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STUDIES ON EFFLUENTS FROM NR PRODUCTION IN MALAYSIA 1/

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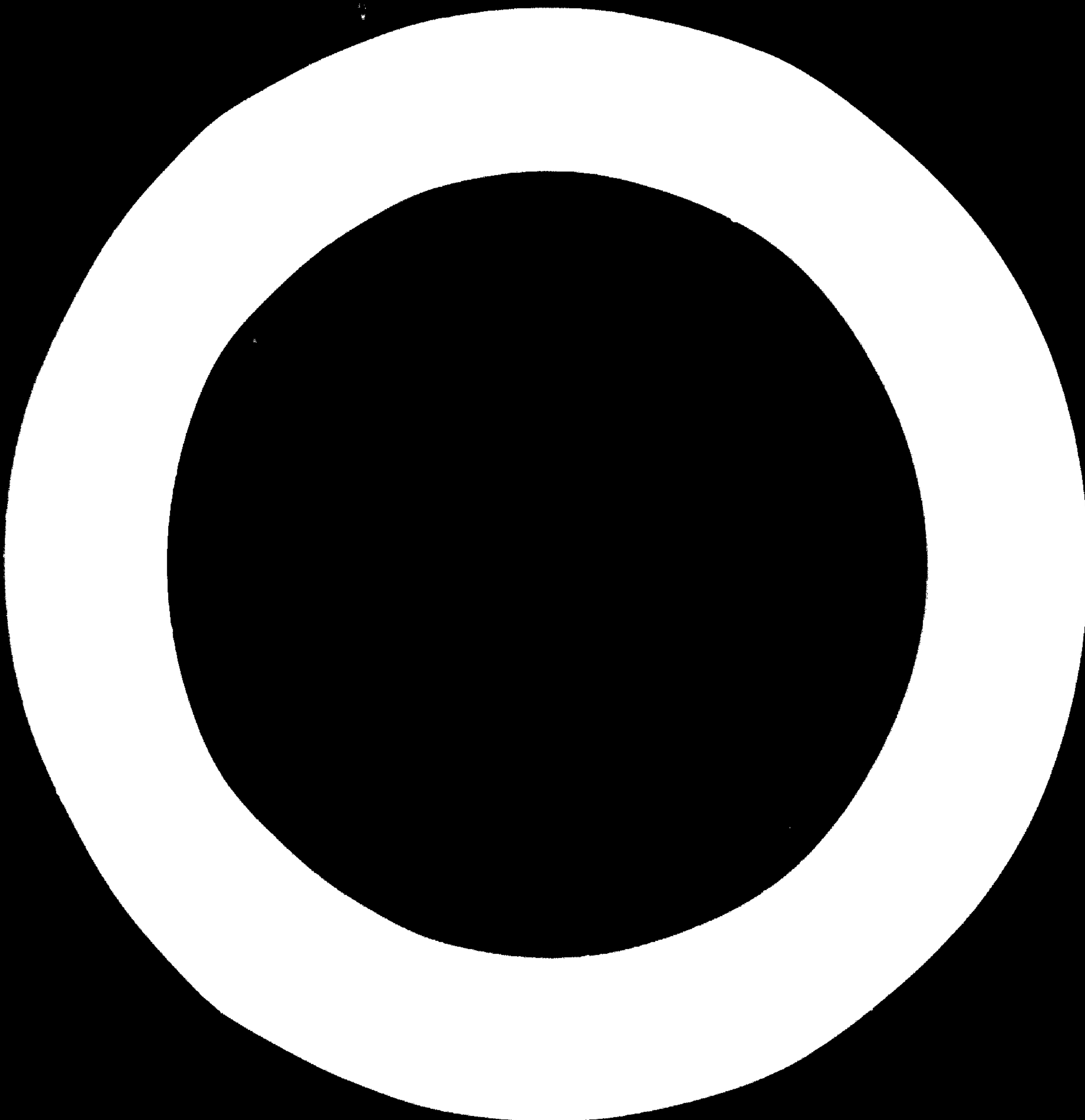

The devastating effect of industrial pollution on the environment is of world-wide concern. The extent of pollution in Malaysia is not near that of developed countries but it is a growing concern and is being considered in national development plans. The largest concern of industrial pollution in Malaysia at present include the agro-based industries (mainly the natural rubber (NR) industry), metallurgical plants and foundries, paper and textile industries. These adopt processes which discharge waste water (effluent) containing very high levels of solids matter, biochemical oxygen demand (BOD) and acidity.

The Malaysian production of NR in 1973 was about 1.47 million tonnes of which about 16% was in the form of latex concentrate produced by the processes of centrifugation, creaming and evaporation, and the rest as dry rubber such as SMR block rubber, RSS, ADS and crepes of all types and grades. SMR constituted about 25% of the total production and is expected to continue to increase rapidly in the near future. It is therefore evident that the effluents discharged from SMR factories assume a priority consideration.

During the processing of rubber, various amounts of water are used for washing, cleaning and dilution. The effluent is subsequently discharged normally and conveniently to a nearby stream or river. It is estimated that an enormous quantity of 80 million litres of effluent is discharged from rubber processing factories per day. The effluent consists of process water, small amounts of uncoagulated latex and substantial quantities of proteins, sugars, lipids, carotenoids, inorganic and organic salts which originate from natural rubber latex. These substances form excellent substrates for the proliferation of micro-organisms generating a high BOD and an objectionable odour.

This paper gives a brief review of the properties of these effluents, their possible uses and treatment.

CHARACTERISTICS OF EFFLUENTS AND THEIR SIGNIFICANCE

A survey[1] was conducted on the physical, chemical and bacteriological properties of effluents from typical rubber processing factories of SMR block rubber, RSS, remilled rubber and latex concentrate. A summary of the results is given in Tables 1 and 2.

Physical and Chemical Properties

From the data shown in Table 1, it is observed that effluents from the four types of factories are acidic as indicated by the pH values ranging from 4.2 to 6.3. Although highly acidic waters may induce adverse effects on plant growth and may also affect corrosion of river structures, these values are within the range of pH 4.5 to 9.0 for most natural waters. The acidic nature of the effluents is attributed to the use of formic, phosphoric, or sulphuric acids in the process lines.

The effluents also contain fairly large amounts of total solids, suspended, dissolved and settleable solids. For example, the total solids of the effluent from latex concentrate factories is about 6000 ppm, whereas those of RSS, SMR block rubber and remilling factories are about 3750, 1400 and 500 ppm respectively. In the first three types of effluent, the major proportion of the total solids content is dissolved solids whereas in the fourth type where the total solids is relatively low, this is mainly of suspended solids.

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(1) R.N. Muthurajah, C.K. John and H. Lee (1974) Developments on the Treatment of Effluent from New Process SMR Factories. Proc. Rubb. Res. Inst. Malaya, Plrs' Conf. Kuala Lumpur 1973, pp.402.

TABLE 1. QUALITY OF THE INCOMING WATER SUPPLY AND THE FINAL EFFLUENT DISCHARGE

(Summary of Physical and Chemical Data)

Sample	pH	Settleable solids	Suspended solids	Total solids	C.O.D.	B.O.D. (30°C/3 days)	Ammoniacal nitrogen	Albuminoid nitrogen
Block rubber factory								
Water tank	6.2	30	45	115	70	30	0	0
Final discharge	6.3	155	230	995	1620	1140	55	20
RSS factory								
Water tank	6.0	0	0	70	30	10	0	0
Final discharge	4.9	50	140	3745	3300	2630	10	100
Remilling factory								
Water tank	6.0	10	15	85	60	40	0	0
Final discharge	6.2	205	330	480	900	740	15	10
Concentrate factory								
Water tank	6.0	5	5	50	80	20	0	0
Final discharge	4.2	100	190	6035	4590	2580	395	85
Mean of water tank supplies	6.05	10	15	80	60	30	0	0
Mean of final discharges	5.4	120	230	2815	2600	1700	120	55

Note: (1) Each figure is a mean of four replications.
(2) Final discharges from both block rubber and concentrate factories were partially treated using ponding, pitting or filtering.
(3) All values except pH expressed as p.p.m.

TABLE 2. QUALITY OF THE INCOMING WATER SUPPLY AND THE FINAL EFFLUENT DISCHARGE

(Summary of bacteriological data)

Sample	Log count/ml		Presumptive count/100 ml		
	22°C	37°C	Coliform	E. coli	Streptococci
Block rubber factory					
Water tank	4.05	4.01	51,000	23,700	1,200
Final discharge	6.50	6.66	10,655,000	2,272,000	6,294,500
RSS factory					
Water tank	2.75	2.66	250	10	10
Final discharge	5.81	5.90	1,540,250	191,300	3,127,100
Remilling factory					
Water tank	2.97	2.88	26,800	20,100	150
Final discharge	7.17	7.13	41,875,000	7,487,500	16,950,000
Concentrate factory					
Water tank	3.86	4.00	5,400	300	100
Final discharge	4.38	4.55	415,200	24,100	31,200
Mean of water tank supplies	3.41	3.39	21,000	11,500	350
Mean of final discharges	5.97	6.06	13,621,400	2,493,700	6,350,700

Note: (1) Each figure is a mean of four replications.
(2) Final discharges from both block rubber and concentrate factories were partially treated using ponding, pitting or filtering.

The BOD values for the concentrate, RSS, SMR block rubber and remilling factories were about 2600, 2600, 1100 and 700 ppm respectively while the corresponding COD values were 4600, 3300, 1600 and 900 ppm. The high BOD and COD values of the concentrate and RSS factories indicate that the total solids in the effluents are mainly of organic origin with high oxygen requirements for their oxidation. It is emphasised that the oxygen demand values for concentrate factories are expected to be much higher in cases where partial treatments like ponding, pitting or filtering are not incorporated; the concentrate factories examined were subjected to partial treatments of pitting or filtering.

Total nitrogen is a measurement of ammoniacal nitrogen combined with organic (mainly albuminoid) nitrogen. In the four types of effluent, the main contribution to total nitrogen is ammoniacal nitrogen. This is due to the use of substantial quantities of ammonia in the preservation of latex.

Ammoniacal nitrogen is highest in effluent from latex concentrate factories (395 ppm). This is followed by SMR block rubber (55 ppm), remilled rubber (10 ppm) and RSS (10 ppm).

In the case of albuminoid nitrogen, the effluent from RSS factories was highest (100 ppm). This is followed by the latex concentrate (85 ppm), SMR block rubber (20 ppm) and remilled rubber (10 ppm) factories. This is contributed mainly by the breakdown of proteins and amino acids in the latex serum.

The presence of albuminoid nitrogen gives an approximate indication of the more readily decomposable nitrogenous organic matter present in waste water. It represents only a fraction of the organic nitrogen present in waste water.

Bacteriological Properties

The final discharge from the remilling factory gave the largest total viable bacterial population, followed successively by SMR block rubber, RSS and concentrate factories (Table 2). A similar relationship is also found in their pH values (Table 1) which may partly explain the difference in the total viable population in the various types of effluents, a near neutral pH conditions is more favourable for bacterial proliferation and growth.

An examination of Table 2 shows that the effluent discharged from the remilling factories contained the largest viable population of all the three types of bacteria - coliform, Streptococci and E.coli - giving 42, 17 and 7 million/100 ml respectively. Bacteriologically, the effluent from remilling factories must therefore be considered polluting. The corresponding microbial population for effluent of SMR block rubber factories were also large being 11, 6 and 2 million/100 ml respectively. The effluent of RSS factories contained more Streptococci than coliform bacteria, being 3.0 and 1.5 million/100 ml respectively but these values are lower than those of remilling and SMR block rubber factories. The high acidity of the concentrate factory effluent (pH 4.2) sustained relatively low amounts of these three types of bacteria.

Thus from the physical, chemical and bacteriological data listed in Tables 1 and 2, it is observed that the effluents contain large amounts of solids, both organic and inorganic, creating a high oxygen demand. The amount of waste discharge is greater with concentrate and RSS factories than with SMR block rubber and remilling factories in respect of physical and chemical properties. On the other hand, bacterial population is greatest in remilling factories, followed by SMR block rubber, RSS and concentrate factories.

UTILISATION OF EFFLUENTS

Should these effluents be utilised in one way or other, it may then be possible to minimise or eliminate the need of treatments. Further, it may also reduce the capital and running expenditure of the processing factory.

As the effluents contain a wide range of chemical compounds as illustrated by the detail analysis of skim serum (Table 3), three aspects of utilisation were investigated, viz.

- its use as a growth medium for a variety of micro-organisms,
- a recovery of some of the major and minor constituents, and
- its use as fertilisers.

In the first aspect, investigations were carried out on the suitability of using the sera from skim, SMR block and sheet coagulation as an isolation growth medium for bacteria, yeast, fungi and algae. SMR block rubber serum agar has been found to be as good as Kligler's iron agar, a rich synthetic medium containing 12 ingredients, for pure cultures and ammoniated concentrate latex and only slightly inferior to fresh and ammoniated field latices (Table 4). The addition of carbohydrate and peptone to the medium has markedly enhanced the growth of bacteria[(2)].

The liquid medium has also been found suitable for the growth of the following organisms: Serratia marcescens, Chromobacterium violaceum, Bacillus mycoides, Mycobacterium phlei, a wide variety of coliform bacteria, and a number of species of the genera Staphylococcus, Streptoccus, Propionibacterium, Microbacterium, Bacillus, Micrococcus, Cornynebacterium and Flavobacter. Further, a large number of unidentified organisms isolated from Hevea latex and Malaysian soils also grew well in the liquid medium[(3)].

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(2) John, C.K. (1972) Non-rubber constitutents of Hevea latex and their possible utilisation. Waste recovery by micro-organisms UNESCO/ICRO Work Study, p.110, Pub. Ministry of Education, Malaysia.

(3) Taysum, D.H. (1956) A medium for the cultivation of bacteria. J. Appl. Bact. 19(1), 54.

Taysum, D.H. (1956) Bacterial culture media from waste Hevea latex sera. J. Appl. Bact. 19(1), 60.

TABLE 3. PROPERTIES OF SKIM SERUM

Property*	Sample 1	Sample 2	Sample 3	Average result
pH	4.10	5.40	4.82	4.77
Total solids	44,520	45,286	37,838	42,550
Volatile solids	38,340	38,646	32,248	36,410
Suspended solids	624	7,348	584	2,850
Total nitrogen	4,664	5,190	3,997	4,620
Ammoniacal nitrogen	3,660	3,660	2,972	3,430
Albuminoid nitrogen	714	923	627	755
Nitrate nitrogen	2	4	3	3
Nitrite nitrogen	1	1	1	1
Total sugars	336	704	241	500
Reducing sugars	450	406	370	409
Al	2.0	0.7	2.0	1.6
Ca	6.0	7.0	5.0	6.0
Cu	2.0	7.0	2.0	4.0
Fe	2.0	2.0	2.0	2.0
K	625	680	550	618
Mg	60.0	68.0	55.0	61.0
Mn	0.6	0.7	0.5	0.6
Na	6.0	7.0	20.0	11.0
P	60.0	68.0	55.0	61.0
Rb	2.0	2.0	5.0	3.0
Si	2.0	2.0	20.0	8.0

*All values except pH are expressed in p.p.m.

TABLE 4. LOG BACTERIAL COUNTS OBTAINED FROM TWO TYPES OF MEDIA

Medium	Pure culture	Fresh field latex	Ammoniated field latex	Ammoniated concentrate latex	Mean
SMR block rubber serum agar	7.86	6.59	6.34	4.22	6.25
Kligler's iron agar	7.86	6.87	6.61	4.31	6.41
S.E. (P = 0.05)		±0.05 (0.15)			±0.03 (0.08

Five species of Candida, two of Saccharomyces and one each of Hansenula and Rhodotorula have grown profusely in SMR block rubber serum. The growth of Rhodotorula has been better than that of the other yeasts, presumably because of its ability to breakdown quebrachitol present in the waste serum.

In a pilot plant trial of 75 litre capacity SMR block rubber serum has been fermented by S.carlsbergensis producing a light tasting alcoholic brew.

Good growth of Volvariella volvacea (Volvaria esculents) and Agaricus bisporus (Psalliota campestris) was obtained in four days, when growth was also obtained from an unidentified Australian edible mushroom. It is thus apparent that waste serum provides excellent culture conditions for a number of edible mushrooms.

A variety of green algae has been grown in these effluents, but an economic method of harvesting is being pursued.

In the second aspect, large quantities of quebrachitol and protein can be recovered from the waste serum. The properties and possible uses of quebrachitol has already been published[(4)]. The use of protein as animal feed is being investigated.

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(4) Van Alphen (1951) Quebrachitol, cyclic polyalcohol from natural rubber latex. Industr. Engrs. Chem. 43, 141.

In the third aspect, it is noted from Table 3 that the serum contains N, P, K and Mg, the essential elements for plant growth. The beneficial influence of diluted serum on the growth of irrigated paddy has been observed recently[5]. The high water content of the serum can also be usefully applied in moisture deficient areas during the dry seasons.

TREATMENT OF EFFLUENT

A wide variety of treatments for the agro-based effluents are available. The selection of a suitable process depnds on a number of factors, of which the property of the effluent, the local environment, the degree of purification expected to achieve and the cost-effectiveness are of paramount importance. The chosen plant should be cheap, simple to operate and requiring the minimum of equipment, materials, and maintenance serivces and skilled supervision.

Early Treatment Methods

Several methods were considered on a laboratory scale[6] and a biological treatment by trickling filtration was selected for pilot plant operation[7].

It was shown that this method could be used for successful removal of BOD from effluents discharged from concentrate factories; improved efficiency was obtained by the use of re-circulation. The removal of nitrogen and sulphate was, however, not satisfactory. Although this method was technically feasible, it was considered expensive and therefore has not been adopted by the Industry.

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(5) Pushparajah, E. and Soong N.K. (1972) Private communication.

(6) Molesworth T.V. (1957) The problem of latex factory effluents and water pollution in Malaysia. Chem. Div. Rep. No.12, Rubb. Res. Inst. Malaya.

(7) Molesworth, T.V. (1961) The treatment of aqueous effluent from rubber production using a trickling filter. Proc. Nat. Rubb. Conf. Kuala Lumpur, 1960, 944.

Recent Treatments

Since the effluents contain about 90% volatile solids, the basic treatment most likely to be successful is a biological method incorporating an anaerobic digestion. Further, such a method requires minimum equipment, maintenance services, and skilled supervision. Land is also available and Malaysian climatic conditions increase the efficiency of the stabilisation ponds.

Plant Operation

An anaerobic-stabilisation pilot plant was constructed alongside a commercial factory. The layout is schematically shown in Figure 1.

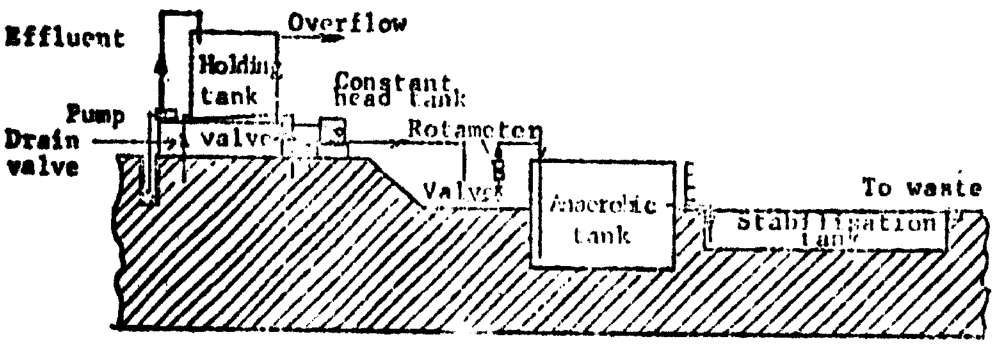

Figure 1: Schematic flow diagram of experimental effluent plant (not to scale)

The effluent from a SMR block rubber factory was pumped up to the holding tank, passed into a small constant-head tank, and then into the anaerobic tank. The liquor then passed through a weir arrangement, to hold back floating particles and slime, into the stabilisation tank from which it overflowed to waste.

Results from six preliminary runs showed that an anaerobic/stabilisation system was capable of treating the effluent, removing approximately 95% BOD, 85% COD, 70% volatile solids, 40% ammoniacal nitrogen and 50% total nitrogen. Thus with a retention period of about eight and seven days in the anaerobic and stabilisation system respectively the BOD concentration was reduced from 1500 to less than 100 ppm in the absence of algae in the treated effluent.

Effect of loading on performance When the organic loading rate was increased total BOD removal efficiency dropped to about 85%. The highest organic loading imposed on the anaerobic tank was 445 kg BOD per $1000 m^3$ per day which further increased the removal of BOD across the anaerobic bed. Even at this high loading no fouling of the tank was observed.

In the stabilisation tank, an increase in organic loading led to an increase in the rate of BOD removal. However, when BOD loading was increased beyond 63 kg BOD per $1000 m^3$ per day, fouling occurred resulting in the destruction of algae, evolution of malodourous gases and reduction in the removal of ammoniacal nitrogen. This indicates that for efficient performance of the stabilisation system, a healthy bloom of green algae is necessary. It is also evident that the stabilisation system is highly susceptible to overloading.

High loading rates have a marked adverse effect on the removal efficiency of ammoniacal and total nitrogen. However, the high loading rates did not adversely affect the removal of volatile solids.

Depth of anaerobic tank Reduction in the operation depth of the anaerobic tank from 2.7 m to 1.8 m did not affect its performance, indicating that anaerobic ponds can be operated at a depth of 1.8 m in areas where a high water table and/or poor soil stability occurs. The build-up of a layer of scum on the surface is advantageous; it promotes a better anaerobic condition in the pond, especially when operating at lower depths, and prevents the release of malodorous gases.

Reduction in micro-organisms

The effect of the treatment system on the microbial population was monitored. Under normal operating conditions about 90% of the viable bacteria and 88% of the indicative bacteria were removed in the anaerobic tank. When the BOD loading rate on the anaerobic tank was very high, the removal of viable bacteria was reduced to about 31%. The reduction in depth of the anaerobic tank from 2.7 m to 1.8 m did not affect the removal efficiency of the indicative bacteria. The final effluent leaving the stabilisation tank had about 99.5% of the indicative bacteria removed from it. Variations in the retention time from fifteen to five days did not markedly affect the bacterial population.

Microscopic examination of the final effluent showed that when the stabilisation tank functioned at optimal conditions, the algae population was mixed, with green algae (mostly Chorella spp.) dominating. When the system was overloaded, the green algae completely disappeared and the tank liquor turned black.

Optimal retention periods Purification of effluent in the anaerobic and stabilisation tanks is a rate process. An optimum retention period in the anaerobic tank with regard to BOD removal depends wholly on the concentration of BOD in the untreated raw effluent. If the BOD level is about 1500 ppm, a retention period of about 10 days is required to reduce the BOD concentration in the outgoing liquor to such a level that it does not overload the stabilisation tank. The liquor entering the stabilisation tank should be retained for a minimum period of 12 days. Thus, a total retention period of about 22 days in the anaerobic and aerobic tanks will ensure that the final discharge has a BOD and ammoniacal nitrogen of less than 100 ppm. The operating depth of the stabilisation tank should not exceed 1.2 metres. The results have been confirmed in commercial operations.

GENERAL RECOMMENDATIONS TO FACTORIES

It is of common knowledge that when one maintains proper hygiene in and around a factory, the pollution content of effluents discharged from the factory is controlled and/or minimised. This consequently reduces the pollution load on treatment plants. Good management always maintains good health standards and it is accepted that good housekeeping is a sign of good management. Hence, factories are recommended to adopt good housekeeping rules.

Treatment Measures

Effluents from SMR block rubber factories have been successfully treated by an anaerobic-stabilisation system and having the following properties:

pH	5.5 to 9.0
Total suspended solids	$<$ 250 mg/l.
Total solids	$<$ 1000 mg/l.
BOD at 30°C for 3 days	$<$ 100 mg/l.
Total nitrogen	$<$ 100 mg/l.

To achieve the above criteria the following design areas are recommended.

Pre-treatment

As the effluent from most SMR block rubber factories contains a fair amount of uncoagulated latex and other solid particles, it is recommended to install a rubber trap to pre-treat the effluent before it flows into the anaerobic pond. A simple rubber trap, large enough to hold liquor for 8 hours, preferably for 12 hours, can remove about 67% total as well as volatile solids thereby reducing the solid loading rate on the anaerobic pond. Part of the cost of providing the rubber trap can be met from the sale of the rubber collected from the trap.

Anaerobic Pond

The operating depth of an anaerobic pond can vary from 1.8 m to 2.9 m or more. Where possible anaerobic ponds should be dug as deep as possible to save land space, however this will depend on the stability of the soil and the level of the water table in various areas. The volume of the pond should be such that it should provide a liquor retention period of about 12 days. Although scum can be left to accumulate on the surface of the pond, it is desirable to remove it once in three months, in order to prevent it from reducing the effective capacity of the pond and possible blocking pipes, drains or weirs associated with the pond. Removal of scum is unlikely to affect the anaerobic condition of the pond seriously as a new layer is easily formed in a few days.

Stabilisation Pond

Stabilisation ponds should be operated at a depth not exceeding 1.2 m. The liquor should be retained for a minimum period of 12 days in order that the BOD and ammoniacal nitrogen concentration of the final effluent be less than 100 ppm as well as/to avoid the possibility of overloading the pond. Any scum that may float on the surface of the pond should be removed regularly so as to allow uninterrupted penetration of sunlight and diffusion of oxygen into the liquor.

Other Considerations

The embankments of the ponds should have a slope of at least 1 : 1.5 to avoid any errosion. The depth of terrestrial vegetation along the banks of the ponds should be prevented to minimise the possibility of mosquito breeding. A weir should be constructed between the anaerobic and stabilisation ponds to prevent the flow of scum from the former into the latter. The possibility of fluid short circuiting in ponds should be minimised by allowing the liquor to enter each pond about 20 to 30 cms above the floor level and to leave the pond at a diagonally opposite point on or just below the surface of the pond. Ponds should have drainage facilities to remove the inactive sludge accumulating on the floor of the ponds.

Cost of Treatment Plant

The effluent discharged from a SMR block rubber factory with a daily output of 16 tonnes of latex rubber and 4 tonnes of cuplump rubber, is estimated at 410,000 litres (90,000 gallons) with a BOD of about 1500 ppm.

With a total retention of 24 days in the anaerobic and stabilisation ponds, the total land space required is about 0.6 hectares, excavating about 9,800 m^3 of earth. The cost of establishing a treatment plant is estimated as follows:

Approximate cost of ponds	=	\$38,000*
Cost of pipes, drains, weirs	=	\$17,000
Fence and gate	=	\$ 5,000
Total	=	\$60,000

* The cost of excavation will vary, depending on type of soil, accessability of machinery etc.

This sum of \$60,000 represents only about 3% of the capital normally required for establishment of a new factory. It also appears to be reasonable for existing commercial factories to operate a treatment plant.

The running cost is estimated at \$200/- per month which is mainly the waves of a labourer, required to maintain the ponds and the area around.

CONCLUSION

The necessity of utilising water to process natural rubber at the plantations has highlighted the concern over the discharge of effluents to rivers and streams. These effluents contain large amounts of solids, both organic and inorganic creating a high oxygen demand, but can be effectively reduced to reasonable levels by an inexpensive biological method. Some studies have established some possible uses for these effluents which may lead to better cost-benefits. It would therefore appear that the effects of water pollution during NR processing are well contained.

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