1051

©2000, Rubber Research Institute of India, Kottayam - 686 009
Natural Rubber : Agromanagement and Crop Processing
Editors : P.J. George and C. Kuruvilla Jacob

Chapter 26

Waste management

Jacob Mathew, M.G. Kumaran,
Kochuthresiamma Joseph and Elsie S. George

1. INTRODUCTION

Environment pollution from crop processing units is of serious concern in the natural rubber (NR) producing sector. The pollutants include liquid and solid wastes. Both demand judicious and efficient management practices in view of their deleterious influence on environment. The most noticeable pollution is caused by effluents, the liquid wastes from primary processing factories, which contain a large number of non-rubber substances in addition to small amounts of rubber and processing chemicals. Solid wastes like sawdust generated from rubber wood processing units can be used as a substrate for mushroom cultivation, while others like latex sludge from latex centrifuging factories as fertilizer. Liquid wastes, in general, demand elaborate treatments for effective waste management.

2. EFFLUENTS

The components of latex are rubber (33.0%), proteinaceous substances (1.0 - 1.5%), resinous substances (1.0 - 2.5%), ash (up to 1.0%), and sugar (1.0%), the rest being water (Blackley, 1997). During the processing of rubber, about 20 to 30 L of water per kg of dry rubber is used for washing, cleaning and dilution (Kumaran, 1988). This water, along with the water content of latex, constitutes the final liquid waste. On an average, about 25 to 30 L of waste water is disposed as liquid waste per kg of dry rubber (Plate 69. a).

The effluent or liquid waste contains small amount of uncoagulated latex and substantial quantities of proteins, sugars, lipids, carotenoids, inorganic and organic salts which originate from natural rubber latex. These substances form a very good substrate for proliferation of microorganisms (RRIM, 1974).

If the effluent is discharged directly to the nearby locality, the proteins of the serum and the small amounts of rubber present in the effluent contaminate the drains, clog the soil and cause a bad smell. This problem of odour nuisance is rather serious if the factory is situated near to dwellings. Further, the acidic nature of the effluent causes damage to crops.

The organic matter when discharged into a stream decomposes as a result of the action of bacteria, which use it as food. The dissolved oxygen present in the water is used by these bacteria. With diminishing oxygen supply, survival of the higher forms of life becomes difficult. Even after the dissolved oxygen has been exhausted, the anaerobic bacteria are still able to survive by deriving the energy from the organic matter. This process leads to putrefaction and gives rise to obnoxius gases such as hydrogen sulphide and methane. Hence the stream has an unpleasant appearance with a foul odour.

Indiscriminate discharge of effluent into public waters is objectionable. All the rubber processing factories in the country are now legally bound to build up facilities to ensure that effluent let out into the public waterways conforms to the specifications prescribed by the respective State Pollution Control Board. The specification parameters and their limits for the treated effluent for discharge onto land and into inland surface water are shown in Table 1 (KSPCB, 1997).

Table 1. Tolerance limits for effluents

Parameter	For discharge to	
	Surface water	Land
Colour and odour	Not objectionable	–
pH	6 - 8	6 - 8
Chemical oxygen demand	250	250
Biochemical oxygen demand	50	100
Dissolved solids	2100	2100
Suspended solids	100	200
Oil and grease	10	200
Sulphides	2	10
Total nitrogen	100	–
Dissolved phosphate	5	–

(All values except pH are in mg/L)

2.1 Characteristics

The pollutants in effluents are judged from a measure of the properties like pH, total solids, biochemical oxygen demand (BOD), chemical oxygen demand (COD), *etc.*

2.1.1 pH

The acidic nature of the effluent is attributed to the use of formic, acetic, phosphoric or sulphuric acids during processing. The variation in pH of effluents from different factories is mainly due to the difference in the quantity of acid used. Highly acidic effluent is harmful to both plants and animals and may also corrode river structures.

2.1.2 Total solids

The effluent also contains fairly large amount of total solids – suspended, dissolved and settleable. Dissolved solids play a significant role in the salinity of the effluent. They affect the mechanism regulating osmotic pressure, which controls the availability of water to plants (RRIM, 1974). In addition, certain dissolved substances may even cause toxicity to aquatic biota. In general, excessive dissolved solids in an effluent may affect aquatic life and may also make it unsuitable for agricultural purposes. The high content of total solids, mainly dissolved organic solids, is responsible for the high oxygen demand. The main pollutants in effluents from rubber processing factories are ammoniacal nitrogen and organic carbon.

2.1.3 Biochemical oxygen demand

Biochemical oxygen demand is the amount of molecular oxygen required to stabilize the decomposable matter present in water by aerobic biochemical action. Oxygen demand is exerted by carbonaceous material, oxidizable nitrogen and certain reducing chemical compounds.

2.1.4 Chemical oxygen demand

Chemical oxygen demand is the amount of oxygen required for the total oxidation of pollutants present in effluent and is estimated using oxygen releasing chemicals like acidic potassium dichromate.

2.1.5 Nitrogenous impurities

Nitrogenous impurities include ammoniacal nitrogen combined with organic nitrogen. The amount of ammoniacal nitrogen is high in the effluents from latex concentration factories. Ammoniacal nitrogen is formed due to the use of ammonia in the preservation of latex. Ammonia is toxic to fish and discharge of ammoniacal nitrogen into rivers or streams is undesirable. It may also cause algal blooms due to the conversion of ammonia to nitrates by aerobic bacteria.

Albuminoid nitrogen is contributed mainly by breakdown of proteins and amino acids in latex serum. Effluents from sheet rubber processing contain the highest amount of albuminoid nitrogen followed by that from latex concentrate, block rubber and crepe factories (Sethu *et al.*, 1977). The presence of albuminoid nitrogen gives an approximate indication of the more readily decomposable nitrogenous organic matter present in waste water.

2.1.6 Bacteriological properties

The final discharge from crepe factories has largest total viable bacterial population, followed successively by that from technically specified rubber (TSR), ribbed smoked sheet (RSS) and latex concentrate factories. A decending trend is found in their pH values (Table 2) which partly explains the difference in the total viable population in these effluents. Near neutral pH favours bacterial proliferation and growth. The high acidity of the effluent from latex concentrate factories adversely affects growth of the bacteria and hence the bacterial population is comparatively low.

2.2 Comparison of effluents

Physical and chemical properties of effluent from different types of rubber processing factories vary considerably (RRIM, 1974) and are given in Table 2.

Table 2. Properties of effluents from rubber processing factories

Properties	Source of effluent			
	Centrifuged latex	RSS	TSR	Crepe
pH	4.5	6.3	5.2	6.5
Total solids	6000	2500	1500	750
Suspended solids	15000	500	600	400
COD	6000	3000	2500	1000
BOD	4000	2000	1500	750
Ammoniacal nitrogen	500	10	50	10
Total nitrogen	800	100	150	50

(All values except pH are in mg/L)

The high BOD and COD of the latex concentrate and RSS factory effluents indicate that the total solids are mainly of organic origin. The presence of high quantities of total solids also gives these effluents a turbid milky colour. The effluent from centrifuging contains high levels of ammoniacal nitrogen due to the ammonia used for preservation of field latex. It also contains fair amounts of phosphates and sulphates.

The colour of effluent from TSR processing varies according to the starting material. When latex is processed, it is milky and when field coagulum is processed, it is brownish and turbid. The volume of TSR factory effluent is high as large quantity of water is used to remove the impurities. Since the raw materials for crepe and TSR processing are similar, the effluents also have similar properties.

2.3 Effluent treatment

With the promulgation of Central Water (Prevention and Control of Pollution) Act, 1974, most of the industries are required to treat wastes to the degree as fixed by the Control Board, before discharging them into any water body or disposing them on land. It is mandatory for rubber processing factories also to treat the effluent to attain the specifications stipulated (Table 1) by the Pollution Control Board.

Many methods of effluent treatment are being practised in the rubber processing industries. Basically the treatment systems can be divided into primary, secondary and tertiary treatment stages.

2.3.1 Primary treatment

The purpose of primary treatment is to recover small pieces of rubber and to remove inert materials which hinder subsequent biochemical reactions.

2.3.1.1 Physical methods

The waste water generated from rubber processing factories may contain coarse, suspended and settleable solids. These have to be removed before the waste water is subjected to secondary treatment. Physical methods for treatment of rubber factory effluents are screening, flotation and sedimentation.

The effluents from rubber processing may contain small rubber particles, grits, *etc.* A strainer is provided in the inlet channel to the rubber trap for the removal of these materials. The screen may be cleaned every day and the rubber collected can be recycled for further processing.

2.3.1.1.1 Rubber trap

A good rubber trap is required for efficient recovery of rubber and reduction of suspended and settleable solids. It should have a capacity to hold the daily effluents (hydraulic retention time – HRT) for at least 12 h. Usually the trap is a long trench constructed with brick or concrete with a series of baffles to facilitate up and down flow (Plate 69. b). Usual depth and width are around 200 cm. The rubber trap removes 60 to 70 per cent of total solids and thereby reduces the load in secondary treatment (Sethu *et al.*, 1977).

2.3.1.1.2 Equalization or compositing tank

The characteristics of wastes discharged from a factory may not always be similar. Such variations may render any uniform treatment ineffective. In order to achieve some uniformity, different streams of effluents after passing through rubber trap are allowed to hold in a tank for a specified period. Equalization is the best means of stabilization of pH and BOD (Manivasakam, 1987).

The equalization or compositing pond is constructed using rubble, brick or concrete with capacity for at least one-day retention. Depth of the tank is usually around 300 cm.

2.3.1.2 Chemical methods

Addition of appropriate chemicals to waste water offers an opportunity to precipitate particulate and colloidal materials thereby reducing the oxygen demand of the waste water.

2.3.1.2.1 Neutralization

Acidic waste water, especially from latex centrifuging factories where sulphuric acid is used for skim coagulation, needs neutralization before secondary treatment. Lime treatment is effective and relatively economic. Neutralization is carried out in specially-designed tanks (Plate 69. c).

2.3.1.2.2 Chemical coagulation

Coagulation is a process by which the colloidal particles are destabilized by the addition of certain chemicals and consequently aggregated to form flocs which settle rapidly. The flocs thus formed absorb and entrap the colloidal and other suspended matter and bring them down (Manivasakam, 1987). The commonly-employed coagulants are aluminium sulphate ($Al_2(SO_4)_3$) or alum ($K_2SO_4Al_2(SO_4)_3$ 24 H_2O), ferric sulphate ($Fe_2(SO_4)_3$) and ferric chloride ($FeCl_3$).

Neutralization of colloid charge is the aim of coagulation. Most of the colloids present in effluents coagulate at a pH less than seven, but the hydroxides of coagulants formed by reaction with neutralizing agents are insoluble only at a pH between seven to ten (Manivasakam, 1987). Hence lime is added to raise the pH and also to aid the precipitation of colloids. The optimum dose of coagulant is determined by laboratory tests. The dosage of coagulants should be minimum, otherwise the reverse effect may take place. Jar test (Hopkins and Bean, 1975) and final plant trials will indicate the appropriate dose.

2.3.2 Secondary treatment

Secondary treatment removes the dissolved organic matter and thereby reduces BOD. All the secondary treatments are mainly biological processes and bacteria are the major organisms that carry out the oxidation (Manivasakam, 1987). They consume the dissolved organic matter as food and thus remove it from the effluent.

The effectiveness of the treatment system depends on the bacterial population, pH, temperature and nutrients. It is highly affected by extremes in pH and the presence of toxic chemicals like ammonia, hydrogen sulphide, *etc.* The common biological treatments are aerated lagoon, activated sludge process, oxidation ditch, oxidation pond and anaerobic digestion.

2.3.2.1 Aerated lagoon

These are large holding tanks or ponds having depths varying from 1.2 to 3.6 m in which oxygenation of waste water is accomplished by aeration units. The effluent after primary treatment is passed on to these tanks and aerated mechanically. The aeration units may be of impeller and paddle-type or turbines, which produce a high degree of turbulence to increase the absorption of oxygen from the air for bacterial growth.

The design criteria depend on the ratio of population of microorganisms in the system to the BOD load of waste water to be treated. This being a constant for a particular treatment system, the controlling factor is the mixed liquor suspended solids (MLSS), *i.e.* the population of microorganisms. Knowing the rate constant of the treatment system, the residence time can be determined. The amount of oxygen required, specifications of the aerator and depth of lagoon are to be calculated. The aerator is usually fixed at the middle of the pond to have maximum area or zone of mixing. The important design parameters are :

(1) Detention time : $\dfrac{\log (Li)/(Le)}{K}$

where Li is the inlet effluent BOD (mg/L)
K is the system ratio constant for biological decay at the operating temperature and
Le is the outlet effluent BOD (mg/L).

(2) Required depth : 2.5 - 3.0 m
(3) Efficiency of BOD removal : 90 - 95%
(4) Shape of pond : Square or rectangular
(5) Construction : Rubble masonry or reinforced concrete
(6) Aerator : Fixed or floating
(7) Oxygen generating capacity of aerator : 1.0 - 1.2 kg O_2/h/kW

The lagoon system can treat the effluent to a very high degree - up to 90 to 95 per cent removal in influent BOD. This is ideal for treatment of effluents having high BOD loading and large volumes. Aerated lagoons are ideal for latex centrifuging factory effluents.

2.3.2.2 Activated sludge process

The most versatile biological oxidation method for treating industrial waste is the activated sludge process (Plate 69. d). In this process, waste water is continuously exposed and subject to biodegradation by microbial flocs suspended in the reaction tank into which oxygen is introduced by mechanical means. The flocs formed in the activated sludge process are masses of living organisms, embedded in their food and slime, and are the active centres of biological oxidation and hence the name activated sludge (Manivasakam, 1987). The effluent from the reaction tank is allowed to settle and a portion (about 20%) of the sludge is recycled to the tank itself for maintaining an effective microbial population. A fresh light sludge is preferable to an old heavy sludge.

Oxygen is supplied either by mechanical means like floating aerators, fixed aerators, *etc.* or diffused aeration systems (Plate 69. e,f). The period of aeration ranges from 6 to 24 h. If the system has to be operated properly, a residual concentration of at least 0.5 mg per L oxygen should be present at all times. If the oxygen supplied is less than the required quantity, anaerobic conditions develop resulting in turbid effluent.

The microorganisms should also be supplied with essential nutrients. The efficiency of activated sludge process depends on pH value, temperature and oxidation reduction potential. The optimum pH range is 6.5 to 9.0.

2.3.2.3 Oxidation ditch

The oxidation ditch is a modification of the conventional activated sludge process (Manivasakam, 1987). The major difference between oxidation ditch and conventional activated sludge process is in the shape of the tank and the aerator. The aerator used in oxidation ditch is a cage rotor placed across the channel (Plate 69. g).

Cage rotors of 70 cm diameter provide 3 kg of oxygen per m length per h with the usual immersion depth of 15 cm at 75 rpm. It is reported that 80 to 95 per cent BOD is removed by this method.

The rotor rotates at a speed of 60 to 75 rpm across the channel, which provides necessary velocity for water movement and also aerates the effluents. The waste water along with the recycled sludge is well mixed in the channel by the rotor movement. During the operation, water gets dispersed in the air and oxygenation takes place. The design criteria for oxidation ditch system are :

(1)	Depth	:	1.3 m
(2)	Free board	:	0.2 m
(3)	MLSS	:	4000 mg/L
(4)	Oxygen required	:	1.5 - 2.0 kg O_2/kg BOD
(5)	Construction	:	Brick masonry
(6)	Rotor speed	:	75 rpm
(7)	Depth of immersion of rotor	:	15 - 16 cm
(8)	Oxygenation capacity	:	2.8 kg/m length of rotor with endless flow
(9)	Shape	:	Elliptical

Oxidation ditches are ideal for units with small volume of effluents and when the BOD load is low (Ponniah, 1975). Land required for treatment is also very little.

2.3.2.4 Anaerobic digestion

This treatment is mainly employed for digestion of the sludge as well as liquid waste containing high level of soluble organic matter (Siriwardena, 1996). As the name implies, the digestion is carried out in the absence of air in a deep tank. In the process, anaerobic bacteria convert organic solids to methane, carbon dioxide, hydrogen sulphide, ammonia, *etc.* (Rajagopalan, 1975). For smooth anaerobic action, the pH must be maintained between six and nine.

There is no dissolved oxygen in any layer of the pond and degradation of the organic matter takes place in two stages. The first stage involves the acid forming bacteria which hydrolyzes the waste into shorter chain organic compounds, especially organic alcohols, acids and ammonia. In the second stage, methanogenic bacteria convert these intermediate products into the gases (Ibrahim, 1983).

2.3.2.4.1 Anaerobic pond

Anaerobic ponds are constructed deep (3 - 6 m depth) to conserve the heat energy and to maintain anaerobic conditions. The waste from primary clarifier is brought to this pond where, after degradation, the solids settle, gases escape and the effluent is discharged for aerobic treatment.

2.3.2.4.2 Enclosed anaerobic digestion

Anaerobic digestion is a biological treatment process which is a net energy producer rather than a consumer as in the case in aerobic systems (Ibrahim *et al.*, 1986). However, the system is not very popular due to two disadvantages : (1) the process is extremely slow and therefore requires very high retention time to give useful reductions in BOD, and (2) it produces malodourous hydrogen sulphide gas. Extensive research has produced more sophisticatedly-designed high throughput digesters, to solve the problem associated with large reactor volumes (Seneviratne *et al.*, 1996). The reduction in volume has made it easy to cover the reactors, thus minimizing the malodour problem. In this way, the operating cost of the subsequent aerobic reactors would be reduced significantly. Since the reactors are covered, it would be feasible to recover the energy-rich biogas, which may be used as a substitute for conventional fuel employed in rubber drying (Ibrahim *et al.*, 1986).

2.3.2.4.3 Anaerobic filter

In this type of reactor, waste water is pumped upwards through a fixed packing media to retain microorganisms so that breakdown of the organic matter occurs as the waste water flows through the unit and comes in contact with the microorganisms (Isa, 1991). Stones and plastics are normally used as packing media. The microorganisms are usually present in suspended form in the void spaces between the packing and a relatively small portion is attached to the surface of the packing media.

2.3.2.4.4 Upflow anaerobic sludge blanket reactor

One disadvantage of the anaerobic filter is the clogging problem, especially for effluents with a high quantity of suspended solids. This has led to the development of upflow anaerobic sludge blanket (UASB) reactor which capitalizes on the agglomeration of granular sludge, forming a stable blanket in the reactor. As a result, the high solids retention time (SRT) required for fast breakdown can be achieved. The reactor is equipped with a gas solid separator (GSS) at the upper part, the main functions of which are separation of biogas from mixed liquor and floating sludge particles and separation of sludge flocs (Ibrahim *et al.*, 1986). The success of the UASB reactor lies in the development and attainment of highly granulated sludge (1 - 4 mm size) which would easily form the blanket. The reactor has been used for many types of waste water using loading rates of 15 to 20 kg COD per m^3 per day.

Since two groups of bacteria coexist in the anaerobic process, careful operation and close supervision is highly essential. Overloading of the anaerobic digesters should be avoided. In case of overloading, the substrate available to the non-methanogenic (acid forming) bacteria increases, leading to increased production of volatile acids, carbon dioxide, hydrogen and other end products. Over-abundance of volatile acids and other intermediates causes a drop in the pH of the system inhibiting the growth of the methanogenic bacteria. A digester failure results if the pH is not maintained. A further decline in the pH will affect the metabolism of non-methanogenic bacteria (Trivedi and Goel, 1986).

2.3.3 Tertiary treatment

The effluent from the secondary stage contains sludge and cannot be discharged directly into streams. This has to be clarified and filtered to obtain clear treated effluent.

2.3.3.1 Settling tanks

In the settling tanks the treated effluent is detained for 2 to 3 h to allow the suspended solids and sludge to settle. For rubber effluents, a detention time of 2 to 3 h and surface loading rate of 30 m^3 per m^2 per day are suggested.

The tanks are designed to have the required loading area and volume. These are usually constructed using brick, with a conical bottom for easy settling and removal of sludge.

2.3.3.2 Sand filters

Sand filter is a packed medium used in waste water treatment for removal of foreign material of very small size and to obtain clear water. The medium may be made up of layers of two or three different materials, so that the percolation efficiency of the effluent can be increased. The design criteria are :

(1)	Hydraulic loading rate :	10 - 30 m^3/m^2/day
(2)	Separator :	Divide the bed into two for interchanging
(3)	Shape of bed :	Square/rectangular
(4)	Packing material :	Coarse gravel and fine sand

2.3.3.3 Sludge drying beds

Sludge obtained from primary settling tank is fed to drying beds so that wastes will be retained in the sludge bed (Plate 69. h). The bottom of the bed is packed with coarse gravel and fine sand. It is a rectangular masonry tank of size around 300 x 200 x 150 cm. The bottom of the tank has a slope.

2.4 Utilization of liquid waste

Utilization of the wastes offers the possibility of using them in a beneficial manner as opposed to the traditional methods of waste treatment. Rubber processing effluent contains readily oxidizable dissolved organic solids in finely divided form. Since the effluent is organic in nature, it could be treated anaerobically to produce methane gas, for use as fuel (Ibrahim *et al.*, 1986). This would not only lead to abatement of pollution but also generate income in terms of energy.

2.4.1 Biogas generation

All organic wastes can be fermented to produce methane, the combustible component of biogas. Biogas plants are based on the technology of anaerobic digestion which serve the dual purpose of reducing environmental pollution and generating energy. Anaerobic treatment is highly useful for wastes of small volume like sheet processing effluent (Plate 70. a,b) containing readily oxidizable dissolved organic solids. The effluent resulting from sheet processing is highly polluted and has an objectionable odour. Since the effluent is organic in nature, it could be treated anaerobically to produce methane.

2.4.1.1 Biogas plant

A biogas plant consists of (1) mixing tank and inlet, (2) digester, (3) gas holder or gas storage dome, (4) gas outlet and valve and (5) pipeline.

The biogas plant constructed by agencies (such as KVIC or Department of Agriculture) approved by the Ministry of Non-conventional Energy Sources can be used for treatment of rubber factory effluents. Any of the two types of biogas plants, *viz.* the Deenbandhu model with fixed dome (Plate 70. c) or Khadi and Village Industries Commission (KVIC) model with floating dome (Plate 70. d) could be used to generate fuel for domestic purposes (Plate 70. e), smoke houses, lighting (Plate 70. f) and for operating dual fuel engines (Siriwardena, 1996). For installation of biogas plants, an elevated, dry and open area exposed to sunshine for greater part of the day is required. As far as possible, plant may be located close to the kitchen and the processing shed. Depending on the availability of waste water, appropriate capacity of the plant may be selected (Table 3).

Table 3. Waste water requirement of biogas plants of different capacities

Capacity (m^3)	Waste water required (L / day)	Approximate quantity of rubber sheets (kg/day)
1	25	2.5
2	50	5.0
3	75	7.5
4	100	10.0
6	150	15.0
8	200	20.0
10	250	25.0
15	375	37.5
20	500	50.0
25	625	62.5
35	875	87.5
45	1125	112.5
60	1500	150.0
85	2125	212.5

To begin with, the tank should be filled almost completely with fresh water. Then slurry from a gobar gas plant or fresh cow dung slurry is added to the extent of one per cent of the total volume of the plant. The waste water from sheet processing is allowed to pass through the inlet into the bottom of the digester. Since there is no oxygen in the digester, the waste water ferments and produces biogas. The gas gets collected in the floating gas holder or in the gas storage dome depending on the design of the plant and is allowed to flow out through a pipeline to the point of its use. Along with the effluent, cow dung, kitchen waste and other organic matter from rubber plantation could be used in the biogas plant to increase the efficiency of gas generation (Mathew, 1994). Waste water generated after coagulation with sulphuric acid should not be used in the biogas plant, since it leads to corrosion of cement structure and enhanced level of hydrogen sulphide in the biogas.

The gas from the biogas plant using sheet effluents also contains toxic hydrogen sulphide (H_2S), the percentage of which is more than that in gobar gas. In order to avoid the adverse effect due to H_2S, the biogas may be passed through a filter gadget filled with calcium hydroxide pellets. The pellets could be prepared by mixing slaked lime (calcium hydroxide) with equal quantity of fine field soil (Mathew *et al.*, 1997). The mixture is passed through a sieve (0.5 cm^2 mesh) and the pellets are dried under shade. These pellets are filled in the filter gadget and attached to the gas line between burner and the plant. The filter gadget can be fabricated with PVC pipes. This gadget should be recharged with fresh pellets as and when it fails to absorb hydrogen sulphide.

An immobilized growth digester has been developed (Mathew *et al.*, 1998a) to enhance the efficiency of the digester using inert media like polyethene mesh or polyurethane foam.

2.4.2 Reuse of waste water

Waste water from any NR processing industry can be reused after treatment. The level of pollution in such treated effluent is comparatively less (Mathew *et al.*, 1998b). Such reuse of waste water is an effective means of reducing the large volume of liquid waste discharged and thereby minimizing pollution.

2.4.3 Water reclamation

The waste water can be used for irrigation and for recharge of ground water if it satisfies the prescribed standards. Use of NR processing effluent for irrigation has been found to be beneficial as a source of nutrients and water. The optimum quantity used for irrigation depends on the composition of the effluent and the method of irrigation. However, higher rates of irrigation may cause adverse effects (Yapa, 1984).

Rubber serum contains a large quantity of micro and macronutrients. It is fairly rich in N, P and K (Senaviratne, 1997) and could therefore be used as a fertilizer for young rubber plants (Yapa, 1984).

Application of a mixed effluent to soils for two years has not resulted in any accumulation of nutrients and organic matter content. However, long-term exposure of soils to rubber factory effluents results in high levels of all nutrients, especially P and K (Yapa, 1984). This also results in an increase in the pH and microbial population of the soil (Mathew *et al.*, 1987).

3. SOLID WASTES

3.1 Latex sludge

Bowl sludge (Plate 71. f) is a waste product from latex centrifuge factories and it contains magnesium ammonium phosphate formed by the reaction between magnesium present in the latex and diammonium hydrogen phosphate added to it. The material is accumulated at the bottom of the settling tank and in the bowl of the centrifuge and hence the name bowl sludge. In 1991, the estimated potential of dried sludge in India was 567 t at full capacity utilization of the centrifuged latex processing industry (George *et al.*, 1994).

3.2 Sawdust

About 70000 t of sawdust is generated as waste from rubber wood industry. A part of this is used as fuel and the rest usually accumulate around the sawmills (Plate 71. a,b) and poses environmental pollution.

3.3 Utilization of solid wastes

Latex sludge is removed from the factory and air dried. It is then powdered and mixed physically with other fertilizers to formulate fertilizer mixtures.

Sawdust is used as substrate for mushroom cultivation after sterilization.

3.3.1 Latex sludge as fertilizer

Bowl sludge is fairly rich in N, P_2O_5 and MgO (Table 4) and can therefore be used as a source of nutrients. As a source of phosphorous for budded stumps of *H. brasiliensis* and for the cover crop *P. phaseoloides*, it is as good as super phosphate in terms of plant growth and P intake (George *et al.*, 1991). For immature rubber under field conditions, bowl sludge is comparable to both super phosphate and rock phosphate. The procedure for formulating 10-10-4-1.5 NPKMg mixture using this waste material has been standardized (George *et al.*, 1994). Commercial utilization of this waste material has been in practice in Malaysia(Lowe, 1968).

Table 4. Nutrient contents of latex sludge

Nutrient	Content (%)
N	5.1
P_2O_5	32.7
K_2O	0.5
MgO	14.5

The formulation of 10-10-4-1.5 NPKMg mixture using latex sludge and the net saving emanating from using this mixture is given in Table 5.

Table 5. Preparation of 10-10-4-1.5 NPKMg mixture (1000 kg) using latex sludge

Component	Quantity required (kg)	Quantity saved (kg)
Urea (46% N)	205	15
Rock phosphate (20% P_2O_5)	340	160
Muriate of potash (60% K_2O)	70	–
Sludge	100	–
Magnesium sulphate (16% MgO)	–	100
Filler	285	–
Total	1000	275

The use of bowl sludge, a cheap nutrient source for rubber is worth considering not only from economic point of view but also as a method for reducing environmental pollution problem.

3.3.2 Sawdust for mushroom cultivation

Rubber wood sawdust is a good substrate for oyster mushroom (Kothandaraman *et al.*, 1991) and *Pleurotus florida*, *P. sajor-caju*, *Calocybe indica* (Plate 71. c-e) and *P. citrinopileatus* can be cultivated on rubber wood sawdust. The substrate is prepared by soaking about 1 kg of rubber sawdust in water for 48 h and washing two to three times in water. This is then sterilized by soaking in boiling water for 30 to 45 min, dried to about 70 per cent moisture and mixed thoroughly with two per cent calcium carbonate (chalk powder) and a bottle of spawn (about 250 g grown on cooked grains). This mixture is transferred to plastic trays of 40 x 30 x 7 cm size and a handful of spawn is sprinkled at the top of the bed. The bed is then covered with a polythene sheet having a hole of 1 cm diameter in the centre for gas exchange. Two beds can be prepared using 1 kg of sawdust.

Instead of trays, transparent polythene (100 - 120 gauge) bags of 30 x 60 cm size can also be used for bed preparation. For this, two holes of 1 cm size are punched in the centre of the polythene bag which is then tied at the bottom with a thread. A handful of spawn is sprinkled at the bottom of the bag and sawdust mixed with two per cent chalk powder is spread over it to a height of 4 cm. A handful of spawn is again sprinkled over this and the process is repeated until 3/4th of the bag is filled. The mouth of the bag is tied and the beds are kept in a ventilated dark room for 12 to 15 days.

Growth of white mycelium is seen all over the sawdust by the end of this period. At this stage, polythene coverings are removed and the beds are kept in a cropping room having a temperature of 20 to 30°C and relative humidity of 70 to 85 per cent. The room should be well ventilated, free from insects, and should receive light for at least 4 h a day. The beds are watered both in the morning and in the evening from the second day of removing the plastic bags till the mushrooms are fully grown.

Mushroom harvesting is done before the sporocarp starts curling upwards or downwards depending on the species under cultivation. After harvesting, 1 cm layer of sawdust is scraped off and the beds are watered to continue cropping. About 700 g of mushrooms can be harvested from 1 kg of sawdust.

REFERENCES

Blackley, D.C. (1997). Polymer latices : Science and technology. Ed. 2. Chapman and Hall, London, p. 79.

George, E.S., Karthikakuttyamma, M. and Mathew, M. (1991). Evaluation of bowl sludge as fertilizer for immature rubber and cover crop. *Journal of Plantation Crops*, 18(Supplement) : 179-183.

George, E. S., George, K.T., Mathew, M. and Joseph, T. (1994). Commercial application of latex sludge as fertilizer : A preliminary assessment. *Indian Journal of Natural Rubber Research*, 7(1) : 46-50.

Hopkins, E.S. and Bean, E.L. (1975). Water purification control. Ed. 4. Robert E. Krieger Publishing Company, New York, p. 37.

Ibrahim, A. (1983). Improved anaerobic digestion of rubber effluent using the upflow anaerobic filter. *Proceedings of the Rubber Research Institute of Malaysia, Planters' Conference*, 1983, Kuala Lumpur, Malaysia, pp. 369-379.

Ibrahim, A., Bakti, N.A.K., Isa, Z. and Karim, M.Z.A. (1986). Cost-effective technologies for pollution control in the natural rubber industry. *Proceedings, Rubber Research Institute of Malaysia, Rubber Growers' Conference*, 1986, Ipoh, Malaysia, pp. 377-387.

Isa, Z. (1991). Treatment of rubber processing factory effluent by a rubberised coir carrier reactor. *Proceedings of the Rubber Research Institute of Malaysia, Rubber Growers' Conference*, 1991, Kuala Lumpur, Malaysia, pp. 441-453.

Kothandaraman, R., Joseph, K., Mathew, J. and Jayarathnam, K. (1991). Preliminary investigation into the feasibilities of growing oyster mushroom (*Pleurotus florida*) in rubber wood sawdust. *Proceedings of the National Symposium on Mushroom*, 1991, Trivandrum, India, pp. 99-101.

KSPCB (1997). Environment, effluent, emission and noise: Standards and guidelines. Kerala State Pollution Control Board, Trivandrum, 105 p.

Kumaran, M.G. (1988). Treatment and disposal of rubber effluents. *Rubber Board Bulletin*, **24**(1) : 21-24.

Lowe, J.S. (1968). Bowl sludge as a fertilizer, *Planters' Bulletin*, **96** : 91-95.

Manivasakam, N. (1987). Industrial effluents: Origin, characteristics, effects, analysis and treatment. Sakthi Publications, Coimbatore, India, 476 p.

Mathew, J. (1994). *Characterization of wastes from natural rubber and rubber wood processing industries and their utilization for biomethanation*. Ph.D Thesis, Cochin University of Science and Technology, Kerala, India, 223 p.

Mathew, J., Kothandaraman, R., and Joseph, K. (1987). Economic utilization of effluent from sheet rubber processing factories. *IAWPC Technical Annual*, **14**: 23-26.

Mathew, J. Kothandaraman, R. and Joseph, K. (1997). On-farm energy generation through anaerobic digestion of RSS effluent. *Proceedings of the National Seminar on Anaerobic Technologies for Waste Treatment*, 1997, Chennai, India, pp. 55-59.

Mathew, J., Kothandaraman, R. and Joseph, K. (1998a). Improved anaerobic digestion of ribbed smoked sheet effluent by the addition of inert materials. *Thirteenth Symposium, on Plantation Crops* 1998, Coimbatore, India.

Mathew, J., Varghese, L., Kothandaraman, R., Mathew, N.M. and Joseph, K. (1998b). Studies on recycling of effluent in latex crepe factory. In: *Developments in Plantation Crops Research* (Eds. N.M. Mathew and C. Kuruvilla Jacob). Allied Publishers, New Delhi, pp. 317-323.

Ponniah, C.D. (1975). Treatment of acidified skim serum by a laboratory scale oxidation ditch. *Proceedings of the Agro-Industrial Wastes Symposium*, 1975, Kuala Lumpur, Malaysia, pp. 94-106.

Rajagopalan, K. (1975). The mechanism of methane formation in rubber factory effluent and its reference to palm oil mill discharge. *Proceedings of the Agro-Industrial Waste Symposium*, 1975, Kuala Lumpur, Malaysia, pp. 33-38.

RRIM (1974). Studies on effluents from rubber processing factories in Malaysia. Rubber Research Institute of Malaysia, Kuala Lumpur, 94 p.

Seneviratne, W.M.G. (1997). Waste water from rubber processing industry in Sri Lanka and related environmental aspects. *Bulletin of the Rubber Research Institute of Sri Lanka*, **35** : 42-48.

Seneviratne, W.M.G., Siriwardane, T.A.S. and Somasiri, H.P.P.S. (1996). Cost effective rubber effluent treatment method. *Proceedings, IRRDB Symposium on the Technology and End Uses of Natural Rubber*, 1996, Beruwela, Sri Lanka, pp. 102-108.

Sethu, S., Chang, W.P., Karim, M.Z.A., Bakti, N.A.K. and Yong, W.M. (1977). Effluent discharge from latex concentrate factories. *Proceedings of the Rubber Research Institute of Malaysia, Planters' Conference*, 1977, Kuala Lumpur, Malaysia, pp. 215-232.

Siriwardena, S. (1996). Investigation of alternative energy resources for drying of natural rubber in Sri Lanka. *Proceedings, IRRDB Symposium on the Technology and End Uses of Natural Rubber*, 1996, Beruwela, Sri Lanka, pp. 123-129.

Trivedi, R.K. and Goel, P.K. (1986). Chemical and biological methods for water pollution studies. Environmental Publications, Karad, 252 p.

Yapa, P.A.J. (1984). Effluent disposal and environmental pollution in rubber plantations in Sri Lanka. *Proceedings of the International Rubber Conference*, 1984, Colombo, Sri Lanka, pp. 391-403.