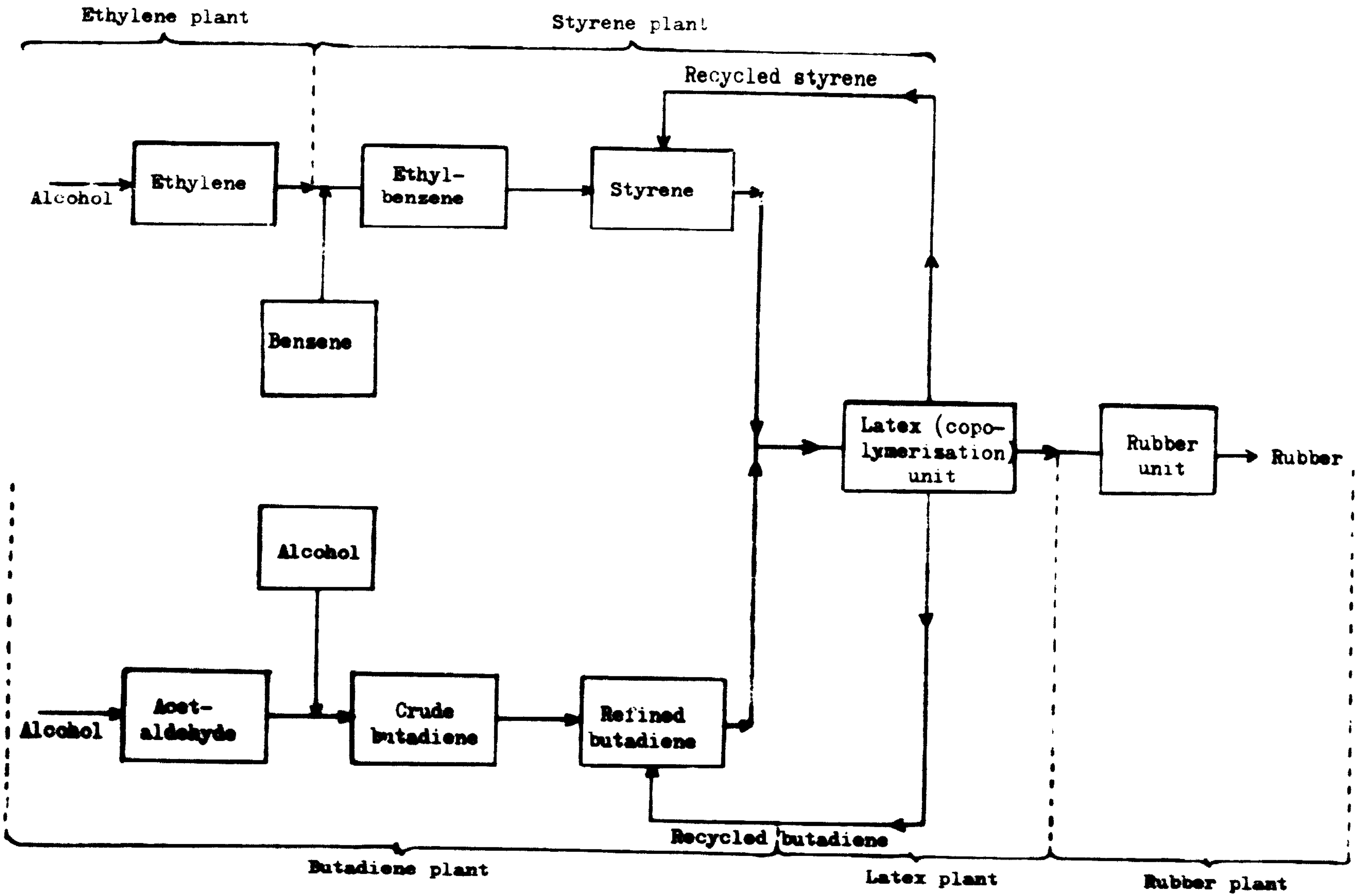


Figure V. Flow chart for production of synthetic rubber at Bareilly

Electricity generation and distribution

Two steam-driven turbogenerators each having 3,000 kW capacity are provided. In addition, a diesel-engine-driven generator of 750 kW capacity is provided for emergency power. Power is generated here to ensure a steady supply.

Water supply and treatment

Fresh water is drawn from five deep tube wells situated along the west side of the factory. Water for steam generation is treated by hot lime, gypsum and magnesium oxide to reduce bicarbonate and silica content followed by pressure filtration and passing through hot zeolite units to remove calcium and magnesium hardness. The recirculating cooling water system is treated with a corrosion inhibitor and sulphuric acid to maintain pH.

Inert gas, brine treatment and miscellaneous facilities

Workshops, maintenance and other stores and warehouses

Effect on environment and health

The factory discharges the following:

(a) Gaseous emissions to atmosphere

Boiler stack	Flue gases 1 x 13,550 SCFM 38×10^6 Btu/h Dust content 0.035 g/SCFM (estimated) 4.4 t/d
Dowtherm furnace Stack	Flue gases 4,550 SCFM 4.7×10^6 Btu/h
Styrene reactor system	Flue gases 3,080 SCFM 1.91×10^6 Btu/h
Butadiene reactor regeneration	Gases 220 SCFM (H_2 burnt) 0.2×10^6 Btu/h
Flare stack	Gases 350 SCFM 2.3×10^6 Btu/h

The flower garden with the synthetic rubber factory at Bareilly in the background

(b) Effluents

To land - Nil

To waterways - 1,236 gal/min

(c) Solid waste

Scrap rubber - 20 t/a (small quantity sold to small manufacturers of wheelbarrow tires, rest disposed of by burning)

Sludge collected from the oil separators (combustibles) - 10 t/a (burnt in open pit away from the plant but within factory area)

Boiler ash - 60-80 t/d (carried over conveyor belts to dumpers, which carry it for land filling)

Gaseous emissions

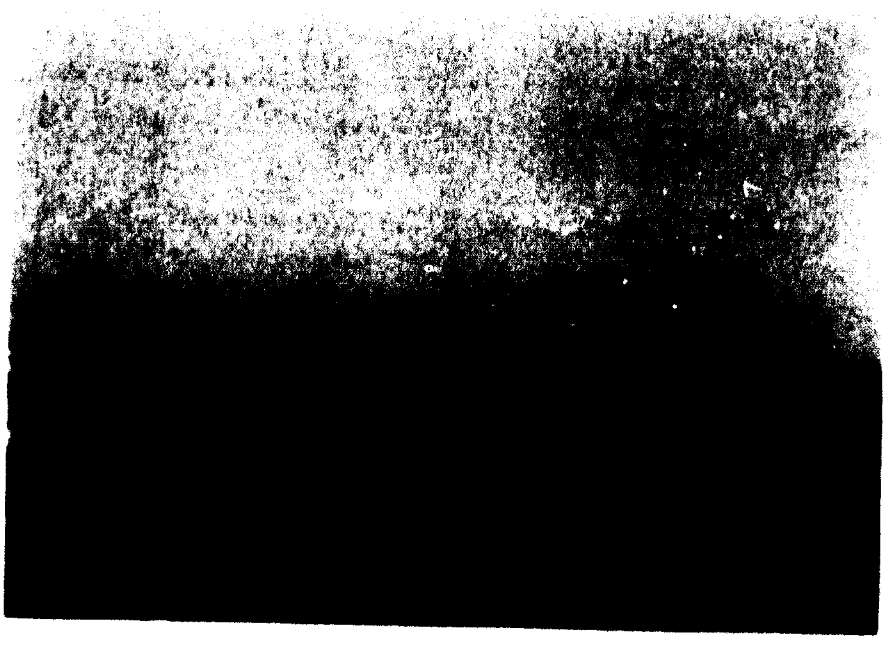
The coal used is of low sulphur content (0.5 per cent). No undesirable effects have been reported as a result of the emissions to the atmosphere. The factory is the only one in the area, which, being an agricultural area, is able to absorb a certain amount of emissions without any significant impact. No bad effects were noticeable in the vegetation around the area. As a matter of fact, the factory has a beautiful flower garden (see photographs).

Effluents

Approximately 5,500 litres/min of effluents are discharged into the Dejora River through a 4-km long pipeline (coated hume pipes) of 30-cm diameter. In the early days the BOD level of the discharge into the river was about 3,000 ppm, and there were complaints from the villagers regarding the strong odour. After treatment, the BOD level now is around 750-1,200 ppm. The effluent standard for BOD set by the Uttar Pradesh State Government is 200 ppm, and the plant authorities have requested the National Environmental Engineering Research Institute (NEERI) at Nagpur to conduct a survey and suggest bacteriological treatment or other measures to improve the quality of effluent to meet the State standards. Dilution in the river is about 1:50 in summer and 1:250 during the rainy season. Map 2 shows how the effluents are discharged.

Approximately 675 litres/min of effluents are sent through settling pits and 10 large lagoons into the Sanka Nulla canal, which is a canal with perennial water used for irrigation. The lagoons are dug in the earth in a zigzag fashion and each lagoon is divided into two to increase the line of flow and detention time. There was algal growth on the surface of the water both in the lagoons and in the canal (see photographs of the lagoons).

One of the effluent-treatment lagoons with the synthetic rubber factory in the background



The canal into which the effluents from the lagoons are released

A typical well-water analysis of the effluent to the Dejora River (1974 average) and of the river water 200 m downstream is given below.

Well-water analysis

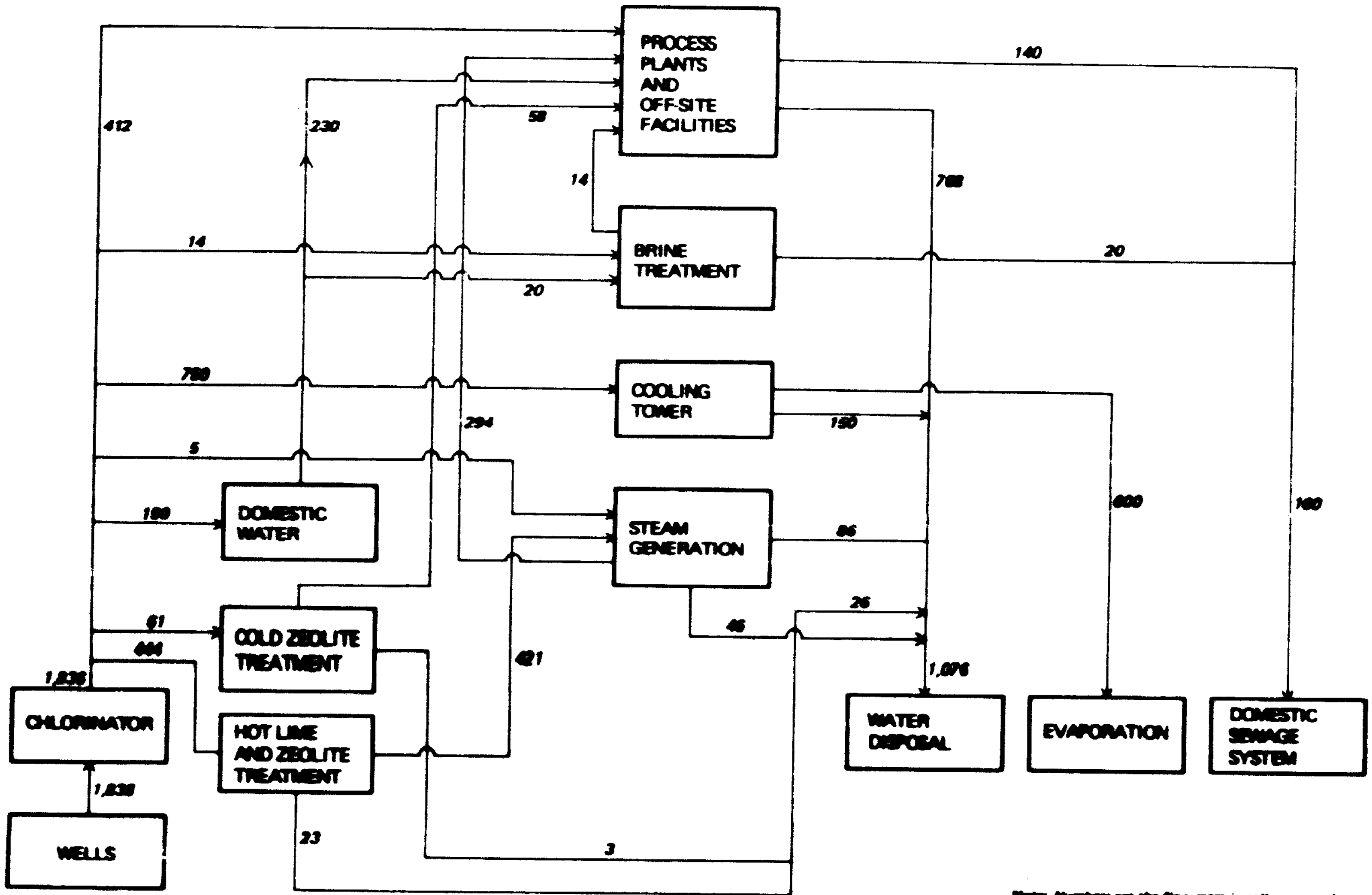
Total hardness (as $CaCO_3$)	55 ppm
M value	242 ppm
Chlorides	38 ppm
Silica (SiO_2)	22 ppm
Ca hardness	40 ppm
Conductivity	495 micromho/cm^3
pH	7.8

Analysis of effluent to the river (1974 average)

pH	5.5 ppm
Turbidity	150 ppm
Total solids	2,865 ppm
Chloroform extractables	194 ppm
Total dissolved solids	2,442 ppm
Chloride (as NaCl)	1,208 ppm
Total hardness (as $CaCO_3$)	491 ppm
Calcium hardness (as $CaCO_3$)	161 ppm
Conductivity	2,855 micromho/cm^3
BOD at 20°C for 5 days	750 - 1,200 max.
COD	200 ppm

Dejora River water analysis 200 m downstream from discharge point on 25 February 1975

pH	8.6
Carbonates (as $CaCO_3$)	62 ppm
Bicarbonates	306 ppm
Total alkalinity	368 ppm
CO_2	Nil
Dissolved oxygen	5.3 ppm
COD	54 ppm



Note: Numbers are the flow rates in gallons per minute.

Figure VI. Block diagram of water balance

Solid waste

The main items of solid waste are soda ash from the water-softening plant and the substandard crumb from the rubber production. The soda ash is used as land fill. From experience in the factory estate, the soda ash has been found to have a salutary effect on plant growth. The waste crumb is used as land-fill or sold for next to nothing.

Resource utilization

There are 5 wells in all, each 108 m deep and capable of giving 2,250 litres/min. Four wells are required for the full capacity of 30,000 t/a of SBR production using approximately 18 million litres/d of water. One fourth of this quantity goes to the boiler, one fourth to cooling water make-up and the remaining half goes for other purposes, including processing. Figure VI gives a block diagram of the water balance using 1,836 gal (8,262 litres)/min from the wells for current production.

The coal-fired boilers consume 450 t/d of coal, or 135,000 t/a. Other raw materials consumed are:

Alcohol (litres/a)	54 million
Benzene (t/a)	2 million
Lime (t/a)	700
Disproportionated resin from pine trees (t/a)	1 thousand
Highly aromatic extender oil (t/a)	3.5 thousand

Catalysts and initiator	Amount (t/a)	Purpose
"Filtrol" (activated clay)	49.8	Dehydration of ethyl alcohol to ethylene
"Shell 105" (iron oxide)	12	Dehydration of ethylbenzene to styrene
"Filtrose" (copper and chromium coated on inert material)	24	Conversion of alcohol to acetaldehyde
Tantalum pentoxide	32–48	Conversion of alcohol and acetaldehyde mixture to butadiene
Paramethane hydroperoxide (PMHP) (Initiator)	50	Initiation of (a) Cold polymerisation at 5°C of styrene and butadiene; (b) Hot polymerisation at 50°C with small quantity of potassium phosphate

The catalysts are disposed of as follows: "Filtrol" and "Shell 105" are dumped as landfill. "Filtrose" and tantalum pentoxide are preserved in drums. Work in progress for reclaiming tantalum pentoxide is particularly expensive.

Occupational hazards

According to the medical officer, there were no occupational diseases except a few cases of dermatitis resulting from contact with acetaldehyde. Regular check-ups of those who come into contact with benzene is required by law, and a register of such persons is maintained. Those employed in sandblasting and spray-painting operations are also examined periodically.

Handling of acrylonitrile monomer in the manufacture of nitrile rubber on a pilot-plant scale is an area of potential danger, and the pilot-plant effluent is isolated, treated with chlorine and diluted prior to discharge.

There is a significant amount of chalk dust in the air where rubber is baled, and the men in the section are constantly inhaling the chalk in the packing section. In other areas hot fumes and ammonia, which can cause respiratory troubles, are quite strong. The sandblasting section, where pipes are sandblasted before being coated, also presents a potential danger to the health of the workers. Gas masks are provided, but, as in many industries, they are seldom used.

Social and economic effects

Social effects

The factory was established in 1961 on a stretch of waste land in the middle of the sugar-cane growing areas. The place was supposed to be an old battlefield and of some historic importance. The team was told that in 1961 not even a cup of tea was available in the area. Today the quiet agricultural village is humming with activity.

When the factory started operation, no skilled labour was available. Workers had only agricultural experience, but they were capable of being trained, which the factory undertook to do. At present the factory employs 1,570 workers. Yearly wages amount to Rs 10 million ($1.3 million)

A housing colony has been established providing accommodation for 220 employees, mostly supervisory staff, who pay subsidised rent. The housing colony is well laid out, and facilities provided include swimming pool, tennis courts, club-house and schools. About 400 workers live in the village nearby and come to the factory walking or on bicycles. Those who live in villages receive a bicycle allowance. Two hundred workers live about six miles away from the factory, i.e. about half way towards Bareilly, in a government housing colony and 750 live in Bareilly itself. Free transport is provided from Bareilly and the government housing colony.

Management takes special interest in safety precautions inside the factory, and the factory won a national safety award in 1973 for the lowest accident rate in the chemical industry and longest accident-free period.

The factory has a medical centre with a full-time doctor in charge. Additional staff consists of one ward boy per shift.

Ancillary industries have been encouraged to spring up in the locality. They make and supply even sophisticated equipment for the factory, like control valves and diaphragms. Equipment and spares, which were previously imported, are produced in the factory's workshop.

Economics of production

For many years the company made no profit. There were many reasons for this. In the first few years the demand for SBR was insufficient to keep the plant running at full capacity. India was importing natural rubber from Malaysia to meet the gap between its requirement and its own production of natural rubber. The tire manufacturers were not keen on switching to SBR, but the Government made it obligatory for them to use a certain percentage of SBR if they wished to obtain licences to import additional natural rubber. The price of SBR, which was fixed by the Government, was higher than that of natural rubber on account of the high cost of alcohol resulting from an extra levy placed on it by the Uttar Pradesh Government.

The company's investment in 1973 was $15.92 million, and the annual sales volume was valued at $14.1 million. Underutilization of installed capacity - production was about 70 per cent of the installed capacity of 30,000 t/a - was due to a shortage of coal and raw materials like benzene besides labour troubles in recent years. In 1973, the year for which the annual report of the company was available, the company's workers went on strike for 77 days.

The company's appeal to the Government to increase the controlled price of SBR did not meet with much success; the Government has referred the question of a comprehensive review of the price structure of synthetic rubber to the Tariff Commission.

The total cost of all antipollution measures does not amount to more than 1 per cent of the total operational costs. This includes cost of chemicals, labour and energy for water and effluent treatment and also the cost of the medical centre.

Expansion and diversification plans

The company has plans to expand, the implementation of which will, of course, depend on (a) availability of raw materials and the demand for SBR, taking into account the requirements to meet the projected demand for tires; and (b) the ambitious programme of the natural rubber industry to double its production by 1980.

The company has a licence to manufacture 2,000 tons of nitrile rubber. Construction of a pilot plant has been completed and pilot production has begun. A pilot plant for nitrile polymers (ABS plastics) is nearing completion and trial runs are expected to commence shortly. The know-how for nitrile rubber and nitrile polymers is based on the process developed at the National Chemical Laboratory, Poona, and the Sri Ram Institute for Industrial Research, New Delhi.

The company has also plans to diversify into the manufacture of steel cord and textile-reinforced and solid PVC conveyor belting.

III. PRODUCTION OF SYNTHETIC RUBBER: PLANT AT HYTHE, UNITED KINGDOM

Background

The company chosen for the study is the largest producer of synthetic rubbers in the United Kingdom of Great Britain and Northern Ireland.

By the end of the Second World War, synthetic rubber had established a place for itself within the rubber industry, but the United Kingdom did not have production facilities. Imports of synthetic rubber rose from 2,773 tons in 1947 to 20,454 tons in 1955. Of the latter figure, about 16,000 tons were SBR. The situation in the industry was becoming difficult, since the country lacked the dollars to pay for imports. No single manufacturer of tires or general rubber goods could afford a captive plant. In November 1955, the company was formed by a consortium of manufacturers of tires and general rubber goods. In October 1958, the plant was officially opened on a 54-acre plot at Hythe near Southampton and well within proximity of the Southampton estuary of the rivers Itchen and Test. It employed 400 persons and had a capacity of 70,000 t/a. Installation cost $12.5 million. It was estimated that the plant would save the country $25 million in foreign exchange annually.

The plant is part of an industrial complex that houses the second largest refinery in Europe of a leading oil company. The refinery provides one fourth of the United Kingdom's petroleum. Nearly 50 per cent of the oil company's investment is in chemical feedstocks to make raw materials for the rubber, plastics, textile and chemical industries. This company produces 44,000 t/a of butyl rubber, used mainly for inner tubes, and is thus the largest producer of butyl rubber in Europe. Other plants in the complex produce polyethylene; organic chemicals; and liquefied air, hydrogen, nitrogen and oxygen.

The major factor contributing to the selection of the site for the synthetic rubber plant was proximity and easy access to the monomer source. The plant is strategically situated less than a mile from the oil refinery, which provides the butadiene monomer and the raw materials for in-house styrene production. A deep-water point had to be selected to facilitate the use of tankers. Besides, a plant of this size needs daily approximately 50 million litres of water for cooling purposes and about 5 million litres for processing. The cooling water is drawn from the sea and the process water from the rivers. The waste water after treatment is discharged into the sea.

[illegible] land was obtained on a [illegible]9-year lease in 195[illegible]. The refinery was built [illegible] reclaimed land, which was marginal as far as agriculture was [illegible]. The terrain of the area consists of gently sloping heath and rough [illegible], varying in elevation from 0 to 35 [illegible] above sea level. Numerous [illegible] and swa[illegible] meadows abound throughout the area. The population [illegible] is [illegible]00,000, including surrounding areas, 350,000. Map 3 shows [illegible] plant is located.

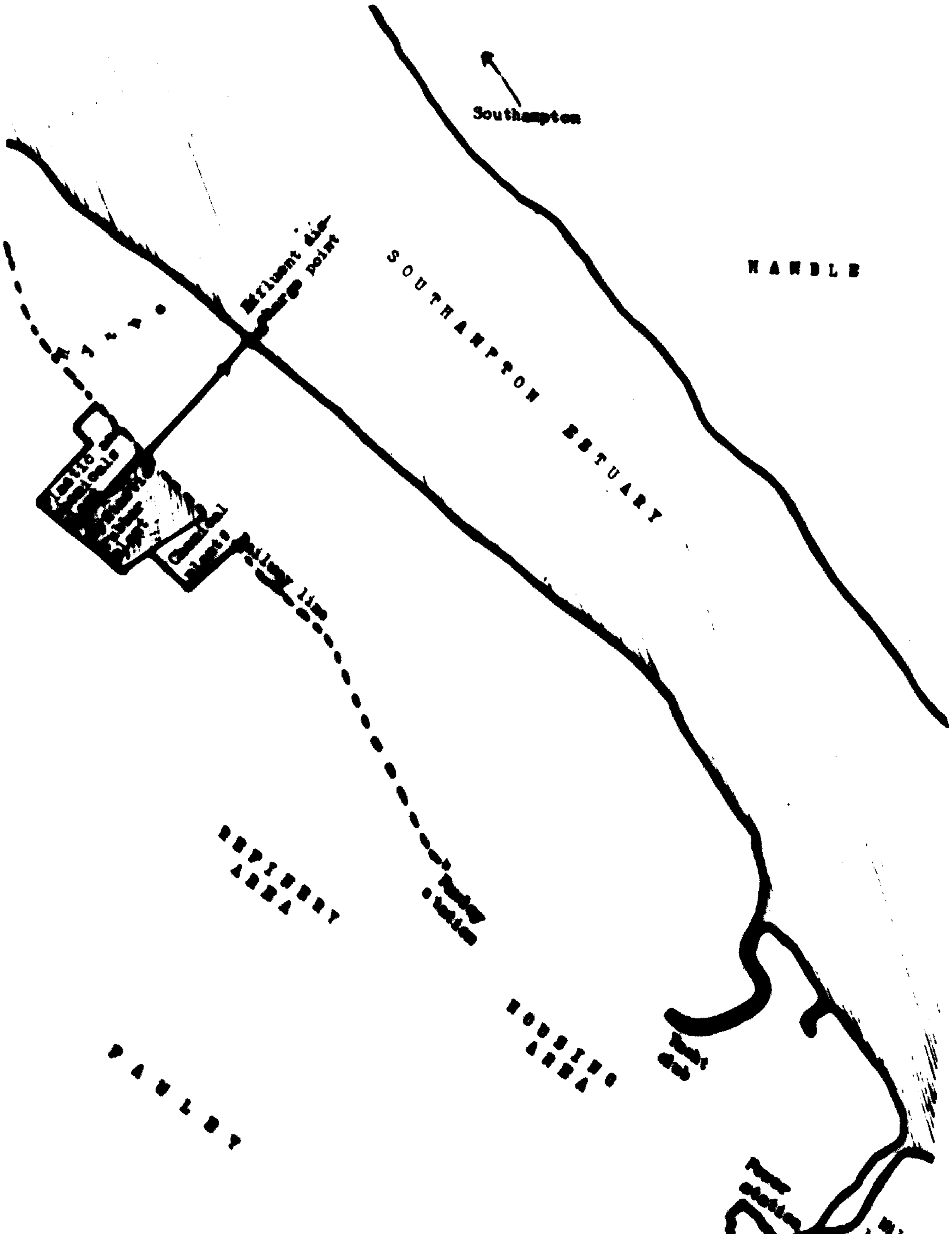
Description of process and production

[illegible] in the solid form as crumb and in the liquid form as high solids latex is [illegible] type of rubber manufactured at the Hythe plant. Total production is [illegible]0,000 tons annually, of which a small fraction, 30,000 tons, consists of ABS and [illegible] latices. The butadiene monomer is obtained from the neighbouring refinery through pipelines and the styrene monomer is manufactured on site. The SBR is produced by the emulsion polymerization process.

Styrene is manufactured from ethylene and benzene through the intermediate step of producing ethylbenzene. This is done by the alkylator reaction in the presence of a catalyst. Ethylbenzene is thereafter dehydrogenated by passing over a catalyst at high temperature producing styrene and hydrogen. Styrene is purified and separated by vacuum distillation, and the hydrogen is burnt off, since it is not considered economical to purify and collect the gas.

Emulsion polymerization is more frequently adopted for the production of SBR than other methods, although a substantial amount is made by solution polymerization, which allows the structure of the individual molecules to be more closely controlled and thus gives different properties to those of emulsion SBR. In the emulsion polymerization process, soap solution, catalyst, activator and modifier are added to the mixture of styrene and butadiene before it goes into the polymerization reactors. The catalyst used is a hydroperoxide. The solutions are made with water from the Avon River after purification. The plant uses the cold polymerization process at 5°C, which is an improvement over the hot process used formerly.

The emulsion with the monomers and the additives is cooled before it is passed into the reactors by an ammonia refrigerant cooling medium, which is chilled brine. The polymerization reaction is carried to 60 per cent conversion of monomer to rubber. Beyond this stage the rate of reaction falls off, and the



Map 3. Location of synthetic rubber plant at Hythe, United Kingdom

quality of the product begins to deteriorate. The resulting mixture is a milky white emulsion called latex. At this stage "short stop" solution is added to the latex to stop the polymerization.

Recovery of the unreacted monomers is essential to the economic production of synthetic rubber. Butadiene, having a lower boiling point than styrene, is first stripped from the latex in a vacuum flash tank at 27°-32°C and the vapours compressed and condensed into a receiver. A small quantity of water collects in the receiver, which is discharged periodically. Styrene is recovered by steam injection in perforated plate stripping columns at approximately 60°C, the resulting steam-styrene mixture being condensed and sent to a receiver. The top layer of styrene is decanted and recycled; and the bottom layer of water, which contains some styrene, is discharged. Rubber solids periodically foul both the vacuum and steam strippers, and they have to be removed by hand and then by steam or water jets. Besides putting the strippers out of commission, this operation produces large quantities of waste water.

After addition of an antioxidant to stabilize it, the latex is pumped into the coagulation tanks, where dilute sulphuric acid and brine are added to coagulate the rubber particles. The coagulated crumb is separated from the liquid in a shaker screen. It is further resuspended and washed in the water in another tank, after which it is dewatered using a vacuum filter and dried in the hot air on a continuous belt. After drying, the rubber is weighed and pressed into bales of 30 kg each, wrapped in polyethylene film and stored, ready for shipment.

Some of the solid SBR is prepared as oil-extended grade by the addition of over 30 per cent of oil to the latex before it is coagulated into solid rubber. The addition of oil imparts processing qualities that make it particularly acceptable to certain rubber-manufacturing industries.

Emulsion polymerization is also used for producing SBR latex in this plant with the same processing steps as for crumb production with the exception of latex coagulation, rinsing, drying and baling. About 10 per cent of all the SBR produced is marketed as latex and used for such purposes as dipping of fabric for tire manufacture, carpet backing, paper coating or latex foam. It is increasingly being used in adhesives and has a potential use in improving asphalt and stabilizing soil.

Effect on the environment

The team investigated various aspects of the natural environment to assess the effects on the environment of the Hythe synthetic rubber plant. Where possible, data were collected from the manufacturer, local and State officials, and from previous reports. Although some of the necessary data were lacking or not obtainable within the time alloted, with the data available the atmospheric emissions, hydrologic discharges and solid-waste disposal could be evaluated.

Sources of pollution

Gaseous emissions

The principal emissions to the atmosphere from a synthetic rubber plant typically originate from the fossil fuel used to provide power services, steam generation and fuel gas. The plant at Hythe uses 2 boilers, each of which emits gases containing SO_2, CO and the like. The only antipollution measure employed to control these pollutants is to have boiler stacks of a certain height. The stack height of 67 m, established in 1969, helps to disperse the atmospheric emissions, which minimizes the effect of the pollutants on the surrounding area. In addition, the fuel is efficiently burned for steam generation; its sulphur content is about 3 per cent.

Butadiene and styrene vapours escape during the stripping of the partially polymerized latex. The odour of these monomers permeates the plant area. However, no data exist on the concentration of these pollutants and whether they pose any health hazard. For example, styrene vapours can become hazardous in confined areas. At the very least these vapours inflict an unpleasant odour on the plant workers and the neighbouring residents.

Before the monomers are polymerized, the emulsion is cooled by an ammonia refrigerant. The odour of ammonia was detectable in this area, but the level of the gas within the area was not tested. Published reports indicate that the maximum level of ammonia permitted within a closed area is about 70 mg/m^3 of air. It is recommended that a few tests be conducted in this area to determine whether the ammonia level is such as to warrant further action.

Occasionally certain hazardous vapours are released because of improper handling. Such gases as ethylene, used in the production of styrene, and hydroquinone, employed during the short-stop phase, can have deleterious effects on the worker and the surrounding environment. For example, certain plant species are extremely sensitive to ethylene vapours, and hydrochloric can cause eye irritation or, in higher concentration, have toxic effects upon the worker. There was no evidence that vapours of this nature were escaping at a level that could cause danger to the industrial worker or to the neighbouring vegetation.

The dispersal of air pollutants depends upon the wind direction and force. Throughout the year the wind comes predominantly from the south-west. From this perspective, the location of the plant is extremely poor. Directly downwind from the plant are the commercial and residential areas of Southampton. It is fortunate for the residents of Southampton that the pollution levels, at present, are being kept to a minimum.

Effluents

By far the most significant pollution caused by the synthetic rubber industry is water pollution. Waste-water contaminants from the manufacturing process include crumb residue, spent catalysts, unreacted monomers and emulsifying agents. These pollutants create high concentrations of suspended solids, and high BOD and COD. To assess accurately the effect of the waste-water effluent, the following pollution parameters should be monitored: BOD, suspended solids, pH, COD and oil and grease. Heavy metals, cyanides and phenols are not found in significant quantities to deserve monitoring. At the Hythe plant, three of the above parameters are continously being tested - BOD, suspended solids and pH. Before the effluents reach the sea, the BOD concentration has been reduced to less than 20 ppm, the concentration of suspended solids is about 30 ppm, and the pH is kept within the range of 5-9.

During emulsion crumb production, various types of waste water are produced at different process phases. These effluents are ultimately passed to the treatment facility. At the Hythe plant, both styrene and butadiene monomers are stored in small tank farms. To stop excessive spills from entering directly into the effluent system, these areas have been adequately diked. Before the butadiene is combined with the styrene for polymerization, it is passed through a caustic soda solution to remove any inhibitors added during storage. The spent caustic soda solution, high in pH and colour, is passed directly into the effluent drain. The flow into the effluent drain from this source is extremely low. Before entering the polymerization reactors, the momomer mixture is combined [illegible] a soap solution in an aqueous medium. The water used for the above solutions, about [illegible].5 million litres/d, is purified after it is piped in from the Avon. This water is also used in rubber and latex finishing and for steam generation. No data were readily available to determine how much water from the Avon the plant uses. During periods of low flow, this volume of water may have a significant impact on the aquatic environment and on the neighbouring ground-water levels. However, since the Avon is fed from underground springs originating in the chalk deposits and since the plant has an emergency alternative supply of fresh water, it is estimated that the volume of intake for synthetic rubber processing has a minimal effect on the stream and its immediate environs.

In the cold polymerization process, the monomer emulsion is cooled with sea water before it enters the reactors. This cooling water is also employed for refrigeration at the recovery area. The daily volume used is about 45 million litres. The cooling water is combined with the non-saline water discharged at the treatment facility and passed into the estuary at a slightly higher temperature. Since the temperature of the effluent is only a few degrees above the initial intake temperature, thermal effects on the estuary are minimal.

During the steam stripping phase, the unreacted monomers are recovered. Waste water from this process is laden with partially reacted monomers in the form of dissolved and separable organics. The water is passed into a crumb pit, where the separable organics form a floating top layer. This layer is skimmed off and collected, while the lower, clarified layer is passed through the effluent drain to the treatment facility.

The latex is passed into a blend tank, where it undergoes coagulation with the addition of a coagulation liquor. Oil may be added to form an extended variety of rubber. The coagulated crumb is separated from the coagulation liquor. Part of the latter is recycled; and the overflow portion, consisting of used acids, dissolved organics and suspended and dissolved solids, is passed to a crumb pit. Here the floatable crumb rubber is separated and collected while the underflow is discharged into the effluent drain.

The process crumb is rinsed and dewatered. A portion of the rinse water is recycled while the overflow is passed to the same crumb pit as coagulation overflow. The rinse-water overflow is high in suspended and dissolved solids and dissolved organics. The Hythe plant contains only one pit for the stripping phase and only one pit for the coagulation liquor and crumb-rinse overflow.

Each crumb pit should have a dual unit to ensure that proper crumb separation shall be achieved during emergencies and pit unit cleaning operations.

The major area of waste disposal occurs during three phases of the synthetic rubber process: monomer recovery, coagulation-liquor overflow and crumb-rinse overflow. Other waste water is generated when the equipment is cleaned and the area washed, where large quantities of uncoagulated latex and suspended and dissolved solids and organics are generated. All of the waste water, laden with contaminants, is passed to the treatment facilities.

The treatment facility at the Hythe plant consists of a rotating circular settling tank where lime and alum are added to cause coagulation of the suspended solids and to neutralize the acid nature of the effluent. The waste water is subsequently passed to three settling lagoons, where further coagulation occurs before the waste water is combined with the sea-water coolant and passed into the estuary. Flocculating agents such as alum used in this treatment process create a bulky disposal product. From the existing data, it can be seen that the plant's treatment facility has little difficulty in meeting the standards required by the local water authority, which are as follows:

Less than 30 mg/litre of BOD

Less than 30 mg/litre of suspended solids

A pH range of 5-9

Further biological treatment is not necessary because the fresh-water effluent is combined with the saline cooling-water discharge so thatthe end-of-the-pipe standards can be readily met. (If the plant were located further inland discharging into a stream, then further treatment would be necessary.) There is no evidence that the synthetic rubber plant at Hythe is significantly polluting the estuary because the volume of the effluent is small compared with the volume of sea water contained in the estuary. The nearest water-testing point is 0.5 mile from the effluent pipe. In general, the estuary appears not to have been affected by any of the plants in the industrial complex. The fisheries over the past few years have improved for salmon, oysters, clams and other estuarine fauna.

Solid waste

Solid waste originates from the crumb pits and the treatment facility. It consists of off-grade rubber materials that cannot be recycled and spent catalysts. Other wastes originate from the normal refuse developed in industrial areas. Approximately 1 per cent of the total production is recovered as solid-waste rubber. Of this amount, 20 per cent is sold for use in low-grade rubber products such as toys, and the rest is disposed of in areas of land reclamation under the authorization of the local county council. Substances found in the solid waste are essentially non-toxic and pose no pollution problem.

Noise

Noise in a synthetic rubber plant originates from the numerous driers, pumps, motors, furnace burners and air-coolers. At the Hythe plant, the noise level is highest in the finishing area, where the rubber is dried and baled. In this area oral communication is virtually impossible. Conveyance of emergency instruction would be severely impaired. Data obtained from the management indicate that the noise level in this area never exceeds 84 decibels and that no plant worker is subjected to long-term exposure. This noise level is just below the generally accepted limit of 90 decibels. Therefore, little if any damage to the hearing of the plant worker is likely to occur. Alterations in the design in the finishing area could reduce the noise level and thereby facilitate oral communication. Outside the plant, the noise diminishes rapidly and poses no problem to the neighbouring residents.

Effect on ecology

Before the synthetic rubber plant was constructed, the vegetation of the area consisted of a non-coniferous forest of oak, elm and other hardwoods interspersed with small patches of heath, moor and pasture land. After construction this continous area of forest and pasture was in part destroyed, leaving isolated areas of vegetation. In certain instances a sufficient number of trees remained to maintain forest production, for example, the small grove of trees located between the estuary and the north-eastern boundary of the plant site. In other instances there is evidence that certain isolated groves contain too few species to maintain production. In these areas, the trees are subjected to over-exposure of wind and sunlight and are not likely to survive.

The wild life in the area has been affected by the alteration of the vegetation. Habitats for the larger fauna, such as deer, were disrupted largely because of increases in development. The wild life that does remain consists of those species more adaptable to small patches of forest and heath. This fauna includes foxes, rabbits, squirrels, and numerous bird species. "Wild" ponies that are actually owned by individuals are seen grazing in the area around.

As a beneficial effect, the synthetic rubber plant has served to isolate certain areas of fauna and flora from further development and the intrusion of the general public. Although the plant has altered the vegetation and wild-life areas, its impact has been diminished owing to the location of the New Forest, a 98,000-acre wild-life preserve, only a few miles away. The deer, for example, have moved into this area.

Marine life does not seem to have been affected in spite of the fact that the refinery alone uses 450,000 litres/min of sea water for cooling purposes. Warm effluents from the industry seem to have a salutory effect on fish life, and the salmon catch in the Test Estuary is considered to be one of the best.

The largest oyster bed in the country exists close to the Fawley power station. The refinery, which uses large quantities of sea water for cooling purposes, has not affected the growth of oysters. They are found to settle better in the area in spite of the heat and the chlorination of some of the water. An oyster-collection company is located behind the power station.

Soil conservation

While synthetic rubber manufacture from fossil oils is a drain on the non-renewable resources, it is heartening to find that the Research and Development Department in the plant has developed a process that can significantly contribute to man's fight against wind erosion. A series of successful experiments in soil stabilization was carried out in the sand dunes of England and in the deserts of the Middle East. It is claimed that sand sprayed with a mixture of mineral oil and synthetic latex, which dries as a thin rubber film, protects the sand against erosion by wind or water long enough to enable holding crops to be grown. The company's product, it is claimed, meets the requirements of th the main sectors where restoration of vegetative cover in the form of grass or crop is required. It is also claimed that the materials used are in no way toxic

Social and economic effects

Benefits to workers

The company has an active sporting club, with activities including yachting, angling etc.

About 70 per cent of the 450 employees come from the local area, the remaining 30 per cent coming from other parts of England. The wages paid are slightly higher than in the surrounding industries.

About a third of the employees live in council houses, which are subsidized because of the high rates the firm pays to the local authorities.

Public services such as transportation and schools have improved.

Occupational hazards

Backache is a regular complaint among the workers, particularly among the packing and maintenance crews. Remedial measures to ease the load in the operations concerned should be possible. Stray cases of dermatitis have been reported by the medical centre.

The medical centre regularly arranges blood count for white corpuscles and platelets on those working in the styrene plant.

No respiratory difficulties caused by air pollution or by the strong odour of the monomers were reported. There was no report of any damage caused by excessive noise.

The International Institute of Synthetic Rubber Producers is studying the effects of all substances used in the synthetic rubber industry.

Benefits to the economy

The synthetic rubber industry in the United Kingdom is making a substantial contribution to the country's economy in the following ways:

(a) The United Kingdom no longer depends on imports of synthetic rubber. It has been estimated that at the 1970 rate of consumption the country will save annually $50 million;

(b) British rubber goods manufacturers have been provided with materials of high quality at economic prices that have enabled the manufacturers to enter competitive export markets and thus to increase the country's exports;

(c) There has been a thriving export trade in raw synthetic rubbers themselves, to about 30 countries, but exports may gradually dwindle in the future as many of the countries establish their own synthetic rubber plants.

Economics of production

The plant has had a phenomenal growth in production, from a nominal capacity of 50,000 t/a in 1958 to 310,000 t/a in 1971/72, including ABS, speciality latices and styrene monomer. The progress achieved by the Hythe plant is shown by the following figures:

Year	Materials	Yearly capacity (thousand tons)
1958	SBR (solid and latex)	50
1960	SBR (solid and latex)	90
1962	SBR (solid and latex)	100
1968	SBR (solid and latex)	130
1969	SBR (solid and latex)	130
	Styrene monomer	60
1970	SBR (solid and latex)	180
	Styrene monomer	60
	ABS and speciality latices	30
1971/72	SBR (solid and latex)	220
	ABS and speciality latices	30
	Styrene monomer	60

In the first full year of production up to the end of 1959, the company made an after-tax profit of $308,000 which could be considered a creditable achievement.

A new plant was opened by the company at Grangemouth, Scotland, at the end of 1963 for the manufacture of polybutadiene rubber. This plant has steadily increased its production from 10,000 t/a to 100,000 t/a of solution polymer. In 1969, the company produced 60,000 tons of styrene monomer by buying a plant on-stream at Hythe. For a plant that uses styrene as a raw material for its products, this was a sound venture.

In 1972, the company, in a joint venture with another company, started production of furnace carbon black in a plant at Grangemouth, with a capacity of 30,000 t/a. The main purpose of this was to supply the tire companies with carbon black master batches with the solution SBR manufactured at Grangemouth. The general view, however, is that the carbon black master batches have not really caught on with the tire manufacturers.

The SBR industry in the United Kingdom has become highly competitive, since it is subject to a tariff on butadiene imports about three times higher than that of its rivals in Europe. But the company has a flexibility of structure and ability to adapt to changing patterns of demand.

IV. ECONOMIC ASPECTS OF NATURAL AND SYNTHETIC RUBBER PRODUCTION

Owing to lack of accurate information and fluctuating prices of raw materials, it was not possible for the team to obtain comparative costs of producing natural and synthetic rubber. Certain generalizations are however, possible and they are given below.

Cost of production

Since the production of natural rubber is highly labour intensive, one of the largest components in production cost is the labour cost; this cost however, be substantially reduced by increasing the yield per hectare.

Studies of the major synthetic rubber production in producing countries of the world have shown that the cost of raw materials, over which the synthetic rubber industry has no control, account for over 70 per cent of the total cost of production of SBR.

Investment

The minimum economic size of an SBR plant in developed countries is said to be 10,000 t/a. The agro-based SBR plant in India, with an installed capacity of 30,000 t/a, was set up with an investment of $40 million. The investment per ton, $1,330, is far above that of an average SBR plant in a developed country, which has been reported as $500. The team was not able to obtain a corresponding figure for natural rubber production in India because of the large number of small small holdings, the difference in land prices for large and small holdings, and also fluctuations of land prices in different areas. However, even a small natural rubber production facility with an annual yield of as little as one ton per year is economic.

Employment potential

A comparison of the employment potential of the three types of production studied is given in the following table:

Type of rubber	Workers (number)	Output (t/a)	No. of workers/ 1,000 tons
Natural rubber (1973)	150,000	123,000	1,219
SBR, agro-based, India, 1973	1,570	21,000	75
SBR, petrochemical-based U.K., 1971/72	450	250,000 a/	1.8

a/ Includes 20,000 tons of ABS and speciality latices but excludes 60,000 tons of styrene monomer.

V. MANUFACTURE OF RUBBER PRODUCTS IN INDIA

Within the comparatively short period of 25 years, the Indian rubber industry has become one of the major industries in India. Besides producing practically the entire requirement of the country for automobile tires and tubes, bicycle tires and tubes, tread rubber, foot-wear, conveyor belting, V and fan belts and miscellaneous rubber goods, it has developed a large export market. It is estimated that there are nearly 2,000 rubber factories - large, medium-sized and small - spread over the country employing about 150,000 persons. The country today ranks as the tenth largest country making rubber products. The following figures for consumption of natural, synthetic and reclaimed rubber for the last 10 years show a steady growth rate resulting in almost a doubling of the consumption during the period:

Year	Consumption (tons)
1963/64	81,096
1964/65	85,711
1965/66	95,092
1966/67	103,190
1967/68	109,704
1968/69	128,022
1969/70	130,734
1970/71	134,745
1971/72	149,435
1972/73	151,507

Products manufactured

Automobile tires and tubes

Automobile tires and tubes account for 50-55 per cent of the total rubber consumed in the country. There are at present seven companies with nine factories manufacturing these products. The increase in production during the period 1966-1972 is shown below.

Year	Production of tires (number)
1966	2,580,553
1967	2,705,739
1968	3,438,351
1969	4,015,014
1970	4,040,946
1971	4,659,129
1972	4,978,218

The demand for tires and tubes is expected to double during the period 1974-1979, and the Government has issued licences to a number of new units besides giving expansion permits to the existing companies. It is anticipated that the country will have a licensed capacity of 11 million tires by 1979, but in view of the oil crisis and the drop in demand for tires that has set in recently, one cannot forecast accurately how much of the licensed capacity will be utilized.

Bicycle tires and tubes

India is one of the largest producers of bicycle tires and tubes in the world. There are 20 large units and about 30 small units producing them. The present production of bicycle tires and tubes is estimated to be about 35 million pieces, and the demand is expected to reach 60 million by 1979.

Camelback (tread rubber)

The third rubber product manufactured on a large scale is camelback, or tread rubber, used for retreading of old tires; output is approximately 20,000 t/a. With the high cost of new tires, production is expected to double by 1979.

Miscellaneous rubber goods

While the above three major items account for 65 per cent by weight of the total rubber goods production, a wide range of miscellaneous rubber goods account for the remaining 35 per cent. An estimated breakdown of these products is given below (percentage):

Rubber and canvas foot-wear	11.7
Belting	4.2
Latex foam and dipped rubber goods	4.5
Hoses	2.9
Cables	0.9
Waterproof fabrics	0.5
Battery boxes	0.9
Ebonite	0.2
Miscellaneous	9.2
	35.0

There are well over 1,700 units manufacturing these products, the total output of which is valued at Rs 1,200 million ($160 million).

Tire factory No. 1, Madras area

The tire factory at Ambattur went into production in 1959. At that time India's production of tires fell far short of demand. The anticipated demand for trucks, cars and bicycles in the Second Five-Year Plan was expected to make the shortage more acute, and this prompted the decision to open a new factory near Madras to serve the needs of South India, which had no large tire factory.

In 1956, the search began for a suitable site for the factory. The most important consideration was the availability of an adequate supply of water. The company sought the assistance of the Geological Survey of India, and Ambattur, a village with many high-yielding wells located 16 km from Madras, was selected. There were also rail and road facilities adjacent to the site selected. Other factors such as availability of labour and scope for future expansion were also taken into account. Map 4 shows the location of the factory.

The project, including land, buildings and plant, cost approximately Rs 25 million ($3.3 million). Truck tires, bicycle tires and camelback formed the initial range of products of the factory. The equipment installed was of the most modern design. Today, in addition to the original lines of production, the factory produces tires for cars, motor cycles, mopeds and tanks, as well as inner tubes for trucks and bicycles and also accessories like vulcanizing and rubber solutions and bicycle rims. The company has invested an additional sum of Rs 100 million ($13.3 million) in the various expansion programmes undertaken. Employing initially about 600, the factory today employs 2,750 persons.

The production capacity is as follows (number except for camelback):

Automotive tires (truck, car and scooter)	901,700
Bicycle tires	6,090,000
Automotive tubes	510,000
Bicycle tubes	5,336,000
Camelback (kg)	600,000
Bicycle rims	760,000

Manufacture of tires

Tire manufacturers produce many types of tires designed for a variety of vehicles, which include passenger cars, trucks (buses and lorries), farm tractors and aircraft. Selection of the rubber and compounding materials and the

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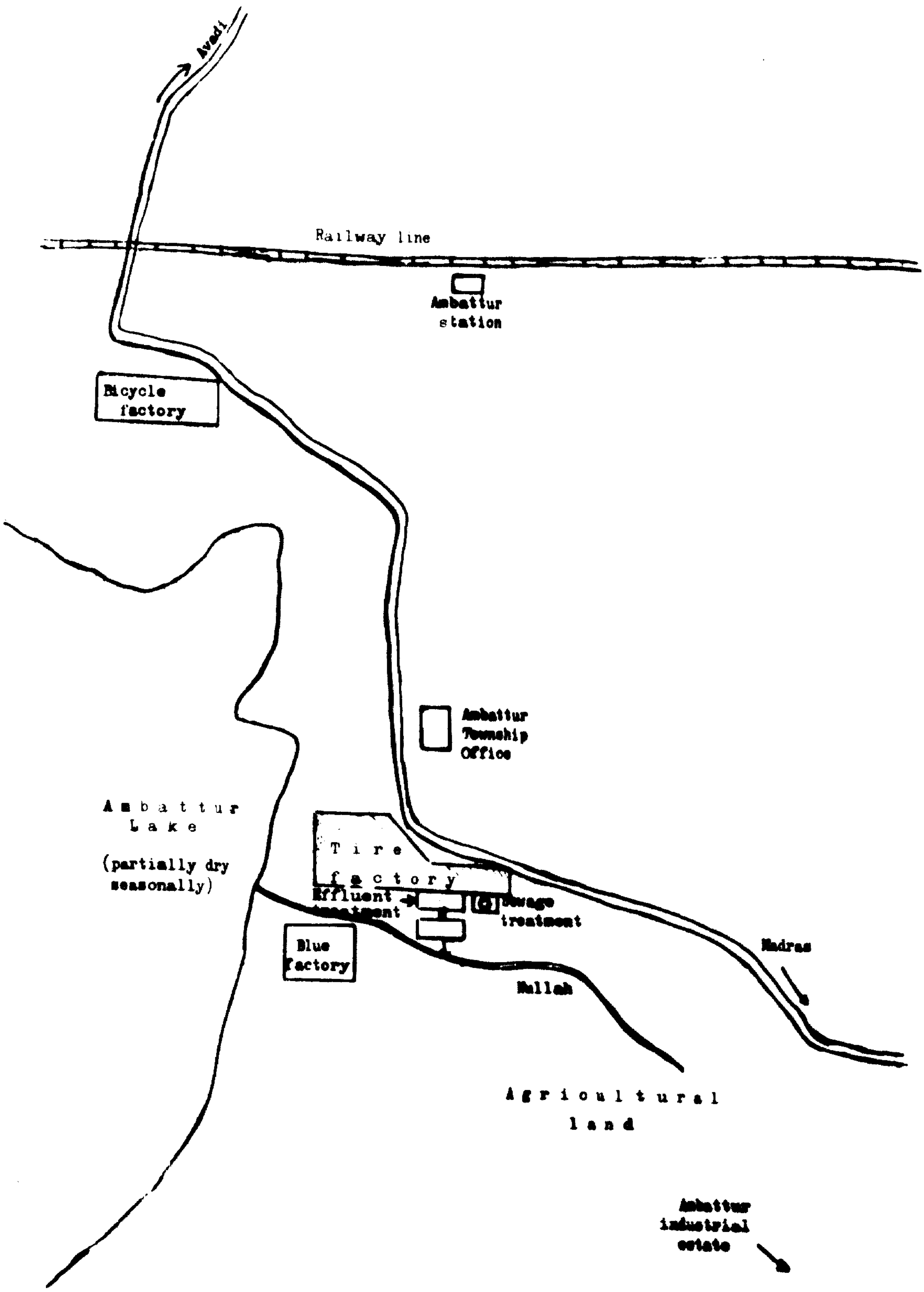

Map 4. Location of tire factory No.1, Madras

proportion of the materials in a tire will vary according to its type. Basically the tire consists of four parts — the tread, the sidewalls, the casing and the beads. Each part has different service requirements and requires a different proportion of the raw materials. For example, long life and good traction are the requirements of the tread, whereas a high degree of flexibility is the requirement of the sidewalls. The basic compound used for tires consists of natural and synthetic rubber, various fillers, extenders and reinforcers, curing and accelerator agents, antioxidants and pigments. The fillers, extenders and reinforcers are used to produce a greater weight or volume and increase the strength, hardness and abrasion resistance of the final product. Carbon black and mineral oil are the most common materials used.

The typical tire manufacturing process consists of the following:

Compounding of the raw materials
Using the compound in the four components
Building, moulding and finishing

Compounding

The basic items of machinery in the compounding operation are the Banbury mixer and the roller mill. A Banbury mixer mixes rubber and other ingredients internally in batches according to set timings and is the key piece of equipment in compounding, which consists of two operations. First, rubber is mixed with fillers, extenders, reinforcing agents, pigments and antioxidants into what is known as stock mix. Since no curing agents have been added, this mix has a long shelf life, and large quantities of a particular recipe can be made and stored for later use. In the second operation, the curing and accelerator agents are added; and the resulting mix, which has a short shelf life and has to be used almost immediately, is known as the final mix.

Carbon black and oil are added in the first operation. Carbon black is a finely divided powder that is easily airborne. To avoid dispersal of the material in the air as well as housekeeping problems, in modern plants the material is added automatically through Redler conveyors. Oil is also added automatically into the Banbury chamber to avoid messy handling. The area is provided with dust-extraction equipment to reduce air pollution from carbon black and other powders used.

After mixing, the compound is sheeted in a set of roller mills. The sheeted material is tacky and is usually coated with chalk in the form of a slurry, which prevents it from sticking together during storage. Chalk in the effluent stream, owing to spills and floor washings, is common and creates maintenance and waste-water problems. Leakages of oil and water from the oil seals in the mills and oil and dust from the dust-ring seals of the Banbury cause further pollution problems.

The final mixed compound has to be converted into the form of one of the final parts of the tire. This involves several parallel processes by which the sheeted rubber and other raw materials are made into the basic tire components: tire beads, tire treads, and fabric pockets. Tire beads are rubber-coated wires inserted in the pneumatic tire at the point where the tire meets the rim and that fix it to the rim. The tire tread is the portion of the tire that meets the road surface, and its design and composition depend on the use to which the tire will be put. The fabric pockets are made from woven synthetic fabrics, usually rayon or nylon impregnated with rubber, cut to the right size. They form the inner body of the tire and give it its strength.

Using the compound in the components

In the production of the tire treads, mixed compound as received from the compounding section is manually fed into a warming-up roller mill. Here the compound is heated and further mixed, heat being provided by the conversion of mechanical energy from the mills. The temperature of the mills is controlled by the use of cooling water within the mill rolls. The compound is passed through a breaker mill and then through a warming mill. The warmed-up compound passes on to another mill where it receives its final mixing and is peeled off the rollers of the mill in thin strips, which are fed continuously to an extruder. The size of dies fitted to the extruder depends on the size of the tread required. The tread leaves the extruder as a continuous strip while still hot and therefore tacky. A cushion layer of compounded rubber is attached to the underside of the tread. Where a separate compound is necessary for the sidewalls, as in most truck tires, two types of compound from two different strip mills are joined together to form the tread and the sidewalls. The tread is then cut to the proper width, cooled in a water trough, size-stamped and then cut to the proper length. Trimmings are transferred back to the strip-feed mill and reprocessed.

Waste-water problems in this area are caused by oil and water leakages from the various mills and from accidental overflows from the cooling-water system.

Rubber stock has to be impregnated onto a pretreated fabric for the production of fabric pockets. The fabric is let off a roll and fed under controlled tension through a festooner into a latex-dip tank. After dipping and when it is still under tension, the fabric is passed through suction lines to remove the excess dip and then through a drying chamber. After that, the fabric is impregnated with rubber by passing through a calendering machine. The fabric is then cut to proper bias angle and length and spliced together. The angle and length will depend on the size of the tire. The rubber used for impregnating the fabric proceeds through the same operations as in the tread extruder, i.e. the warm-up mill and the strip-feed mill.

Effluent problems in this area are caused by the latex drippings and also by leaking of the oil and water.

In the production of beads, rubber is extruded through a small extruder onto a series of copper-plated steel wires, which are then solutioned, wrapped and cut. Effluent problems are similar to those in the tread extruding process.

Building, moulding and finishing

The tire is built up as a cylindrical assembly on a collapsible rotating drum. Beads and layers of fabric as required are put on the cylindrical drum, the beads being attached to the tire by folding over the ends of the fabric.

Finally, the tire tread is placed and firmly fixed over the assembly. The cylinder, which is known as the green tire, is removed from the drum and is ready for further processing. Before moulding, the inside of the green tire is painted with a water-based solution. The potential exists for spills or left-overs of the solution during the weekend cleaning, which cause waste-water streams.

The tire is moulded in an automatic press. A curing bag made of rubber compound is inflated inside the tire to permit the tire to take its shape. The mould is closed over the shaped tire, and heat is applied by steam through the mould and the bag. Excess rubber and trapped air escape through vent holes. After a specified time of cure when the temperature is controlled, the press opens automatically, the tire is removed with the bag, the condensed water is syphoned from the bag,and the bag is removed from the tire by means of a debagging machine.

The more recent method of moulding, called Bagomatic moulding, makes use of a bladder that stays in the press permanently for a certain number of cures depending on the life of the bladder. The moulds are sprayed with a solution containing silicon after each cure. Moulds are also cleaned after a certain number of cures by sandblasting or shotblasting.

In the moulding operation, owing to the use of steam, the working conditions are hot, and hot fumes emanate from the presses. When there are many presses in a typical plant, there is always the chance for a mould to leak. There is also a rather remote possibility that a bag or bladder will burst. The water and some of the lubrication oil used in the area, of which there is a large amount, can cause a water contamination problem in the discharge.

After moulding, the tire proceeds to the finishing operations. These include trimming the vent spews and grinding the uneven surfaces as necessary. In the case of white sidewall tires, additional grinding is necessary.

The trimmings of the vent spews are thin cylindrical pieces of cured rubber. These are collected and used for reclaimed rubber or thrown away in the scrap yard to be disposed of with other scrap materials. The grindings from the tires are relatively small particles and will stay in the air for long periods of time. A cyclone type of dust collector is used to control these emissions.

After trimming and grinding, a few tires may require minor patching up of the uneven surface. Passenger tires, particularly the white sidewall tires, are spray-painted. Although this painting is done in a hooded area, it causes some air pollution.

Figure VII gives a water-flow diagram for a typical tire plant.

The process described above applies to the manufacture of passenger car tires and standard truck tires. Larger truck tires and "off the road" tractor tires are cured in giant moulds that are not automatically operated. Hoists are required to open and close the moulds. Curing can take many hours. The process variations do not have a significant difference as far as pollution problems are concerned.

Camelback, or tread rubber, is used for tire retreading. The process and waste problems are the same as for tread extruding described above.

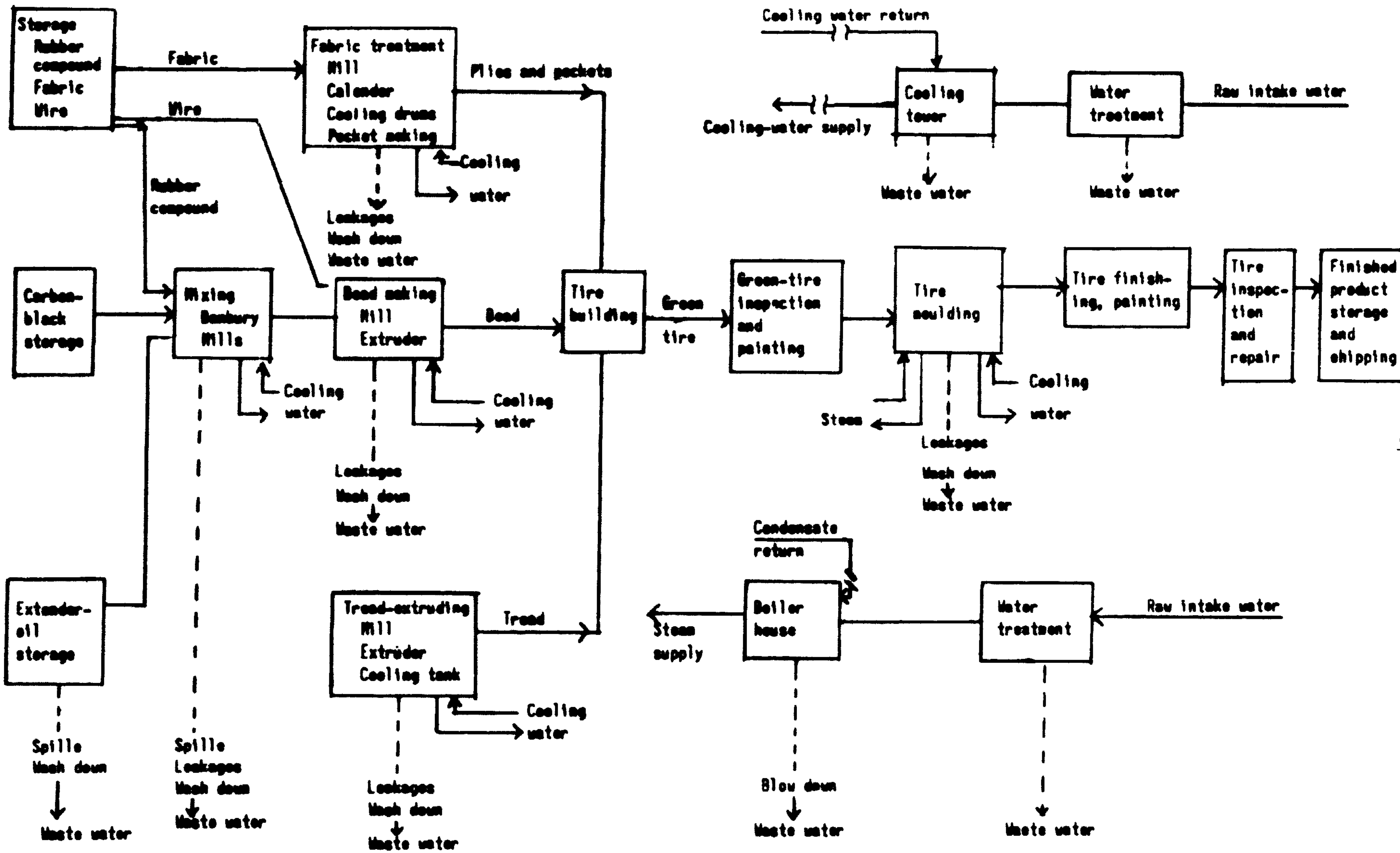

Figure VII. Water-flow diagram for a typical tire plant

Manufacture of inner tubes

The process for the manufacture of inner tubes is similar to that described for tire manufacture as far as the following steps are concerned:

Compounding of the rubber with other raw materials
Extrusion of the compound to form a tube
Building and moulding to form the final product

Compounding

Banbury mixers and roller mills are used and stock mixing and final mixing of the compound are done. One minor difference is the use of butyl rubbers in inner-tube manufacture. Besides, a soap sollution in place of the chalk slurry is sometimes used to coat the stock-mixed compound. The soap solution is not discharged but used up with the compound. Effluent problems with leakages, drippings of oily materials and powders are similar to those in the compounding area of tire manufacture.

Extrusion

The process for extrusion is similar to the extrusion of the tread for tires except that the rubber is extruded into the form of a continuous cylinder. French chalk is sprayed inside the tube as it is formed in the extruder to keep the insides from sticking to each other. The tube is size-marked and passed through a water-cooling tank. After cooling, the water is blown off the tube and French chalk is sprayed on the outside of the tube. Excess powder must be collected in a dust collector. Other waste problems are similar to those in the tread-making process for tires.

After extrusion, the tube is cut to length and ends spliced together. A valve is also fixed.

Moulding

After valve fitting, the tubes are moulded in steam-heated presses. After moulding the tube is inspected and packed ready for shipment.

Effect on the environment

The team identified the following areas as having potential for environmental pollution and/or for health hazards:

Banbury and compound mixing areas
Latex dipping
Use of naphtha in case making
Moulding section
Buffing of tires and curing bags
Sandblasting of moulds
Tube extruding
Gaseous emissions and effluents
Solid waste

Banbury and compound mixing areas

The factory has a Redler system feeding carbon black automatically into the Banbury chamber. The dust-extraction system was working efficiently when the team visited the factory. Bulk handling and master batches of carbon black should be considered. Because of the possible risks to health from the contamination in the air, free milk is supplied to the workers in the mill department.

Latex dipping

The latex dip contains formaldehyde and other chemicals that produce very unpleasant fumes in the area. The main problem is from the drippings that find their way into the effluent stream.

Use of naphtha in case making

Stray cases of dermatitis have been reported owing to the regular contact of the hand with pads dipped in napthta. These cases were reported to be of a temporary allergic nature and the workers gradually become immune to the effects.

Moulding section

In the moulding section the temperature is high owing to the use of steam. Working conditions are particularly uncomfortable during the summer. In the construction of the building, special attention was given to the ventilation in this section, taking the wind direction into account. The factory inspector usually ensures that this is done when the building plan is approved. In the summer season the workers can suffer from dehydration owing to excessive sweati[ng]. The factory management has been giving the workers saline tablets during summer months to make up for the salts lost through perspiration. The saline tablets contain the following components in the right proportions: calcium lactate, potassium chloride, magnesium sulphate, sodium chloride, sodium citrate, sodium acid phosphate and dextrose.

Silicone is sprayed on the inside of the moulds at a sufficiently great distance from the worker so that no undesirable effects seem to be produced.

The noise level in the bagging section is high where the curing bag is introduced into the green cover by a process of inflation and simultaneous pressing to shape in the hydraulic presses. No hearing troubles have been reported, however. The more modern Bagomatic process, where a diaphragm replaces the curing bag, eliminates this noise.

Buffing of tires and curing bags

Buffing of tires for minor repairs in the finishing section produces rubber dust; but the amount of buffing done is small, and the usual precautions taken of using a dust-extraction unit and having the operator cover his nose with a fine cloth seem to be satisfactory.

In the curing-bag-repairing section, there is significant amount of buffing and consequent dust pollution. The dust-extraction units have to be more powerful, and the workers should wear gas masks. As usual, the workers resist using gas masks and resort to the practice of covering their mouth and nose with a fine cloth. The necessity for repairing the bags should be eliminated if at all possible by use of suitable compound. After the stipulated life of the bag, the bag should be scrapped.

Sandblasting of moulds

Sandblasting of moulds, although done in an enclosed chamber with a glass window through which the operator can watch the progress, emits too many sand particles, some of which are bound to be inhaled and cause trouble in the lungs. The factory has now changed over to shotblasting, which is less hazardous to health.

Tube extruding

Use of chalk in tube extruding, which produces chalk dust in the air, makes this one of the most uncomfortable operations for workers. Chalk-extraction units can have only a limited mitigating effect. Regular health checks should be made of the workers in this operation. Wet slurry should be used as far as possible.

Gaseous emissions and effluents

The team briefly went through the areas of pollution inside the factory. The boiler in this factory is oil-fired, and the height of the chimney ensures that the smoke is released away from the factory area.

The factory's average daily consumption of raw water is approximately 600,000 gallons (2,700,000 litres).

The plant has an effluent-treatment as well as sewage-treatment system on which approximately Rs 500,000 ($66,000) is spent yearly.

The effluents are collected into two large tanks, one of which is used for treatment while the other receives the effluents in alternation. In this tank the effluent is treated with alum at a concentration of 0.5-1 kg/1,000 litres, allowed to settle and pumped into strainer beds made of wood chippings and wood sawdust. From the strainer beds the effluent is discharged into settling tanks before release into the canals.

The sewage is first collected in a settling tank with two covered drying beds by the side for drying sludge. From the settling tank the liquid is passed through an automatic dosing syphon to filter beds made of granite chips with a revolving sprinkler fitted on the top. From the filter bed the liquid passes into a humus chamber before being discharged into the channel.

The pumps, sprinklers etc. were originally supplied by a firm in the United Kingdom, but similar equipment is now available locally.

At the request of the team, copies of analyses of effluents discharged into the channel were supplied. These are given in tables 3 and 4. The discharges are released into a channel that is used mainly for agricultural purposes, and no adverse reports have been received from the farmers using the water. As a matter of fact, owing to the severe water shortage in the locality, the discharged water is much sought-after for agricultural purposes.

Table 3. Results of analysis of effluents and sewage from tire factory No. 1 (all results except pH and sodium expressed as ppm)

Test	Effluent discharge at 12 noon on 18 Oct. 1974	Effluent discharge average over period 10 a.m. to 5 p.m. on 21 Oct. 1974	Sewage plant discharge
pH	6.5	5.5	5.5
Total dissolved solids	1,210	1,435	1,425
Sulphate (SO_4)	540	789	443
Chloride (Cl)	170	195	213
Sodium (per cent)	22.7	14.9	3.5
BOD 5 days at 20°C	600	1,050	900
Oils and grease	38	62	Nil
Boron (B)	Nil	Nil	Nil
COD	269	289	340

Table 4. Results of analysis of drain water and rim effluent at tire factory No. 1 (all results except pH and sodium expressed as ppm)

Test	Drain water (near new raw material stores)	Drain water (west of new base stores)	Rim effluent
pH	5.5	6.5	6.0
Total dissolved solids	995	2,210	1,982
Sulphate (SO_4)	284	516	961
Chloride (Cl)	142	532	213
Sodium (per cent)	3.8	2.5	14.1
BOD 5 days at 20°C	700	1,000	1,200
Oils and grease	5	44	86
Boron (B)	Nil	Nil	Less than 1
COD	118	181	502
Total chromium (Cr)	-	-	6.0
Hexavalent chromium (Cr)	-	-	2.5
Nickel (Ni)	-	-	Nil
Organic matter (by permanganate digestion)	-	-	217

The sludge collected from the sewage-treatment plant is used as manure in the factory farm, in which rice and vegetables are grown to be used in the factory canteen.

Solid waste

The sludge collected from the effluent treatment is used as landfill. Sweepings from the factory, packing materials and other scrap materials are stored in the salvage yard and auctioned to scrap dealers periodically.

Social and economic effects

Until the late 1950s, Ambattur was a small, quiet village, unknown to many. Like other backward and isolated villages, this village depended mainly on agriculture. Paddy was the main crop with small quantities of pulses and vegetables. There were no proper transport facilities or other communciation facilities, hospitals, schools or recreation centres.

A bicycle-manufacturing unit was the first plant to be established in this village, followed by the tire factory in 1959. Then came the tank factory at nearby Avadi and the industrial estate at Ambattur.

Ambattur, categorized by the census of India as a "non-city urban area" or a "core city", has an area of 774 hectares. According to the 1971 census, the population increased from 11,128 in 1959 to 45,586 in 1971. The present population is estimated at 52,000. This large increase in the population is the result of the rapid industrialization that has taken place during the past 10 years. Ambattur is a rural-urban mixture. Ambattur is being connected with all important places through buses. A slow but steady socio-economic improvement has taken place in this village.

Report of interview with local residents

After the establishment of the bicycle factory, many private parties and the Government started purchasing land. The factories have opened up new avenues of employment, and the conversion of agricultural lands into factory sites has not resulted in unemployment among the farmers to any significant extent.

The waste water from the three factories mixes with the canal water, and the farmers who own land around the factories use it for irrigation. Since the water in Ambattur lake is available for only six months, for the remaining six months the farmers have to depend solely on the waste water supplied by these factories.

Twelve of the persons interviewed pointed out that the waste water released from the rubber factory was purified before discharge, while the water from the other two factories was not. On many occasions the crops were damaged because of the chemical content in the water.

Some of the farmers pointed out that they depended on the water from the rubber factory for irrigation. It was said that the factory, which has a large area behind it, recently started cultivating about five acres of land adjacent to it. So the waste water from the factory is used for irrigating its own land and only the remaining water is supplied to the nearby farmers.

The establishment of factories, regardless of size, has resulted in the construction of new roads; increased transport facilities; new education, health and recreational facilities; and above all in the free flow of money. With the influx of workers, accommodation has become a problem. Rents have increased fivefold.

Almost all those interviewed said that the rubber factory paid more than the other factories in that area. It was pointed out that most of the labour unions in the other companies during the past five years had demanded the same wages as given in this factory.

Most of those interviewed pointed out that the existing socio-economic betterment was mainly due to the tire factory and the bicycle factory. Almost all the shopkeepers near the plant said that they depended on the factory workers for their business. It was mentioned that four bicycle shops and several hotels had started business near the factory to cater to the needs of the workers.

The existence of these factories has resulted in the establishment of new schools, hospitals and recreational centres. Now there are 2 high schools, 6 middle schools, 4 higher elementary schools and 10 elementary schools. There are also 2 hospitals, 1 municipal dispensary and 3 cinemas. The social and recreational activities in the small rural community have changed their pattern with the coming of cinemas, restaurants and clubs for recreation and games. The once tiny, unknown village has changed completely with new types of buildings and modern methods of transport and communication.

The team attempted to find out the effect of industrialization on health and in particular the effect of the rubber factory. It should be noted that two other factories are situated adjacent to this factory. One makes wire products and the other one manufactures ultra-marine blue.

The Ambattur lake water that passes through canals also passes through the rubber factory estate.

No one complained about any smoke or bad smell from the rubber factory, while all those interviewed stated that the smell from the neighbouring blue factory was unbearable at times.

It was pointed out that those who worked in areas using carbon black were forced to inhale the dust, and the bodies of these workers were entirely covered with carbon black during work.

The carbon black bags are sold to a contractor who has a dumping place of his own, very near to the factory. This dumping place is not well covered the area is often covered with carbon black bags. It was pointed out that this dumping place caught fire some time the previous year mainly for lack of attention. This was the major complaint against the rubber factory.

Owing to a power cut the rubber factory is working with the help of a generator. Nearby residents complained about the noise coming from the generator.

Ancillary industries

Several small industries fabricate metal parts for the maintenance and repair of the factory, since importing of spare parts is restricted by the Government. Much of the light machinery used in the tire plant is manufactured locally. Mill rollers and moulds used for all sizes of tires are now produced locally. A large portion of such work is done in the industrial estate in Ambattur.

Tire factory No. 2, Madras area

The second tire factory the team visited is located at Thiruvottiyoor on the sea-coast, about 15 km from Madras. The factory began production of tires and tubes in 1965, although production of camelback had begun earlier. The factory employs 1,800 men and has a yearly production capacity of 1 million each of automotive tires and tubes, 2 million each of bicycle tires and tubes, besides 8 million kg of camelback. Part of the requirement of mixed compound is supplied by another factory belonging to the same company in Kerala. This arrangement has helped the plant to overcome the difficulties caused by the power shortage in the State of Tamil Nadu.

The factory uses approximately 900 litres of water/min. This water is taken from wells that, though situated very close to the sea, give good water that is not brackish. There are several other industries in the area, e.g. a match factory, a factory manufacturing dry-cell batteries, a factory manufacturing trucks in collaboration with a company in the United Kingdom, a factory manufacturing motor cycles, and other engineering industries.

The factory uses the same production process as tire factory No. 1.

Effect on the environment

The main differences with the factory described earlier are as follows:

(a) Carbon black is not fed automatically into the Banbury chamber. Instead, the bags are handled in the section, which results in greater contamination from black in the area;

(b) Wet sandblasting is used for cleaning moulds;

(c) The wind direction was not taken into account in locating the Banbury, with the result that black and powders are blown into the other production areas;

(d) Effluents are not treated. They pass through pipes connecting to the main pipes through which the city's effluents are discharged into the sea.

There is no sewage treatment either, except for some septic tanks, which are allowed to overflow into the drains that connect to the main effluent discharge into the sea. Tables 5 and 6 give the results of effluent analysis made by NEERI at the request of the team.

Table 5. Results of analysis of raw water used in tire factory No. 2 (all results except pH expressed as ppm)

Test	Results
pH	7.4
Turbidity (silica scale)	8.0
Total alkalinity (as $CaCO_3$)	180.0
Chloride (Cl)	178.0
Total hardness (as $CaCO_3$)	96.0
Sulphate (SO_4)	80.0
Iron (Fe)	0.15
Manganese (Mn)	0.20
Dissolved solids	600.0

Table 6 A. Results of analysis of effluents from tire factory No. 2 (all results except pH expressed as ppm)

Test	Results	
	Process waste a/	Combined waste and sewage b/
pH	7.3	7.5
Alkalinity (as $CaCO_3$)	160	280
Chloride (Cl)	180	235
Sulphate (SO_4)	85.0	130.0
BOD 5 days at 20°C	25.0	500.0
COD	86	810
Total solids	700	1,100
Total nitrogen (N)	-	120.0
Phosphate (PO_4)	0.75	2.25

a/ Process water is reused and only a fraction is discharged as waste.

b/ The combined waste and sewage is discharged into the sea.

B. Results of air-pollution study

Suspended particulate matter (mg/m^3)	Results
Inside factory a/	621
Banbury b/	234

a/ This is a closed area; hence, particulate matters do not escape and the concentration is greater.

b/ Because of good air conditioning in this area the particulate suspended matter is low.

Social and economic effects

Thiruvottiyoor was a small village until some of the large industries started establishing their factories there. Unlike Ambattur, this area has no industrial estate with many small industries. There are only large factories in the area. Since the village is on the coast, almost on the beach, no agricultural land has been affected by the industrial growth. According to the township records, the population of the village rose from 37,571 in 1961 to 82,353 in 1971.

Of all the factories in the area, the workers of this tire factory and of one of the engineering companies are the best paid. Transport facilities in the area have improved considerably as a result of the establishment of the many factories. Many small restaurants and hotels have also sprung up to cater to the requirements of the workers. Educational facilities have improved considerably. There are 17 primary schools, 6 middle schools and 2 high schools. Apart from the medical facilities provided in the factory, several private doctors have started practice and many shops sell pharmaceutical products.

There are three cinemas and a few recreation clubs.

Interviews with local residents

Fishermen in the area were asked how industrialization had affected them. Many said that the demand for fish had increased and it had become easy for them to sell their catch. The effluents discharged into the sea do not seem to have adversely affected the fishing in the area. It was suggested that the discharge of the city's sewage into the sea provided food for the fish in the particular area. There is a distinct difference in the colour of the water where the effluents are discharged into the sea, and seagulls feed on the refuse that floats (see photograph).

A cross-section of 15 persons (4 workers, 5 from the general public, 4 fishermen and 2 shopkeepers) were questioned about the general effects of the factory on their living habits. Some said that the noise from the factory disturbed them at night, but most said that they had become used to the noise. Some said that because of the increased traffic it was risky for their children to play outside.

Ancillary industries

A number of small metal-fabricating units cater to the needs of the industries in the area. No industries have been set up to use the waste materials from the rubber factory.

Point where the effluents from one of the tire factories are released into the sea along with a large volume of the city's refuse

VI. RECYCLING OPERATIONS

Retreading factory in Madras

The retreading factory the team visited is located right in the heart of Madras. The owners also own a large automobile workshop and a sales office for new cars and trucks. Production capacity of the factory is 36,000 tires/a.

The plant is situated on level ground about 4 km from the sea-shore and surrounded by commercial establishments and a few workshops. The plant is well connected by road to other important places in the city. Madras has a population of 2.4 million. The climate is hot and humid most of the year, with temperatures of 20 -40°C.

Production process

A flow chart of the retreading process is given below:

Inspection
↓
Buffing
↓
Trimming, rasping and repairing
↓
Solutioning
↓
Coating
↓
Stitching
↓
Curing
↓
Finishing

Inspection

All tires are inspected for defects to ensure that only tires fit for retreading shall be selected. Tires having damaged or weak casing are rejected at this point.

Buffing

After inspection, the tires are buffed over the outer surface of the tread to remove surplus rubber and even out the surface, at the same time making the surface rough for proper adhesion of the tread rubber. Band tacks are used on the buffing machine. Output per operation is approximately

80 tires per shift. Dust-extraction equipment is provided, and the operator uses a gas mask to avoid inhaling rubber dust. The worker wears goggles to protect his eyes.

Trimming, rasping and repairing

After buffing, the uneven particles are trimmed off, the tires are put on the rasping machine, and after rasping, minor repairs are made if necessary.

Solutioning

Rubber solution is applied manually to the buffed surface by an operator using a brush. The operator is provided with a gas mask as protection against solvent vapour.

Coating

After solutioning, the tread rubber is laid on the solutioned surface.

Stitching

The purpose of stitching is to fix the tread rubber to the old tire and simultaneously to drive the trapped air from between the new tread and the casing.

Curing

The tires are cured inside moulds of the right size and pattern in presses using steam at 50-60 lb/sq in. for 75-105 min according to the size of tire. Vertical boilers are used. Moulders wear gloves for handling hot tires.

Finishing

Finishing includes trimming of vent spews and also spraying a coat of paint.

Effect on the environment

General

Retreading has a very good effect on the environment because the waste tires that would otherwise pose a problem are recycled. The industry also conserves resources. In retreading, the operations that have to be watched are:

(a) Buffing and rasping. Use of dust extractors reduces the air pollution from rubber particles. The particles collected through the dust extractor are packed in bags and sold as reclaimed rubber at $40/ton. The workers are subjected to a certain amount of inhalation of the particles, which is minimized by the use of gas masks. Goggles give adequate protection to the eyes;

(b) Solutioning. Masks used by the workers help to prevent the ill effects of the solvent vapour (SBP spirit) from the vulcanizing solution;

(c) Curing. Hot working conditions can affect the health of workers. Gloves are provided for handling hot tires.

No occupational hazards have been reported. The factory has a medical centre that gives each worker a medical check-up once a year.

The team did not have sufficient time to visit some of the smaller units operating on the roadside, but heard that such units pay little attention to pollution problems. They employ very few workers and do not come under the Factories Act.

Two oil-fired boilers produce some air pollution, which does not appear to be significant.

Water used for washing tires is discharged into the storm-water drain. There are no other effluents.

Solid wastes are disposed of as follows:

(a) Packing materials - polythene backing and hoop iron are sold. Cardboard boxes and centres from tread rubber are sent back to the factory for reuse;

(b) Unusable tires are returned to the customers;

(c) Waste from dust collectors, approximately 3 tons per month, is sold as reclaimed rubber. It is proposed to use this material for a brake-lining factory to be put up in the future.

Social and economic effects

Employment

The company has 12 retreading plants operating in different parts of the State that provide employment for a total of 650 persons. There are 88 persons employed in the plant visited and approximately 50 persons in each of the other plants, all being locally recruited. The wages paid are slightly above the average for industrial workers in the State. There are 9 wage classifications. No labour troubles were reported to the team.

Welfare measures

Canteen facilities are good. Three sets of uniforms are provided to each worker and are washed free of charge. Educational grants are given to workers for their children's education. Promotion is given up to foreman level after internal training. No significant shift of population takes place, since workers are recruited locally.

Economic benefits

There is an acute shortage of truck tires in the country, and new tires are usually sold by dealers at a premium. A new tire of the size (9.00-20) used on trucks costs approximately the equivalent of $200, whereas retreading of a used tire costs only $43. For a passenger-car tire, the cost of retreading is $13, as against the price of a new tire of around $25.

Indian standards have not been established for retreading. The big retreaders, about five in all, generally maintain a good standard, but the approximately 4,000 small retreaders having small units on the roadside are not in a position to apply strict quality control. It is said that a small retreading plant can be established for a cost of $4,000. The plant visited has an investment of approximately $116,600 and a yearly sales volume valued at $400,000.

Rubber-reclaiming factory near Ernakulam

The team visited a typical rubber-reclaiming factory situated in the countryside 25 km from the town of Ernakulam, Kerala. The site was originally selected where labour was less expensive. Also, the land was cheap. The site is surrounded by paddy fields, coconut and rubber plantations. Since it lies on the main road, raw materials can be transported by road. The area is hilly. Since the factory site is on higher ground than the surrounding fields, there is natural drainage for the rain water.

Old tires and other rubber products used as raw materials for the industry are stocked in the open - 15 tons approximately. Outside go-downs store approximately 300 tons to avoid high requirements of labour in the area of the factory. The factory's consumption is made up of old tires, approximately 25 per cent, and peels from retreaders, 75 per cent.

About 90 per cent of the world's supply of new rubber is not reclaimed but ends up as unwanted waste that has to be disposed of. There are many methods for reclaiming rubber. Reclaimed rubber is a useful compounding ingredient in new rubber compounds for many reasons besides its low cost.

Consumption of natural, synthetic and reclaimed rubber in India for five years for which figures are available are as follows (tons):

Year	Natural rubber	Synthetic rubber	Reclaimed	Total
1964/65	61,057	15,285	9,569	85,711
1965/66	63,765	21,553	9,774	95,092
1966/67	68,685	23,592	10,913	103,190
1967/68	74,518	23,324	11,862	109,704
1968/69	86,615	27,238	14,169	128,022

At present, about 8 units in the country produce reclaimed rubber with a total annual production of around 16,000 tons.

Brief description of process

Old tires and other scrap-rubber products are first ground in grinding mills. Metals are then separated by means of magnetic separators and air suction. The ground rubber is fed into a Reclaimator and through an internal mixer, where it is mixed with chemicals and oils and fed into refiner mills, where reclaimed rubber is finished in the form of sheets.

The following advantages are claimed for the particular dry Reclaimator process used in this factory:

(a) Greater saving of resources, since no materials are destroyed. In other processes parts are burnt or destroyed;

(b) Hardly any effluents. Other processes require:

(i) Washing of the raw materials

(ii) Washing of the digested crumb in the digester process to remove caustic soda and other chemicals;

(c) Both in the digester process and in pan thermal reclaiming, tailings represent up to 30 per cent of the batch owing to uncooked, overcooked or undigested materials as the case may be. Digested effluents and the condensate from the autoclaves have to be disposed of. Owing to the use of steam, sulphur oxides and other toxic ingredients in the rubber are released as effluents, which does not happen in the Reclaimator process.

Effect on the environment

Solid wastes

Rubber particles in the atmosphere in the building are very much in evidence in spite of suction and exhaust arrangements. The sweepings are recycled. Fibre is sold to cotton-waste dealers. Sand is used as landfill.

Effluents

No effluents are released to the outside by this process. Water from the factory's own wells is used for the chilling plant, and the chilled water is sent round for the cooling mills, reclaimator grinder etc.

Gaseous emissions

The odour of burnt rubber is quite strong, but no adverse effects have been reported. The odour is so strong around the factory that motorists unaware of the existence of the factory often stop to check whether anything is wrong with their cars. Air pollution is high inside the factory because carbon black is added in the internal mixer up to 6 per cent; china clay and other fillers are added according to the customer's requirements. It is proposed to add oil and carbon black as a slurry to the crumb, which would reduce air pollution in the factory.

Social and economic effects

Labour in the area was previously engaged in making crushed granite, which is a low-paid job. Wages paid by the plant are more than double what the workers earned previously. Families of the workers have a higher standard of living than before.

There are 29 workers, all locally employed and living in the area. Twelve supervisory staff members have been recruited from different areas. The neighbouring factory is government-owned and makes transformers and structural work. Another factory is being constructed close by. It will produce gas cookers.

No adverse effect has been observed on agriculture. There are no ancillary industries using products from the factory or supplying the factory's requirements.

Fifteen tons of material come in and out every day.

Testing facilities (tensile tester, hardness tester, thickness tester) are made available to manufacturers of rubber products, even those not using reclaimed rubber.

Workers inhale the dusty air, since no dust collectors are installed. They do not like gas masks but prefer a piece of cloth tied over the nose.

Dumps of scrap rubber and old tires are stacked around the factory, which collect water during the rainy seasons and could be a source of mosquitos. However, reclaiming old tires reduces unwanted scrap dumps in other areas.

Expansion plans

It is planned to increase capacity for grinding and refining to match the capacity of the reclaimator. It is also proposed to establish another unit in Calcutta of the same capacity, i.e. 4,500 t/a (3 shifts). Half of the present production is sold in the Calcutta region. The establishment of smaller grinding units in various parts of the country is being considered, since tires are large articles and it would be cheaper to transport ground rubber.

A photograph of the plant is shown below.

The rubber-reclaiming plant set in rural surroundings near Ernakulam, Kerala

Conclusions

There are technical limitations on the use of reclaimed rubber, but it is no doubt an ingredient that can be used in compounding with advantage. Some of the advantages are:

(a) The material being already plasticized, less power will be required for mixing;

(b) Use of reclaimed rubber in the compound helps to reduce the curing temperatures;

(c) Reclaimed rubber, being cheaper than new rubber, can be used to make a cheaper compound for many articles where the use of a high-grade compound would be a waste, e.g. cycle pedals, car mats, solid tires, battery cases. In fact, reclaimed rubber can be used as the sole elastomer in some low-quality compounds. (One of the disadvantages in the use of reclaimed rubber is the reduction of abrasion resistance of the compound. This can be overcome to some extent by the use of new rubber and carbon black loading.)

(d) Use of reclaimed rubber undoubtedly helps to conserve resources. Reclaiming old tires and other scrap products helps to preserve the environment from unsightly and unhealthy dumping of scrap;

(e) The rubber-reclaiming industry provides employment in the factory and in the collection and transport of materials.

The plant visited by the team has little effect on the environment or on the health of the workers, since the plant is located in rural surroundings. Proper dust-collection equipment should form an essential part of the plant.

The addition of extender oils and carbon black to form master batches with reclaimed rubber would help reduce pollution in the manufacturing industries using the reclaimed rubber.

VII. LEGISLATION, ENVIRONMENTAL PLANNING AND CO-ORDINATION IN INDIA

Pollution-control legislation

In February 1974 the Indian Parliament passed the Water (Prevention and Control of Pollution) Act of 1974 to provide legislation for (a) preventing and controlling water pollution; (b) maintaining or restoring the wholesomeness of water; (c) establishing boards for the prevention and control of water pollution; (d) conferring on and assigning to such boards powers and functions relating thereto and for matters connected therewith.1/

Only two States in India have any regulations concerning water pollution. The Factories Act of 1948 is very vague and general and is not particularly easy to enforce.

The Water Act of 1974 provided for the establishment of a Central Board, State Boards and Joint Boards. The Central Board will consist of a full-time chairman and member-secretary, five officials nominated by the Central Government, three non-officials representing agriculture, fisheries and industries, up to five members representing State Boards and two representing private or public enterprises. The Central Board will have the following functions: (a) to advise the Central Government on any matter concerning the prevention and control of water pollution; (b) to co-ordinate the activities of State Boards and resolve disputes among them; (c) to provide technical assistance and guidance to State Boards; (d) to plan and organize training of persons engaged in pollution control; (e) to organize through mass media a comprehensive programme regarding pollution control; (f) to collect, compile and publish technical and statistical data relating to water pollution; (g) to lay down, modify or annul in consultation with State Governments standards for a stream or well; and (h) to plan and cause to be executed a nation-wide programme for the prevention, control or abatement of water pollution.

A State Board will consist of one full-time Chairman and Member-Secretary, five officials nominated by the State Government, five members representing local bodies, three non-officials representing agriculture, fisheries etc. and two persons representing industry.

1/ Copies of this act can be obtained from the Ministry of Works and Housing of the Government of India.

The functions of a State Board are: (a) to advise the State Government on pollution control; (b) to plan a comprehensive programme for pollution control and collect and disseminate information on the subject; (c) to collaborate with the Central Board in various activities; (d) to encourage research on the subject; (e) to lay down standards and inspect sewage and industrial effluent-treatment plants; (f) to evolve efficient methods of treatment; (g) to evolve methods of using sewage and effluents for agriculture; and (h) to establish effluent standards.

An agreement may be entered into by two or more States to have a Joint Board, consisting of a full-time chairman and member-secretary, one official nominated by the Central Government, one non-official nominated by the Central Government and two persons from industry. The Government of the State for which a joint board is constituted shall be competent to give any direction to a matter within the exclusive territorial jurisdiction of the State. These boards may establish or recognize a laboratory or laboratories to enable the board to perform its functions efficiently, including the analysis of samples of sewage or effluent.

Any officer empowered by the boards has powers to enter the premises of any industry and collect samples. Whoever fails to comply with a direction given by a board may, on conviction, be punishable with imprisonment for up to three months or with a fine of up to Rs 5,000 or both. If non-compliance continues, an additional fine of up to Rs 1,000 may be levied for every day it continues. The Act further states:

> "(a) no person shall knowingly cause or permit any poisonous, noxious or polluting matter determined in accordance with such standards as may be laid down by the State Board to enter (whether directly or indirectly) into any stream or well; or
>
> "(b) no person shall knowingly cause or permit to enter into any stream any ... matter which may tend, ... to impede the proper flow ... or to lead to a substantial aggravation of pollution ...."

The Central and State Governments may (a) establish central or state water laboratories or (b) specify any laboratory as an authorised laboratory to carry out the functions assigned to it.

Work done by Indian Standards Institution in water-pollution control

Long before any antipollution laws were passed, the Indian Standards Institution (ISI) had drawn up standards necessary for water-pollution control and guides for the treatment of certain industrial wastes. ISI prepares three standards for the disposal of industrial effluents into different environments. They comprise tolerance limits for the industrial effluents discharged (a) into inland surface waters; (b) into public sewers; and (c) on land for irrigation.

As there are no statutory standards, several State Governments and municipalities are using the ISI standards for controlling water pollution.[2]

Enforcement of pollution control

Difficulties are bound to arise with industries that lack adequate finances to undertake waste disposal. In the case of new industries it may be possible to incorporate waste treatment from the beginning or choose favourable sites for their location. In the meeting held with the Joint Secretary for Industrial Development, the team was told that provision had been made in all applications for licences to start an industry to ensure that antipollution measures should be provided, and letters of intent were given on the distinct understanding that such measures would be introduced. For small industries, common service facilities on a co-operative basis may be the answer. For cities and towns that will be pressed to install sewage systems, finance will be a problem, and it is anticipated that they will turn to the Government for loans.

For industries required to install expensive waste-water-treatment equipment, it is thought advisable to give tax incentives as is done in some of the Western countries, for example, writing off the entire depreciation on the waste-treatment plant in one year.

The National Committee on Environmental Planning and Co-ordination

The National Committee on Environmental Planning and Co-ordination has been set up by the Government to review and advise on matters related to the environment with the following terms of reference:

(a) Identifying and investigating the problems of preserving or improving the human environment in the country in the context of population growth and its distribution and economic development;

(b) Reviewing policies and programmes that have a significant bearing on the quality of the environment and advising the Government, public authorities

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2/ Copies of the ISI standard tolerance limits can be obtained from the Indian Standards Institution, Manak Bhavan, 9 Bahadur Shah Zafar Marg, New Delhi.

and industry concerned, on environmental repercussions of the activities, programmes and policies and on matters relating to appropriate environmental management;

(c) Reviewing existing legislation, regulations and administrative machinery for environmental management and advising authorities concerned regarding necessary changes;

(d) Proposing solutions to environmental problems after taking into account, as far as possible, all relevant factors, including cost effectiveness;

(e) Ensuring that environmental policies and measures shall be co-ordinated with economic policies and measures and the results of environmental investigations and research shall be fully utilized in the wider framework of planning for economic and social development;

(f) Advising on conservation of nature in all its aspects, with a view to increasing the knowledge of nature, deepening a love of it among the people and safeguarding for the future the rich heritage of nature in the country;

(g) Promoting research in environmental problems and establishing facilities for such research wherever necessary;

(h) Promoting and strengthening environmental education at various levels in the educational system;

(i) Promoting and enlarging public awareness of environmental problems through conferences, seminars, symposia or any other means;

(j) Co-operating with the United Nations and other international agencies in environmental programmes of global concern and keeping in close touch with developments in the environmental field in other countries.

Office of Environmental Planning and Co-ordination

The Office of Environmental Planning and Co-ordination (OEPC), consisting of scientists and engineers of various disciplines, was set up to aid the National Committee on Environmental Planning and Co-ordination in formulating and co-ordinating plans and programmes related to environmental improvement. OEPC works with the appropriate ministries to ensure the proper use of pollution-control equipment when future plants are set up. Some of the activities of OEPC are:

(a) Environmental education and training programmes. These include lectures, seminars and articles in newspapers and magazines to increase "environment consciousness" among citizens;

(b) Environmental research. OEPC encourages work in national laboratories to develop techniques for the treatment and disposal of sewage and solid waste from domestic and agricultural sources. In addition to encouraging the evolution of technological solutions, OEPC actively promotes work on other possible options such as proper location of pollution-generating activities and the development of alternative methods of disposing and reusing wastes. It has set up two committees to formulate and co-ordinate programmes of research in environmental protection:

(i) Environmental Research Committee (ERC). This committee conducts research in human settlements, environmental pollution and management of natural resources;

(ii) Indian National Man and the Biosphere Programme (MAB). This committee in co-operation with the MAB programme of UNESCO, deals with the ecological aspects of the environment such as natural conservation, wild-life management and crop and soil management. A symposium on noxious aquatic vegetation was conducted in 1973 at which 54 papers on ecology, hydrology, limnology, fisheries, agronomy, botany, engineering and physics were read. This interdisciplinary approach resulted in the evolution of guidelines and strategies for combating pollution;

(c) Wet-land survey. After a country-wide survey, a wet-land map of India has been prepared. Another survey of aquatic weed infestation in the country in in progress;

(d) Project appraisal. OEPC, together with the project-appraisal division of the Planning Commission, is developing guidelines for evaluating the relative costs and benefits of development projects that take account of environmental factors. Quantitative evaluation procedures and an environmental impact matrix method are being worked out. Some of the projects that have been taken up to assess the environmental effect are:

The proposal to establish a six-million-ton refinery at Mathura

Proposal to locate a naval academy at Chilka Lake

Guidelines for site selection of super thermal power stations

Proposal to locate a hydroelectric power project in the middle of the wild-life sanctuary at Mudumalai

(e) Planning. Five-Year Plan proposals on environmental improvement have been submitted to the Planning Commission. The project areas include:

Environmental aspects of human settlements

Environmental pollution

Environmental aspects of natural resources management

Ecological and environmental research training and education;

(f) Noise. OEPC is collaborating with the Consumer Council of India in initiating steps to tackle the growing problem of noise;

(g) Participation in the Technical Advisory Committee of the Ministry of Irrigation and Power. OEPC is represented on the Committee.

National Environmental Engineering Research Institute

The National Environmental Engineering Research Institute, which has its headquarters at Nagpur and eight zonal laboratories spread over the country, has been making recommendations for economic methods of pollution control that suit local conditions in the following fields:

Industrial waste treatment

Water treatment

Sewage treatment

Air-pollution surveys of major cities

Microbiological studies

Studies on methods of solid-waste disposal

Training courses for field personnel in public health engineering and seminars on important subjects, e.g. treatment and disposal of tannery wastes, estuarine pollution

Special mention must be made of the research in industrial waste treatment and industrial air-pollution surveys carried out by NEERI as a significant contribution to environmental pollution control in India.

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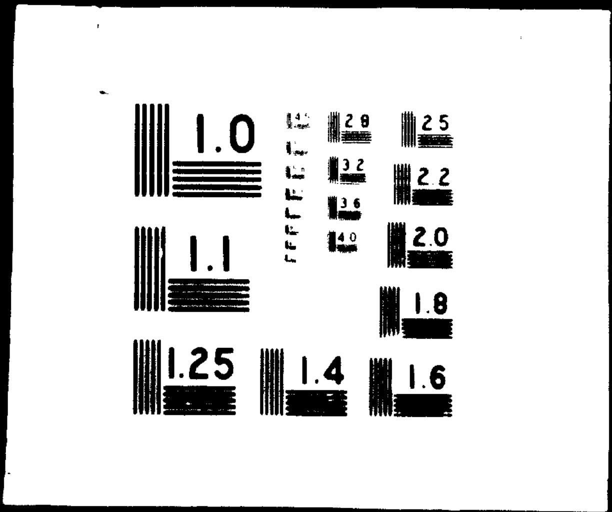

VIII. EXISTING AND PROPOSED POLLUTION-CONTROL LEGISLATION IN THE UNITED KINGDOM

Types of pollution

Air

Under the Alkali Act of 1906 and the Clean Air Acts of 1956 and 1968, standards were established for industrial emissions into the atmosphere, including smoke, grit and dust from specific industrial and chemical processes, and the "best practicable means" of reducing air pollution. The synthetic rubber plants come under the jurisdiction of these acts. In essence, a set stack height for the boilers was established. The height was determined in 1969 with consideration of the production levels of that year. No additional measures have been undertaken.

Water

The team had discussions with a pollution officer in the Southern Water Authority, which controls Southampton. The Clean Rivers (Estuaries and Tidal Waters) Act of 1960 brought under its control new or altered discharges, whereas the 1951 Act applied only to non-tidal waters and certain specified tidal estuaries. This means that only new discharges after September 1960 are subject to the control of the Southern Water Authority.

The standards established earlier are flexible and consider the volume and composition of the effluent, the dilution available and the probable effect of the discharge on the receiving water. Data from these tests are not available to the public. If the contaminants are excessive in the waste water, the local authority can only recommend that the problem be corrected. There is no legal authority behind the existing legislation. Fortunately, stronger legislation is pending, such as the Control of Pollution Bill, which will regulate effluent emissions into estuaries and coastal waters. Through this and similar legislation, it is hoped that more frequent "end-of-the-pipe" tests will be conducted, which will include the following pollution parameters: BOD, COD, pH, suspended solids, and oil and grease.

Noise

The Factories Act of 1961 prohibits noise of such a nature as to "cause risk of bodily injury". Numerous reports have been published that describe the hazards of noise levels and provide methods of achieving noise reduction. The Safety and Health at Work Bill that is now pending in the legislature provides provisions for noise abatement.

Pollution control

Since the nineteenth century, the need to control atmospheric emissions has been recognised. As far back as the 1860s, standards were established to control factory emissions. In recent years, considerable improvements have been achieved in reducing air pollution. Control of domestic smoke has been a more recent development. The Clean Air Act of 1956 has given local authorities control of domestic emissions.

The quality of the public water supply and pollution control have become major considerations in recent years. Ten regional water authorities have been established to administer the country's water and sewage services. The Department of Environment (DOE) has the general responsibility of ensuring satisfactory operation of these water authorities.

DOE was set up in November 1970.3/ It is responsible for a whole range of functions that affect the environment in which people live, including:

Land-use planning
Road building and traffic management
Improvement of the urban environment
Conservation and recreational use of the countryside
Protection of ancient monuments and historic buildings
Control over many types of pollution
Provision of water and sewage-disposal facilities
General supervision of the construction industries
Housing
Development of new towns
Many aspects of inland surface transport
Regional development

The head of the department is the Secretary of State for the Environment, and the number of staff employed is about 80,000 with an annual budget of close

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3/ The Department of the Environment has published a book on its work. This book can be obtained from the Department of the Environment, 2 Marsham St., London SW1.

to $10 billion. Although everything that DOE does is concerned with environmental protection, the following are the specific areas of pollution control it concentrates on:

Cleaning the air

Water supply and sewage disposal

Cutting down noise

Solid-waste disposal

In the field of noise pollution, DOE has general jurisdiction for governing local activity. Noise pollution can be curtailed by isolating the source of the noise from the people or by reducing the noise level itself. Additional controls include a Noise Advisory Council established as an independent source of government recommendations.

Organizational systems for solid-waste collection and disposal come under the authority of the local government. DOE has ocoasionally exercised its control over these operations. In certain instances, toxic wastes have been disposed of improperly and have created a danger to public health. In cases where the public health might be affected, DOE has intervened to place limitations on the local authorities.

IX. CONCLUSIONS AND RECOMMENDATIONS

Natural rubber production

Conclusions

1. Natural rubber production offers the possibility of employing large numbers of workers in both the plantations and in the processing factories. Unemployment is one of the major problems in a developing country like India.

2. Many small holders are involved and therefore the social impact is great.

3. Rubber plantations have the following ecological advantages:

(a) They purify the air;

(b) Rubber is a better reforestation crop than other forest crops;

(c) The areas where rubber is grown are not ideally suited for food crops except for a few items. Food crops are likely to permit soil erosion;

(d) The leguminous ground cover normally resorted to in scientific cultivation serves as a soil stabiliser.

4. Inadequate attention is being paid to the damages caused by the release of liquid effluents from the production of concentrated latex and solid rubber into streams. In the summer months particularly, the dilution levels may cause significant damage, the extent of which, owing to lack of regular monitoring and analysis, the team was unable to assess.

The team did not receive any reports of land contamination from the use of fungicides.

5. The industrialists have in the past given low priority to environmental considerations, having been more concerned with the social benefit of providing employment The team felt that cost was not the main reason for this low priority but a lack of awareness of the importance of environmental protection in rural surroundings possibly arising because of the capacity of the environment to absorb a certain amount of pollution without tangible adverse effects.

Recommendations

1. Steps should be taken to mitigate environmental pollution caused by the release of effluents from the processing plants, among which the latex concentration factories produce effluents with the highest BOD and COD values.

Much work has been done on low-cost treatment methods using aeration and an algal culture, and industrialists should be persuaded to treat effluents even before permissible standards have been established and the new pollution-control legislation takes effect.

2. The Government and the Rubber Board should take speedy measures to enforce the pollution-control legislation.

3. Co-operative societies, which serve a very useful function in helping small growers, whose holdings occupy 69 per cent of the total area in which rubber is grown, should be encouraged with financial assistance to establish units capable of using modern processing methods such as those used in making solid block rubber.

4. Loans and subsidies should be given to rubber growers to encourage them to undertake new planting and replanting schemes. The team had the opportunity to meet a World Bank team that was visiting the area to consider this proposal.

5. Greater emphasis should be given to disseminating the results of research carried out by the Rubber Research Institute of India on the economic use of fertilizers for rubber trees, the judicious use of yield stimulants and the beneficial effects of having _peuraria phaseoloides_ ground cover.

Synthetic rubber production in India

Conclusions

1. The plant the team visited is located in a rural area with plenty of waste land for lagoons for effluent treatment. The major portion of the effluents is, however, discharged into a river used for irrigation through a 4-km pipeline after only partial treatment. The lagoons used for treating the smaller part of the effluents for irrigation appear to be effective.

2. From the environmental point of view, the effluents let out into the river may constitute a danger to the health of human beings who bathe in the river and to fish life. This is particularly so with the high concentration in the summer time. Pollution-control legislation has been introduced only recently. Although control boards have been formed, permissible standards are yet to be fixed. The present BOD level of 750 ppm is much higher than the standard of 200 ppm fixed by the Uttar Pradesh State Government, which is generous according to international standards and those established by the Indian Standards Institution. The company has asked for recommendations for effluent treatment from the NEERI laboratories.

3. The industry has undoubtedly made a significant contribution to the local economy in providing employment to over 1,500 persons, and the welfare amenities provided in the housing colony are to be commended. The company's policy of encouraging ancillary industries in the locality has also contributed to the prosperity of the area.

4. The factory gives the impression of being well designed and well managed. The underutilization of capacity and low profitability are due to factors beyond the control of the management.

Recommendations

1. Efforts to reduce the BOD in the effluents released into the river by bacteriological treatment need to be continued more vigorously.

2. Analysis of the effluents from the lagoons should be made at the point of release to the stream, which is used for irrigation and watering of cattle.

3. In starting a new synthetic rubber plant, provision should be made for adequate land for settling pits and lagoons.

4. Better utilisation of the substandard crumb, which is now sold at a give-away price, should be explored.

5. The health hazards from handling of chalk in the packing section should be eliminated, possibly by opening up one side wall.

6. A feasibility study taking into consideration the costs and availability of raw materials should be made before establishing a highly competitive industry like synthetic rubber. The Indian SBR plant was conceived in the late 1950s primarily as a means of using surplus alcohol from sugar-cane available as a by-product of the distilleries of Uttar Pradesh State, which was then exported at unremunerative prices, and benzene, a by-product of the steel plants. It would appear from later results that costs and availability of the raw materials were not adequately considered, and the factory made no profit for several years after starting production.

7. Another important factor that developing countries should consider is the availability of markets for the products. The Indian SBR plant has worked only to about 70 per cent of its capacity partly because the manufacturers of rubber products have been reluctant to buy synthetic rubber at higher prices than natural rubber without a significant improvement in performance.

8. Developing countries starting production of highly competitive lines should establish a competent research and development (R and D) department. This company now, after several years, has invested substantially in R and D, and production is being diversified to include nitrile rubber and ABS plastics, but much valuable time has been lost.

Synthetic rubber production in the United Kingdom

Conclusions

1. Within the limited time available, the team was able to make only a qualitative survey. On the basis of this survey and on information given by the industry and the local authorities, the team concluded that the synthetic rubber plant at Hythe, Southampton, was not affecting the environment adversely.

2. Since the plant is part of a large industrial complex, the effect of this plant on the environment will not be easy to identify, unless pollution reaches a significant level. The same may be said of most synthetic rubber plants, which usually form part of a petrochemical complex. In this particular case, it was noticed that neither this plant nor the combination of plants in the complex was polluting the environment significantly. The only exception would be the rather strong odour of the monomers, which could be smelt in the entire area of the factory. However, it was not strong enough to be objectionable to the local residents, since new housing projects have sprung up adjacent to the plant.

3. The major source of pollution from a synthetic rubber plant is the effluents discharged. The Hythe plant discharges daily two streams of effluent: 10 million imperial gallons of sea water for indirect cooling and 1 million imperial gallons of fresh water. The sea-water effluent is practically unpolluted, but is discharged at a higher temperature. It is the fresh water, used for processing, that is the major source of pollution. The plant is strategically located to enable the effluents to be discharged, after treatment, into the Southampton estuary.

Discharges into tidal waters do not come under the purview of the present legislation as long as the volume or content does not exceed the level of September 1960. It is expected that new legislation will bring the tidal waters under the control of the Southern Water Authority in the near future. However, the civic sense of those connected with the industry and the relations between them and the government authorities are so good that without threat of penal action, corrective measures can usually be initiated by the authorities, who periodically check BOD and coliform levels near the discharge points. From talks with the local authorities, it was found that there had been instances in the past of depressed levels of oxygen and high ammonia levels about 2 km away from the discharge point, but the situation had been rectified promptly.

No adverse effects have been reported on marine life.

4. The main source of external air pollution is the burning of oil with 3 per cent sulphur content in the boilers. The plant contains a waste gas header system terminating in a flare stack for burning hydrocarbons in the event of a bursting disc failure. This occurrence is infrequent. With the stack height and the predominant wind direction as they are, the gaseous emissions have a tendency to fall over the city of Southampton.

5. The maximum continuously permitted noise level in the plant is 84 decibels at 1.3 m from the source. No one is continuously subjected to this noise level at any point.

6. Approximately 1 per cent of the total production is recovered as solid-waste rubber. Of this amount, 20 per cent is sold for use in low-grade rubber products and 80 per cent is disposed of in areas of land reclamation under the control of the local County Council.

Recommendations

1. To avoid a high degree of pollution in the Southampton area caused by the stack emission, antipollution devices such as sulphur-stack scrubbers should be employed.

2. Tests should be conducted in the ammonia-refrigerant cooling area to determine whether the ammonia levels are high enough to warrant corrective action.

3. The plant has only one pit for the stripping phase and only one pit for the coagulation liquor and crumb-rinse overflow. Each crumb pit should have a dual unit to ensure that proper crumb separation shall be achieved during emergencies and pit-cleaning operations.

4. Since the plant has no provision for keeping rain run-off from flowing into the effluent drain, the crumb pits and the treatment facility can be flooded after a heavy rainfall and thus rendered ineffective. Additional lagoons should make provision for separating storm-water run-off from process waste water and domestic sewage.

5. If tests show that COD levels are high in the effluent pipe (-500 mg/litre), the plant should investigate the feasibility of employing activated carbon to reduce them. Implementation costs may prove to be expensive. However, a study recently carried out in the United States of America indicates that 70 per cent of COD removal could be achieved at a cost of $369/million gallons of effluent.

6. During the coagulation phase, the coagulation liquor consists of an acid and a brine solution. This type of liquor produces large quantities of total dissolved solids that are discharged into the coagulation liquor overflow. Use of an acid polyamine liquor would substantially reduce the total dissolved solids in the effluent.

7. Efforts should be made to reclaim a higher proportion of the solid waste for use in industries that make use of cheaper rubber, e.g. toy, shoe-sole manufacture.

Manufacture of rubber goods

1. Regardless of whether natural rubber or synthetic rubber is used in the production of rubber goods, the pollution problems will be the same.

2. The main sources of pollution in the industry have been identified as (a) carbon black in the compounding area; (b) chalk used in tube extruding; (c) rubber particles from the grinding operations; (d) process waste water; and (e) sewage.

Carbon black

Tire factory No. 1 has a Redler conveyor system that considerably reduces pollution in the compounding area. The handling of free black in the section is eliminated, but bags are still opened in the warehouse, which is a messy operation. The better arrangement would be the bulk handling of black. A factory to be opened in West Bengal is located near a carbon black manufacturing plant, which would make it possible to supply the black direct from the factory by pipelines pneumatically, probably the most desirable method of dealing with the problem.

Carbon black solution master batches produced in the natural or synthetic latex production areas have a high level of dispersion, but have not gained the popularity they were expected to gain in the rubber goods industry even in the

United Kingdom. Their use means lower power requirements for the mixer, shorter mixing cycles and fewer housekeeping problems. The advantages of the process will be lost if a wide range of grades of black is demanded. Much work has to be done to make standard batches attractive to the tire maker, who will have to modify slightly his approach to compounding.

Chalk

The only means of combating pollution from chalk is to use effective dust-extraction equipment and wet slurry wherever possible. Operators should be required to wear gas masks.

Rubber particles

In grinding operations the machines should be supplied with hoods and dust-extraction equipment. Here again the use of gas masks is essential. The rubber collected can be reclaimed.

Process waste water

The treatment of process waste water in tire plant No. 1 is recommended for industries in developing countries that have the necessary land. This plant has an end-of-pipe treatment for all process waste-water streams. After chemical treatment in large settling tanks, the effluents are pumped into strainer beds and again into settling tanks after which they are released to the outside canals. No specialized equipment is required. Water is scarce in many developing countries, and the treated water is useful for irrigation.

Sewage

Tire factory No. 1 has very effective sewage treatment, and similar systems could be used by other factories. The equipment required is now manufactured locally. Sewage treatment is highly desirable from the point of view of public health and because of the high nutrient value of the residue, which can be used in farming, and the water made available for irrigation.

3. Occupational dermatitis is probably the most widespread hazard in the processing industries. Effective control by reduction of skin contact and provision of adequate washing facilities should be maintained.

Health hazards may arise from the toxicity of certain chemicals used in compounding. Certain additives have in the past led to ill effects, including bladder cancer, and the use of such chemicals has been banned. Screening of any new material used in processing is absolutely essential. Occupational exposure should be subject to environmental monitoring, and workers involved should be subject to regular medical examinations.

Recycling

Retreading

The retreading industry, a low-cost, small-scale industry, not only has minimal potential for environmental pollution, but also preserves the environment from unwanted tires, conserves resources and meets the needs of the consumer at economic prices. Quality standards are to be established, which will ensure the safety of the users.

Reclaimed rubber

The problem of disposing of old tires and other waste rubber in developing countries is adequately solved by retreading and reclaiming.

When wet processes are used, the effluents need to be treated. When the dry Reclaimator process is used, air pollution can be combated by using effective dust-extraction equipment.

With the low cost of transport in developing countries, the industry can supply material to the rubber goods industry at attractive rates. When reclaimed rubber is mixed with new rubber in the right proportions, the quality or performance of the product is not affected. The industry does not harm the environment; it conserves resources and creates employment in the production industry as well as in collection and transport.

The rubber industry as a whole

1. The rubber industry cannot be classed among the industries that seriously pollute the environment. Natural rubber production in fact could be beneficial to the environment, if effluents were treated. Hitherto little or no attention has been paid to the treatment of effluents because rural surroundings are capable of absorbing some environmental pollution and because a higher priority has been given to the creation of employment.

2. The establishment of an agro-based synthetic rubber industry located in a rural area can be recommended, particularly since the raw material sources are renewable, the pollution it causes can be controlled, and it will bring immense social benefits.

3. In selecting effluent-treatment methods, developing countries can, with advantage, select low-cost methods that do not require advanced technology, but require large areas of land and many workers. Settling tanks and lagoons that require periodic cleaning are a good example.

4. Pollution-control costs have not exceeded 1 per cent even in the industries that have satisfactory pollution-control measures. Some measures pay for themselves partly through the products recovered, e.g. sulphur from stack recovery, rubber dust from dust-extraction units, manure and water from sewage-disposal systems.

5. Pollution-control legislation, together with the establishment of allowable pollution standards and provisions for strict compliance, is essential in developed and developing countries. The recently passed legislation, the work of the Office of Environmental Planning and Co-ordination (OEPC) and NEERI in India should prove to be of value to other developing countries.

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