CHAPTER 17

PRIMARY PROCESSING

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The main crop from rubber plantation consists of latex and field coagulum. The proportion of these materials varies depending upon the tapping system followed, climatic conditions, stability of latex, stimulant application, age of the tree etc. On an average, it is observed that the proportion of latex and field coagulum is in the range of 80 to 85% and 15 to 20%, respectively. While latex can be processed and marketed in any one of the forms such as latex concentrate, ribbed smoked sheet, technically specified rubber, crepe rubber or chemically modified rubber, field coagulum is processed and marketed as either technically specified rubber or crepe rubber. Whichever be the method adopted for processing the latex, it is to be preserved adequately so as to prevent precoagulation in the field and also during various processing operations.

PRESERVATION OF LATEX

For effective preservation of latex against precoagulation, factors affecting the stability of latex are to be understood and taken care of. There are several theories postulated for the auto-coagulation of latex, out of which the following assume importance.

Natural rubber latex contains about 4 to 5% non-rubber constituents consisting mainly of carbohydrates, proteins and lipids. Bacterial proliferation occurs at the expense of these non-rubber substances, resulting in the formation of acids, particularly volatile fatty acids (VFA). As the VFA content increases coagulation of latex occurs (John, 1974). A second theory postulates that hydrolysis of various lipids present in latex liberates higher fatty acid anions which get adsorbed onto the surface of the latex particles, possibly by replacing the adsorbed proteins. The free fatty acid anions interact with metallic ions such as calcium and magnesium, which are either present in latex initially or are gradually released by the action of enzymes. The formation of insoluble higher fatty acid soaps of calcium/magnesium draws the latex particles together resulting in coagulation (Madge et al. 1950). Yet another theory suggests that a proteolytic enzyme, coagulase, hydrolyses the protective layer of proteins surrounding latex particles, thereby exposing the surface of the particles which leads to coagulation (Woo, 1973). Possibly all the factors described in these theories may be having a combined role in the autocoagulation of fresh natural rubber latex, as indicated by an increase in VFA, change in pH and formation of insoluble salts of calcium and magnesium during the process of autocoagulation of natural rubber latex.

Any chemical or combination of chemicals to work as an effective preservative for NR latex should have the following basic features:

act as a bactericide - ie. it should be able to destroy microorganisms or supress their activity.

preferably have an alkaline nature so that it will increase the colloidal stability of the rubber particles by increasing the negative electric charge.

have some chelating or precipitting effect on the divalent metallic ions present in latex.

be effective as an enzyme poison so that the effect of enzymes such as coagulase can be minimised.

have some substrate-complexing activity so that non-rubber materials such as carbohydrates may not be decomposed by bacteria.

When it is required to preserve latex for a few hours, chemicals such as formalin, sodium sulphite and ammonia at very low dosages of 0.02, 0.05 and 0.01% respectively on latex are employed. These are termed anticoagulants and are used to prevent precoagulation in the field. Dilute solutions of these chemicals are added in latex collection cups and buckets. A detailed account on the uses of anticoagulants has been given by Cook (1960).

Since 1853, ammonia has been recognised as the most effective and popular preservative for NR latex as it fulfils most of the requirements for an ideal preservative. However, this chemical has certain drawbacks as well. To be effective for longer periods, a higher dosage is to be used. This necessitates a higher quantity of coagulant for subsequent processing operations. Higher levels of ammonia in latex also leads to atmospheric pollution. Because of these problems, preservation systems comprising of low levels of ammonia, in combination with other chemicals were introduced (Cheong and Ong, 1974; John et al. 1984). A review of the various types of chemicals used as preservatives for NR latex has been presented by Ng and Lau (1978). Mathew et atl. (1976) reported the use of monomethyl amine as an effective alternative for ammonia in preserving concentrated latex. The commercially available low ammonia systems are those containing sodium pentachlorophenate (SPP), zinc diethyldithiocarbamate (ZDC) or boric acid along with 0.2% by weight of ammonia. The main drawbacks of these systems are high toxicity, lower mechanical and storage stability, poor chemical stability and slow rate of cure respectively for the SPP, ZDC and boric acid preserved latex. A composite preservation system consisting of tetramethyl thiuram disulphide, zinc oxide and ammonia, popularly known as the LA-TZ system was introduced during 1975 (John et al. 1975) and subsequently commercialised. But this system has the drawback that the chemicals TMTD and zinc oxide, are to be prepared as dispersions and in many cases they sediment during long term storage. This system is unsuitable as a preservative for latex to be processed as block rubber and sheet rubber as it affects plasticity retention index (PRI). Another preservation system, consisting of 0.3% ammonia, and 0.05% of a biocide containing triazine/benzotriazole derivative, was reported to be capable of preserving field latex for at least one week and the latex thus preserved could be processed into concentrate, solid block or sheet rubber without any difficulty (John et al. 1986). A non-toxic system of preservative comprising of 0.4% ammonia and 0.05% Dowicil [cis-1-(3-chloroally)-3,5,7-triaza-1-azonia-adamantane chloride] was found to be as good as the LA-TZ system for field latex as well as for latex concentrate (John et al. 1985). The search for still better preservatives for latex is continuing and identification of an ammonia-loving bacteria by Shum and Wren in 1977 has intensified this search for a preservative system devoid of ammonia.

CONCENTRATED NATURAL RUBBER LATEX

The dry rubber content (DRC) of NR latex, as obtained from the tree, varies from 30 to 40% by weight. Clonal characteristics, age of the tree, length of tapping cut, frequency of tapping, stimulant application, time of tapping, environmental conditions etc. are some of the factors that affect DRC of latex (Kang and Hashim, 1982). On the average, the DRC of field latex is taken as 33%. For economic transportation of latex and for product manufacture, such a low DRC is undesirable and it has to be raised to about 60%. Increasing the DRC has the additional benefit that the latex becomes purer, since some of the nonrubber materials will be removed during the process of concentration, except in the case of evaporation. Even though several processes have been developed for concentration of latex, only two of them namely, creaming and centrifuging, are widely practised.

Creaming

Latex is a two-phase colloidal system consisting of rubber particles as the dispersed phase and the aqueous phase as the dispersion medium. Since the dispersed particles carry a negative charge, they are in constant Brownian movement which maintains the colloidal nature. Dispersed particles cream or sediment depending upon the difference between the densities of the dispersed particles and the dispersion medium. Applying Stokes's law, the velocity of creaming, v, is given by the relationship.

$$v = \frac{2gr^2 (d_s - d_r)}{9\eta}$$

where r = average radius of the rubber particle
g = acceleration due to gravity
η = coefficient of viscosity of latex serum
d_s = density of latex serum
d_r = density of rubber particles.

As is evident from the above relationship, larger particle size, higher difference between the densities of the serum and the dispersed rubber particles and lower viscosity of the serum favour higher velocity of creaming. Several materials have been reported to function as creaming agents which facilitate faster creaming of NR latex. Edgar and Sekar (1938a,b) reported the use of sodium salt of sulphonated lauryl alcohol and tamarind seed powder as creaming agents. Davey and Sekar (1947) evaluated methyl cellulose for this purpose and found that 3 g of methyl cellulose per litre of field latex was sufficient to effect the process. Baker (1937) identified a large number of naturally occurring materials such as gum arabic, pectin, gum tragacanth, gum karaya, tragon seed gum, alginic acid, alginates etc. and synthetic materials like polyacrylic acids and their salts, polyvinyl alcohol and their ethers, and derivatives of polyethylene oxide, which can be used for creaming of NR latex. Microscopic observations made by Baker revealed that, in the presence of creaming agents, rubber particles in latex formed large agglomerates and the Brownian movement of the particles was arrested within a few minutes of addition of the creaming agent. These clusters were redispersible on diluting the cream. This observation led to several theoretical explanations for the creaming process.

Creaming agents, in general, are hydrophilic colloids, swelling in water and forming highly viscous solutions at very low concentrations. It has been suggested that the creaming agent gets adsorbed onto the surface of the rubber particles thus favouring the agglomeration of the particles into relatively large groups of 10 to 20 microns diameter having reduced movement. Reduced Brownian movement and larger size of the agglomerates favour higher rate of creaming since there is a fairly significant difference between the density of the rubber particles (0.92 g cc^{-1}) and that of the serum (1.02 g cc^{-1}). Another theory postulated by Duckwork (1964) suggests that a definite structure is formed by the gum in solution and that adsorbed on the particles, which develops into a kind of molecular net restricting the movement of the rubber particles. The clusters thus formed, grow by continued entrapment of the particles. This structure gradually shrinks and rises to the surface, squeezing out the serum. This theory is supported by the fact that the line of separation between the serum and the cream starts at the bottom of the creaming vessel and moves upwards. However, there are several observations which remain unexplained due to the lack of proper theoretical support. It is observed that addition of a small portion of serum to latex helps in increasing the rate of creaming. Another observation is that with certain types of creaming agents, repeated creaming operation is not possible for more than three or four times, whereas the some other types unlimited repeated creaming is possible. It is also noticed that a small percentage of rubber present in the serum does not undergo further creaming eventhough the serum contains part of the creaming agent, whereas the cream always undergoes further creaming on storage.

In practice creaming operation is done in the following way. Field latex after sieving and bulking is ammoniated to about 1.0 to 1.2% by weight of latex and desludged by adding calculated quantity of diammonium hydrogen phosphate. The dosage of the creaming agent depends on the type, age and DRC of latex. Normally, depending on cost and availability, either ammonium alginate or tamarind seed powder is used for this purpose and the dosage varies from 0.2 to 0.3% of the dry material calculated on the aqueous phase of the latex. About 3% solution of tamarind seed powder is prepared by cooking the dry material with water for about one hour. It is filtered to remove the uncooked material. Addition of a small quantity of higher fatty acid soap such as potassium oleate, at the level of about 0.15% by weight of latex, increases the efficiency of the creaming agent. If the latex is sufficiently aged, the above dosage could be reduced further. Maintaining a temperature of 40°C in the creaming tank helps in reducing the induction time. The ammoniated and desludged latex is thoroughly stirred with the solutions of creaming agent and soap for about one hour and then kept undisturbed. Initially there is an induction period of several hours during which no visible creaming takes place. Between 24 and 48 h, the rate of creaming is maximum and thereafter the process is rather slow. Normally it takes about 72 to 96 h to complete the process. After this period, the serum layer is drained out and the cream collected. It is then tested for ammonia content and the same made up to the required level. The DRC of the cream depends on several factors such as concentrations of creaming agent and soap, creaming period and the quality of the field latex used. The DRC of the serum also varies from 1 to 3% depending upon the conditions of the creaming process.

The creaming process has several advantages over other methods of concentration of latex. It requires only simple equipments to operate, involves very low power consumption and labour and has the flexibility to adjust the production capacity from very low to very high levels. The disadvantages include slowness of the process, its dependence on the quality of field latex and type of creaming agent and the after creaming that invariably occurs during storage of the cream.

Centrifuging

The centrifugal method is the most important one among the various commercial methods of concentration of NR latex. Theory of centrifugal concentration of latex is basically the same as that of creaming. In this method, separation into latex concentrate and skim is effected by means of centrifugal force rather than by gravitation. The process consists of subjecting the latex to a centrifugal force many times greater than gravity, in a centrifuging machine which rotates at high speed. The centrifugal acceleration 'f' on a particle rotating with an angular velocity 'ω' and having radius of rotation 'R' is equal to $R\omega^2$. If 'n' is the speed of rotation in rpm, then:

$$f = (2\pi n)^2 R$$

The centrifugal acceleration can be expressed as a multiple of gravitational acceleration 'g' and the separating power 'c' of the machine is often described as

$$c = \frac{f}{g} = \frac{(2\pi n)^2 R}{g}$$

At a point about 15 cm away from the axis of the machine rotating at 6000 rpm, the separating power will be about 6160. Thus the velocity of separation of the particles, under the above conditions, will be over 6000 times greater than that under the action of gravity alone. Since the suspended rubber particles are lighter than the serum, the concentrate accumulates at the centre of the bowl and the serum at the rim. The separating force on the particle increases with increasing distance from the centre of rotation of the bowl. As the serum flows outwards from the centre, the rubber particles tend to be removed in the order of their size and at the same time, the particles in the serum are subjected to an increasing force. The viscosity of the cream increases very rapidly as the dry rubber content increases, until it reaches a point at which the latex will not flow. Thus in the concentrate the particle velocity falls rapidly and the tendency for further concentration is reduced by the increase in viscosity and diminishing separating force, as the concentrate flows towards the centre of the bowl.

Different types of centrifuges have been commercially available. The basic design of these machines is similar and it consists of a rotating bowl in which a set of concentric conical metallic separator discs are enclosed. Latex enters the bowl through a central feed tube and passes to the bottom of the bowl through a distributor. A series of small holes on the separator discs, positioned at definite distance from the centre, allow the latex to get distributed and broken up into a number of thin conical shells within the bowl which rotates at high speed. At steady state running of the machine, the DRC of the latex at the periphery of the bowl will be much lower than that of the latex at the centre. The latex concentrate which has above 60% DRC flows towards the axis of rotation and is collected through a galley at the top. The skim latex which contains about 6 to 10% rubber is collected through a separate galley. The DRC of the latex concentrate and that of the skim depends on several factors such as speed of rotation of the bowl, pressure head in the feed cup, diameter of feed tube, length and diameter of the skim screw and DRC of the feed latex. Shorter skim screw, low feed rate of latex and higher DRC of field latex favours a higher DRC for the concentrate. Factors affecting efficiency of different types of machines have been studied in detail and operating conditions to get the maximum bowl efficiency have been worked out (Piddlesden, 1940 and Sum et al. 1982). When the DRC of the latex is above 66%, it is known as high DRC latex, which can be produced by proper adjustment of the skim screw and feed rate (Zachariassen et al. 1972).

Latex for centrifuging is to be adequately preserved against bacterial growth and development of volatile fatty acids. The dosage of ammonia required for preserving the field latex depends on the period of storage before centrifuging operation and varies from 0.3% to 1.0%. Only the minimum essential quantity of ammonia is to be used for preserving the latex since a substantial quantity will be lost in the skim during centrifuging. The preserved latex is treated with calculated quantity of diammonium hydrogen phosphate to remove magnesium ions as magnesium ammonium phosphate. On storage, this material settles down at the bottom of the tank as sludge. Desludged latex is fed into the centrifuging machine at a constant rate. The machine can be run at standardised conditions of speed of rotation, rate of feed and skim screw settings, continuously for about 3 to 4 h. By this time, small clots of rubber and sludge get accumulated between the separator discs and the efficiency drops. At this stage, the machine is stopped and the bowl cleaned. It is possible to run the machine continuously for more than 4 h if the feed latex is properly desludged and passed through a clarifier initially. By proper setting of the skim screw and by adjusting the rate of feed, DRC and the total rubber recovered in the concentrate can be controlled. Normally it is observed that attempts to increase DRC of the concentrate beyond a certain level causes more loss of rubber in the skim. The DRC of the concentrate is usually kept slightly above 60% and finally adjusted to 60% by dilution.

Since most of the preservatives used in the feed latex would be lost in the aqueous phase of skim, it is necessary to supplement the concentrate with the required quantity of preservative depending upon the type of preservation system adopted. The concentrate may be preserved with ammonia alone or with a combination of ammonia with chemicals such as boric acid, sodium pentachlorophenate, zinc diethyl dithiocarbamate, triadine 10, zinc oxide, tetramethyl thiuramdisulphide etc. A small quantity of a higher fatty acid soap such as ammonium laurate is also normally used to boost the mechanical stability of the latex. Each of the above mentioned preservative systems has been studied in detail and the conditions for effective preservation of the concentrate standardised (Bloomfield and Mumford, 1970; Angove and Pillai, 1965; Poh, 1983; John et al. 1986). Recent legislations in some of the developed countries resulted in objections to the use of high ammonia type latex. Among the low ammonia preservative systems, the one consisting of 0.2% ammonia, 0.013% each of tetramethyl thiuramdisulpide and zinc oxide (LA-TZ system) is the most popular. Table 1 gives a list of various types of commercially available preservative systems for latex and their compositions. Details of some of the speciality natural rubber latex concentrates are given in Table 2 (Wahab, 1983).

There are about thirteen characteristics of natural rubber latex concentrate based on which the quality is assessed as per ISO specification 2004. The requirements of ISO 2004 and the test methods are listed in Table 3.

TABLE 1

Preserviative systems for latex concentrate

Type of systems	Composition
1. High ammonia (HA)	0.6% ammonia minimum.
2. Low ammonia - sodium pentachlorophenate (LA-SPP)	0.2% ammonia + 0.2% sodium pentachlorophenate.
3. Low ammonia - Boric acid (LA-BA)	0.2% ammonia + 0.24% boric acid + 0.05% lauric acid.
4. Low ammonia - Zinc diethyldithiocarbamate (LA-ZDC)	0.2% ammonia + 0.10% ZDC + 0.05% lauric acid.
5. Low ammonia - tetramethylthiuram disulphide zinc oxide (LA-TZ).	0.2% ammonia + 0.013% TMTD + 0.013% ZnO + 0.05% lauric acid.

TABLE 2

Speciality natural rubber latex concentrates

Types	Description
1. High DRC latex	Centrifuged latex having DRC in the range of 64% to 67%.
2. Purified or multiple centrifuged latex	Prepared by diluting centrifuged latex to 30% DRC with water containing ammonia and then recentrifuging to 60% DRC. It has a low non-rubber content.
3. *Prevulcanized latex* concentrate.	*Prepared by heating a stabilised latex concentrate* with dispersions of sulphur, zinc oxide and an ultrafast accelerator at temperatures of about 70°C for 2 h.
4. Methyl methacrylate grafted (MG) latex.	Prepared by grafting methyl methacrylate onto NR in latex form. MG latex having 30% and 49% by weight of polymethyl-methacrylate are available. This type of latex has a self reinforcing effect and provides a means of substantially improving the tear and puncture resistance of dipped goods.
5. Low constant viscosity (LCV) latex.	Prepared from specially selected clonal latices by treatment with 0.15% of hydroxylamine salts immediately after centrifuging. This type of low viscosity latex is advantageous in low pressure tack adhesive formulations.

TABLE 3

ISO 2004 (1974) requirements for centrifuged natural rubber latex concentrate.

Parameter	HA	LA	ISO test method No.
Total solids content, min; %	61.5	61.5	124
Dry rubber content, min; %	60.0	60.0	126
Non-rubber solids, max; %	2.0	2.0	-
Alkalinity, as ammonia, on latex weight, %	0.6 (min)	0.29 (max)	125
Mechanical stability time, min; s	650.0	650.0	35
Coagulum content, max; %	0.05	0.05	706
Volatile fatty acid number, max.	0.20	0.20	506
Potassium hydroxide numbr, max.	1.0	1.0	127
Copper content, max; mg/kg solids	8.0	8.0	1654
Manganese content, max; mg/kg solids	8.0	8.0	1655
Sludge content, max; %	0.1	0.1	2005
Colour	No blue or grey		
Odour	No putrefactive odour *after neutralization* with boric acid.		

While most of the parameters are stable and do not change during storage, three important characteristics namely volatile fatty acid (VFA) number, potassium hydroxide (KOH) number and mechanical stability time (MST) increase with time of storage of latex. These parameters are also affected by handling of latex, seasonal effects, pumping, exposure to air etc. The changes in VFA, KOH number and MST of latex are the result of two effects - changes associated with bacterial action in latex and those associated with hydrolytic action. Proper preservation can control the first *effect whereas no control over the second can be exercised.*

The volatile fatty acids in latex consist primarily of acetic and formic acids. They are produced by bacterial activity in latex utilising a glucose-amino acid complex as substrate (Lowe, 1960). The breakdown of this complex occurs via triose compounds, 3 phosphoglyceraldehyde and dihydroxy acetone phosphate, to pyruvic acid. The volatile acids can be produced *from pyruvic acid and alanine through many metabolic pathways.* VFA of latex concentrate is found to be between one third and one half of the VFA number of the field latex from which it is prepared (Cook and Sekhar, 1955). Hence field latex having a VFA number greater than 0.3 is considered to be unsuitable for latex concentrate production. In the event of serious bacterial contamination, the whole plant is to be disinfected by using a 1% solution of any one of the chemicals such as 5, 5'dichloro-2,2'dihydroxy diphenyl methane, alkyl-dimethyl-benzyl ammonium chloride or sodium hypochlorite, to control VFA formation. Work conducted by Lowe (1959) revealed that formation of VFA is a limited enzymic process which is influenced by the following factors:

- the quality of field latex, level of bacterial population in latex and length of time they have been allowed to remain viable in the latex
- temperature variations of latex before and after processing
- amount of serum substrate available for the enzymic process
- degree of inhibition exerted by the level of ammoniation
- the redox potential of latex

Well preserved latex concentrate may have a VFA level of 0.01 to 0.02 at the producers' end and may reach 0.08 to 0.10 at the consumers' end. At VFA levels of 0.25 to 0.35, putrefactive smell is evident and the latex concentrate is difficult/impossible to process.

Potassium hydroxide number is a measure of the ionic strength of the serum in the presence of ammonia. This represents most of the ions present in the latex but not all, since a significant amount of potassium ions is also present. KOH number of latex concentrate rises slowly during storage. Exposure to air tends to enhance the natural increase, presumably by absorption of carbon dioxide and the formation of carbonate/bicarbonate ions. The increment in KOH number during storage arises primarily from increase in the ions adsobred at the particle surface as the serum ion concentration is found to be unchanged during storage. A poorly preserved latex will have a high KOH number, but a high KOH number need not be an indication of poor preservation conditions since the presence of ions such as phosphates, amino acids and many others increases the KOH number, yet the preservation level may be quite satisfactory. Commercial latex concentrates on production may have a value of 0.5 which rises to 0.6 or more during storage.

The mechanical stability time of concentrated latex on the day of production will be low, in the range of 80 to 100 seconds, but will rise steadily within the first four to six weeks to give a value of 600-1500 seconds. External addition of soaps such as ammonium laurate will instantly increase MST. The spontaneous increase in MST during storage of latex is attributed to ammoniacal hydrolysis of lipids which produce fatty acid soaps which get adsorbed on the particle surface. Increase in temperature of latex is found to have the same effect on increasing the MST of fresh latex concentrate. The exact reason for the temperature effect is not understood but may involve the temperature/solubility dependence of the naturally occurring soaps. Recent work on MST of latex revealed that increase in MST is not related to electrical potential at the particle surface, indicating that the application of the electrostatic stabilization theory and the relation of particle charge to MST of natural rubber latex is questionable (Pendle, 1990).

Even though the production of concentrated NR latex by the centrifugal method is well established and a lion's share of the concentrate is produced by this method, further work on the following lines will be of great interest.

1. To develop a process by which the desludging process could be accelerated. At present it takes about 48 h for settling of the sludge, necessitating large storage capacities to be built up.
2. To develop a more effective and water soluble preservation system, as ammonia at higher levels is objectionable and none of the low ammonia systems is fully satisfactory. The LA-TZ system has the disadvantage of giving low PRI for skim rubber, inconsistency in quality of dispersion and settling of the added chemicals.
3. To develop a centrifuging machine having better efficiency and capability of self cleaning. The average efficiency with respect to concentrate recovery of the currently available machines varies from 86% to 90%. There is a need to re-examine the design of the machine so as to provide a higher feed rate with an accompanying high rate of concentrate recovery. Another point which requires attention is the facility to run the machine continuously. Since all the commercially available centrifuges are to be stopped for cleaning after about 3-4 h running, considerable time is lost even if a spare bowl is kept ready. A self cleaning machine will be advantageous in this respect.

Use of a latex clarifier is reported to have solved some of these problems to a certain extent (Kumaran, 1990). Passing preserved field latex through the clarifier removes most of the sludge present in it, which enables the centrifuge to be run continuously for about 8-9 h.

Treatment of skim latex

Skim latex may contain about 6-10% rubber depending upon the efficiency of separation. The rubber particles in skim are relatively smaller in size and have most of the proteins adsorbed onto them. The serum contains dissolved nonrubber solids and a major portion of the preservative used in field latex. All these factors make skim latex a highly stable one and render separation of rubber from it a difficult task. However, different methods have been developed for recovering the rubber. Normally the latex is first deammoniated by aeration and then coagulated with dilute sulphuric acid. The coagulum is thoroughly washed and processed into crepe rubber. Enzymic deproteinisation of skim latex using trypsin, followed by coagulation was reported to improve the quality of skim rubber (Morris, 1954). Creaming of skim latex using tamarind seed powder followed by coagulation also improves the quality of skim rubber (Thomas and Jacob, 1967). Skim rubber obtained by microbial fermentation is having better properties compared to those of rubber recovered by calcium chloride treatment (Resing, 1960). Quaternary ammonium surfactant as an alternative coagulant was reported (Sum, 1983). Rubber having properties equivalent to those of SMR 5L could be produced from skim latex by following the process described by Ong (1974). In this process the skim latex is treated with sodium metabisulphite (0.04% on DRC) before acid coagulation. The coagulum is soaked in 3% sodium hydroxide solution, washed and then soaked in 0.15% sulphuric acid solution. It is then washed and treated with a composite solution consisting of thiourea and oxalic acid (1% w/w). The rubber thus recovered is reported to have very high PRI and constant viscosity characteristics.

RIBBED SMOKED SHEETS

Converting natural rubber latex into ribbed smoked sheets (RSS) is the oldest method of processing. This method is widely adopted by small and medium scale rubber growers because of the following reasons.

1. This is the most convenient method when the quantity of latex is small.
2. It requires only simple equipments.
3. It does not require great technical expertise to adopt the process.
4. Overall cost of processing is less compared with other methods.

Latex intended for processing into RSS is treated with any one of the short-term preservatives such as sodium sulphite, formalin or ammonia, if it shows a tendency for precoagulation. A combination of formalin and sodium metasilicate is reported to be an ideal anticoagulant system for latex to be processed into RSS (Cook, 1960). Latex in reception at the collection centre/processing factory is sieved using 40 and 30 mesh sieves to remove suspended impurities. Since the quantity of chemicals required for processing latex into RSS is based on its DRC, a quick estimate of the same is made, usually by the hydrometric method. A detailed account of estimation of DRC was given by Chin and Singh (1980) and Chin (1981a,b). Latex from different fields/estates is pooled to make rubber of uniform quality. The bulked latex is diluted to a standard DRC of 12.5%, by adding water, to improve the quality of the sheets produced. Sheets from diluted latex have better colour, transparency and show less tendency for mould growth. It also makes the sheeting operation easy and helps faster drying of the sheet. On allowing the diluted latex to remain undisturbed for about 10-15 min, the denser impurities settle fast and the latex is transferred to another tank, without disturbing the sediments. Chemicals such as sodium bisulphite and paranitrophenol are added to the latex at this stage, if found necessary.

Sodium bisulphite is added to prevent discolouration of the coagulum, caused by enzymes of the polyphenol oxidase type. Phenols and aminophenols present in latex combine with oxygen from the air to form orthoquinones, which react with naturally occurring amino acids and proteins in latex, to give coloured products resembling melanin. Reduced melanin is tan coloured and the oxidised one is black. The enzymes are believed to catalyse the above reactions and sodium bisulphite prevents the discolouration by preferentially getting reacted with atmospheric oxygen. The dosage of sodium bisulphite depends on the extent of enzymic activity and concentrations of amino phenols, amino acids, proteins etc. in latex. About 1.2 g of sodium bisulphite is normally found to give satisfactory protection for latex containing 1 kg dry rubber. It is added as 2% solution. Use of excess quantity of this chemical may lead to slow drying of the sheets. To prevent mould growth on the surface of the sheets, the wet sheets are dipped in 1% solution of paranitrophenol or a 1% solution of the chemical is added to the latex before coagulation, at the rate of 1 g per kg DRC. The second procedure is reported to be more effective (Hastings and Piddlesden, 1938).

Diluted latex of about 12.5% DRC is coagulated in pans, troughs or tanks. Coagulating pans are usually made of aluminium whereas the tanks may be of aluminium or masonry which is lined inside with aluminium sheets or glazed tiles. When the number of sheets to be prepared is small, pan or trough coagulation is done. For larger scale operation coagulation tanks provided with partition plates are used. Solutions of volatile acids such as acetic and formic acids at low concentrations are used for coagulating latex. Such weak acids provide uniform coagulation and excess acid if any, gets volatalized off during drying of the sheets. The pH of coagulation is kept at about 4.6 to get complete recovery of rubber, avoid fermentation of latex and to get a soft coagulum. Attempts to use strong acids such as sulphuric acid for coagulating NR latex were made as early as in 1932 (Wiltshire, 1932; Martin and Davey, 1934). It was reported that properly diluted sulphuric acid, when used in correct proportions did not cause any deterioration in properties of the rubber. Corrosion to machinery and utensils also did not occur if they were properly washed after the use. Later work by Baker and Philpott (1950) and that by Best and Morrel (1955) also confirmed the earlier reports. However Neef (1950) reported that rubber coagulated with excess of sulphuric acid showed considerable softening when it was heated at 140°C for 3 h. Renewed interest in the use of sulphuric acid started during early 1980's since the price difference between the volatile acids and sulphuric acid became attractive. Othman and Lye (1980) reported that pH of coagulation is very important when sulphuric acid is used as coagulant for NR latex and recommended a pH around 5.0 as more suitable for sheet rubber production. More recent studies indicated that sulphuric acid can be used as coagulant for NR latex in sheet rubber production, if all factors such as dosage, dilution and washing of sheets and machinery are taken care of (George et al. 1990). Another nonvolatile acid that is recommended for latex coagulation is sulphamic acid. Use of optimum dosage and proper washing of the coagulum during sheeting to remove residual acid were reported to yield good quality sheets when this chemical is used (Sebastian et al. 1982).

Latex coagulum is sheeted after maturation. Sheeting operation squeezes out serum present in the coagulum and reduces its thickness to about 3.0 mm. This is done by passing the coagulum through a set of hand operated plane rolls, several times, followed by one pass through another set of grooved rolls on which the grooves are spirally cut at an angle of 45° and at 3 to 5 mm width and depth. The ribbed design helps to increase the surface area of the coagulum for faster drying and also prevents sticking of the dried sheets when these are stacked in bundles. A sheeting battery consists of four or five sets of plane rolls and one set of grooved rolls arranged in a row with their nip gap progressively reduced. It is used for sheeting the coagulum prepared in large tanks. Uniformity and softness of the coagulum are the two important parameters that affect the efficiency of the sheeting battery (Bishop and Wiltshire, 1932). The coagulum is washed thoroughly during sheeting to remove the serum and residual acid. Sheeted coagulum is soaked in 1% solution of paranitrophenol if it has not been added to latex before coagulation.

Drying of sheets can be done in a smoke house or hot air chamber and the dried sheets thus obtained are termed ribbed smoked sheets (RSS) or air dried sheets (ADS), respectively. Partial drying in sunlight followed by smoke drying is also widely practiced. A survey of the factors involved in the drying of sheet rubber (Gale, 1959) revealed that upto a moisture level of 10%, syneresis is the main process of water removal and drying below this level is diffusion controlled. Method of preparation of the wet sheet (pH of coagulation, softness of coagulum, extent of machining etc) and drying conditions such as temperature, relative humidity and speed of air circulation in the chamber etc. have profound influence on the rate of drying. The sheeted coagulum is allowed to drip off water emerging due to syneresis, before it is fed into the smoke house or drying chamber. Several types of smoke houses such as those with furnace inside or outside the drying chamber, batch type or continuous type are in operation (peries, 1970a). The RRIM tunnel type smoke houses described by Graham (1964) meet almost all the requirements of an ideal smoke house. In this type of smoke house, the furnace is outside the drying chamber and smoke and hot air are led into the chamber through underground flue inlets. By controlling the rate of burning of firewood and regulating the openings for flue inlet, ventilator and exhaust, the temperature inside the chamber at different regions can be controlled and maintained in the range of about 45°C to 60°C. The sheets are put on reapers placed on trolleys which moved on a central rail track inside the chamber. The capacities of the trolley and the chamber are designed in such a way that each trolley can accommodate one day's crop and the chamber, four days' crop. The sheets take about four days to get dried.

Since firewood has become scarce and its price increased several fold, efforts to reduce its consumption have been made. Use of solar energy to dry sheet rubber has been attempted in many ways. Direct exposure of wet sheets to sun light did not affect the dynamic properties of the sheets. However, exposure of dried sheets even for a few hours, adversely affected these properties (Tan et al. 1977). Experiments using solar power-boosted smoke houses (Rama Rao et al. 1986; Nair et al. 1988) show that there could be a saving of about 50 to 60% firewood by using solar energy for drying. In such smoke houses, the main drying process occurs with the help of hot air generated by solar panels and firewood is used only as a subsidiary heat source to maintain the temperature of the drying chamber from dusk to dawn. While the initial expenses of the solar boosted smoke house is higher than that of a conventional smoke house, its recurring expense is lower.

The dried sheets are visually examined and graded, adopting the norms prescribed by the International Rubber Quality and Packing Committee under the Secretariat of the Rubber Manufacturers Association Incorporated, USA and which are described in the 'Green Book'. The important parameters considered in grading the sheets into RSS 1X to RSS 5 are degree of dryness, presence of foreign matter, virgin rubber, oxidised spot, blisters, bubbles, resinous matter, transparency, colour, tackiness, over smoking, mould growth, dark or coloured spots etc.

TECHNICALLY SPECIFIED NATURAL RUBBER

Visual grading followed for quality assessment of sheet and crepe rubbers, has many drawbacks. Hence attempts were made as early as the 1950s to study the variability in sheet rubber and to evolve a better method of grading, based on technical parameters (Fletcher, 1950; Newton et al. 1951; Baker, 1954). By early 1960s, parameters that could provide a satisfactory indication of the quality of NR were identified (Baker et al. 1967). NR in technically specified form was first introduced in 1962 by the SOCFIN group of companies in Ivory Coast. However, only with the launching of the Standard Malaysian Rubber (SMR) Scheme in 1965, this new form got wider consumer acceptance. Now, a lion's share of NR processed in major NR producing countries is in technically specified form.

Advantages of technically specified rubber (TSR) include assurance of quality with respect to important technical parameters, consistency in quality, minimum space for storage and clean and easy to handle packing (Bekema, 1969; Pike and Ramage, 1969). This new method enabled NR producers to process both latex and field coagulum, using almost the same set of machinery and to reduce the processing time to less than 24 h. The competitive position of their produce with respect to cleanliness, presentation and appearance also improved. Even though different methods were developed to produce TSR, all these processes involve certain common steps such as coagulation of latex/precleaning of field coagulum, size reduction, drying, baling, testing, grading and packing. Differences among commercial processes lie in the method of coagulation or in the machinery used for crumbling the coagulum. Crumbs of coagulum may be prepared by purely mechanical means (Smith, 1969) or by a mechano-chemical process (Muthukuda, 1967).

The Dynat method of processing involves four basic machines - a rotary cutter, pelletiser, drier and baling press. Coagulation of latex is done at field DRC. Assisted biological coagulation produces a coagulum which is porous in nature and hence easy to process and dry (Thompson and Howorth, 1964). A slitting machine splits the slab into strips which are then fed to the pelletising machine. When field coagulum is processed, a rotary cutter with a perforated screen is employed (Thompson et al. 1966) for initial size reduction. The pelletiser operates by a process of extrusion and cutting. Extrusion takes place with minimum mechanical working of the coagulum, and cutting knives placed both inside and outside the die plate, cut the coagulum into small pieces of about 3 to 4 mm diameter. The face of the extruder is sprayed with water to lubricate the knives and for effective washing (Howorth, 1966). These machines are reported to have lower power requirements (Heyneker, 1967). The washed crumbs are dried in a vertical semicontinuous drier. Drying in the stack employs a relatively low temperature (60-65°C) with high humidity at the top or feeding point and a high temperature (90-93°C) and low humidity at the bottom or discharge point. The dried crumbs are weighed and baled using a 60 tonne self contained hydraulic unit giving 3 to 4 min dwell time under pressure (Shaw, 1968).

The Decan remill process, described by Gyss and Fleurot (1969) for preparing Nat-rubber, consists of coagulating latex in cylindrical tubes, veneering, calendering and granulating the coagulum to produce fine crumbs. Coagulation is done by assisted biological method. Macerators and scrap washers are replaced by granulators and hammermills for preparing crumbs from estate scrap and smallholders' coagulum. Rapid drying is achieved by adjusting flow rate, humidity and temperature of the air passed through a bed of crumbs. Use of zinc pentachlorothiophenate for preparing TSR (Peptorub) from field coagulum grade rubber was described by Hastings (1964). Scrap washed coagulum was put into a rotating cement mixer into which a measured quality of the peptising agent is sprayed as dispersion. It is further processed using a creper and a granulating machine. The granules are kept in open steam for 20 min and then dried in an air circulated oven maintained at about 63°C. It takes about three days for drying of the crumbs.

The Heveacrumb process introduced by the RRIM makes use of castor oil as the crumbling agent. A full account of the process has been described by its originators (Sekhar et al. 1965) and also by several others (Bateman et al. 1965; Graham and Morris, 1966). Addition of a small quantity of castor oil either in the latex stage or during processing of the coagulum prevents reagglomeration of the crumbs. The advantage of this mechano-chemical process over the purely mechanical process is that even conventional machinery such as crepers can be used for producing crumbs. For processing small holders latex coagulum and field coagulum several combinations of machinery such as crepers with hammermill, shredder or granulator may be employed. Use of prebreaker enables processing of even dried field coagulum into fine crumbs which can be blended more effectively and processed further. Polypropylene glycol of average molecular weight 2000, was reported to be an effective alternative to castor oil (Chin, 1974). Use of this chemical along with zinc stearate can reduce the dosage of the former from 0.7% to about 0.35% on DRC of latex. Methods adopted for processing latex/field coagulum have a profound influence on the quality of TSR produced. DRC and method of coagulation, type of coagulant, maturation of coagulum etc. are reported to influence the quality to a great extent (Graham, 1969; Morris, 1969; Sekhar, 1971). Coagulation at original DRC using formic acid gives a higher plasticity retention index (PRI). Assisted biological coagulation is better than the natural one to get a higher PRI.

Further efforts were made to modify the process and machinery to achieve better properties and higher outputs in TSR production. Continuous coagulation of latex was attempted by Harris et al (1974) based on the principle of matched gravitational flow of diluted acid and latex. More cost effective methods for continuous coagulation of latex using dilute sulphuric acid (Mcintosh and Wilkinson, 1975) and by heat gelation technique (Fah and Peng, 1975) were reported to produce more uniform coagulum within a very short time. Factors affecting power consumption and output of machinery used for SMR production were identified for improving the efficiency. Speed of rotation in hammermills and that of the faster roll in crepers are reported to be the deciding factors for peak load on electric motor, rather than friction ratio and nip gap of the rolls (Lim and Sethu, 1974). Higher speeds and deeper grooves on creper rolls increase the output, but require more power (Subbiah et al. 1976). Drying of the crumbs also consumes much energy. Three stages involved in drying of wet crumbs are the constant rate period and the first and second falling rate periods. Influence of parameters such as humidity gradient, air velocity and temperature during each stage of drying has been identified (Sethu, 1967). Later work by Yushan et al. (1985) revealed that the maximum temperature for drying latex grade crumbs is 125°C and the ideal bed thickness is 25-28 cm, whereas for field coagulum grade crumbs, these will be 115°C and 17-20cm respectively. The drying time in both cases will be 2.5 h. However, Roudeix (1985) reported that latex crumbs could be dried at 120°C within 2 h, if the coagulum is made porous by adding yeast (0.5 g kg^{-1} DRC) and sugar (6-8 g kg^{-1} DRC) before coagulating the latex. Since higher baling temperature influences the rate of storage hardening of NR, temperature below 60°C is recommended for baling the crumbs (Fah, 1977).

Technically specified form of NR is produced in constant viscosity (CV), oil extended (OENR), superior processing (SP) and deproteinised (DPNR) varieties also. Addition of 0.02% on DRC of xylyl mercaptan to latex along with 0.15% on DRC of latex of hydroxylamine hydrochloride is reported to yield SMR 5 CV from high viscosity rubbers (Ong and Lim, 1978). CV rubber having Mooney viscosity in the range of 50±5 can also be produced by using 0.15% by weight on DRC of latex of hydroxylamine neutral sulphate and 0.0037 to 0.014% by weight on DRC of latex of Renacit VII (Tillakaretne et al. 1981). Methods for producing OENR, CV rubber and SP rubber by Heveacrumb process was reported by Sung (1966). The preparation and properties of OENR have been described by Sung and O'Connell (1969) also. Chin et al. (1974) and Cheang et al. (1987) have given a detailed account of the production of deproteinised form of NR.

Since its introduction in 1965, the SMR scheme has been under constant monitoring and revision. There were only three grades (SMR 5, SMR 20 and SMR 50) initially, and six parameters (dirt, ash, nitrogen, volatile matter, copper and manganese) based on which the grading was done (Rubber Research Institute of Malaysia, 1965). Methods to improve parameters such as PRI of the raw material (Watson, 1969) and the significance of the specification parameters on the technological properties have been established (Bateman and Sekhar, 1966; Bristow, 1990). The first major revision of the SMR scheme was made during 1970. Copper and Manganese were replaced by PRI. Wallace plasticity (Po) was introduced as one of the specification parameters. Nitrogen and ash limits of SMR 5 were changed and two new grades, SMR 10 and SMR EQ, were introduced. The second revision of the scheme was made in 1979. The major changes involved in these revisions are described by Tong and Kamaruddin (1984). Work conducted by Ong et al. (1987) pointed out the need for introducing parameters other than PRI in predicting the mastication and mixing behaviour of CV rubber. The main complaints against TSR are the presence of wet rubber and contamination by plastic materials (Rao and Tong, 1984). The scheme is being continuously updated to meet consumer demands within the framework of producer capabilities. The latest SMR grades and their specification are given in Table 4. Other TSR producing countries also update the specifications of their produce from time to time.

Introduction of the technical specification shceme was an important step in the development of NR processing industry. It enabled the consumers to have a better idea of the quality of their raw material. However,

TABLE 4

Standard Malaysian Rubber Specification Scheme Mandatory from 1 October 1991.

Parameter	SMR CV60	SMR CV50	SMR L	SMR 5	SMR GP	SMR 10CV	SMR 10	SMR 20CV	SMR 20
	LATEX			SHEET MATERIAL[a]	BLEND	FIELD GRADE MATERIAL			
Dirt retained on 44 µ aperture (max, % wt)	0.02	0.02	0.02	0.05	0.08	0.08	0.08	0.16	0.16
Ash content (max, % wt)	0.50	0.50	0.50	0.60	0.75	0.75	0.75	1.00	1.00
Nitrogen (max, % wt)	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
Volatile matter (max, % wt)	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
Wallace rapid plasticity (Po) (min)	-	-	35	30	-	-	30	-	30
Plasticity retention index (PRI) (min, %)[b]	60	60	60	60	50	50	50	40	40
Lovibond Colour:									
individual value (max)	-	-	6.0	-	-	-	-	-	-
range (max)	-	-	2.0	-	-	-	-	-	-
Mooney viscosity ML(1'+4')100°C[b]	60(+5,-5)	50(+5,-5)	-	-	65(+7,-5)	c	-	c	-
Cure [d]	R	R	R	-	R	R	-	R	-
Colour coding marker	Black	Black	Light Green	Light Green	Blue	MAGENTA	Brown	Yellow	Red
Plastic wrap colour	Trans-parent	Trans-parent	Trans-parent	Trans-parent	Trans-parent	Trans-parent	Trans-parent	Trans-parent	Trans-parent
Plastic strip colour	Orange	Orange	Trans-parent	Opaque White	Opaque White	Opaque White	Opaque White	Opaque White	Opaque White

a Two sub-grades of SMR 5 are SMR 5RSS and SMR 5ADS which are prepared by direct baling of ribbed smoked sheet and air-dried sheet (ADS), respectively.

b Special producer limits and related controls are also imposed by the RRIM to provide additional safeguard.

c The Mooney viscosities of SMR10CV and SMR20CV are, at present, not of specification status. They are, however, controlled at the producer end to 60(+7,-5) for SMR 10CV and 65(+7,-5) for SMR 20CV.

d Rheograph and cure test data (delta torque, optimum cure time and scorch) are provided.

advancement in the rubber product manufacturing industry necessitated a re-examination of the specification parameters and the possibility of introducing new parameters which may truely reflect the processability and technological properties of NR. To have automated processing and computer controlled machinery in product manufacture, strict batch to batch consistency in raw rubber has become very essential. Even though TSR meets most of the requirements of the consumer, the quality specified is to be consistent also. In addition to this, for better control of manufacturing processes such as extrusion, calendering, injection moulding etc. more information on viscosity, physico-chemical and rheological properties of the raw material is necessary. Baker and Bristow (1991) have identified the important parameters and their limits, which are to be controlled for producing TSR having the quality and consistency acceptable to the consumers. However, the inherent variability and that introduced due to difference in processing techniques make it a challenge to produce TSR of really consistent quality (Livonniere, 1991). Quality has to be designed and built into the rubber from the very beginning so that the entire produce conforms to the requirements. For meeting the ISO 9000 series of quality systems, strict control on basic source material and the production process is to be effected. The system introduced should be such that it is economically viable to the producer and the quality acceptable to the consumer at an affordable price.

CREPE RUBBERS

There are 29 grades of crepe rubber, contained in six different types which are described in the Green Book. However, based on the raw material used, crepe rubbers can be grouped into two, namely latex crepes and those produced from field coagulum. For low quality crepes field coagula such as cup lump, tree lace, shell scrap, earth scrap, bark scrap etc. and cuttings and rejections of pale latex crepe and smoked and unsmoked sheets are made use of. The manufacturing procedure depends on the type of raw material used and the grade of the crepe to be produced. However, for all the grades, steps such as sorting of the coagula, precleaning/power-washing, maceration, remilling, refining etc. are involved. The quality of the final product depends, to a large extent, on the number of passes through each machine and on the extent of washing given at each stage. The lower grade crepes are dried in sheds at atmospheric temperature. Crepe rubber produced from tree lace is of inferior quality compared with that from cup lump since tree lace undergoes severe degradation on storage (Arumugam and Morris, 1964). With the advent of technically specified rubber, production of lower grade crepes has come down drastically. But, the latex grade crepes, namely pale latex crepe (PLC) and sole crepe are preferred to even the best quality TSR, in some applications such as pharmaceutical and food contact products, electrical insulation, rubber solution and cements, white and bright coloured products etc. because of their high purity and light colour (Karunaratne, 1977).

PALE LATEX CREPE AND SOLE CREPE

These are manufactured from latex, under strictly controlled conditions. Detailed procedures for their manufacture are described by Morris (1964) and Peries (1970b). Latex which contains a lower concentration of yellow colouring pigment, which is less susceptible to enzymic darkening and which yields rubber having a higher Mooney viscosity is found to be the ideal one for PLC and sole crepe. Considering the above factors, latex from PB 86 is the most suited one, even though that from other clones can also be used, either alone or in blends with PB 86 latex. The best anticoagulant for the latex to be processed into PLC is sodium sulphite. To prevent enzymic darkening sodium bisulphite is recommended.

For removing the yellow colouring materials, fractional coagulation or bleaching method or a combination of these two, is usually followed. For fractional coagulation diluted latex is treated with a small quantity of 2% acetic or oxalic acid solution and stirred well until small clots of rubber containing the yellow pigment are formed. The clotted fraction is removed by filtration and the filtered latex coagulated using 1% formic or 2% oxalic acid solutions. The bleaching process consists of treating the latex with thiols such as xylyl mercaptan which preferentially reacts with the colouring matter. Due to high toxicity, xylyl mercaptan is being replaced by other chemicals such as sodium/potassium salt of tolyl mercaptan and that of para-tertiary butyl thiophenol (Karunaratne, 1983). Quantity of the bleaching agent to be used depends on the extent of colouring matter present and is determined by trials. The bleaching action of the above chemicals is reported to be effected through oxidised carotene of xanthophyll and other oxygenated forms of carotene and not through carotene itself (Tillakarente *et al.* 1984). The bleached latex is coagulated using either 1% solution of formic acid or 2% solution of oxalic acid. Use of oxalic acid gives better colour and retention of colour during storage of the crepe. The coagulum is passed through a set of machinery consisting of macerators, crepers and smooth rolls. Thorough washing during machining is given to remove serum and excess coagulant but the final pass through the plane rolls is done without spraying water to facilitate quick removal of surface moisture. The thickness of the crepe coming from the plane rolls is adjusted between 0.8 to 1.0 mm. Drying of the crepe is done in sheds maintained at a temperature of 32-35°C. Several modifications to the conventional boiler-radiator system for heating the air in the sheds have been done from time to time. Use of finned air heater-forced draft blower arrangement, is reported to be more economical than the conventional system (Tharmalingam et al. 1977). A simple air heater arrangement which extracts heat from the flue gases prior to discharge up the chimney has been reported to improve the efficiency (Walpita et al. 1984a). Use of solar energy and application of partial vacuum are found to reduce the drying time of latex crepes considerably (Walpita et al. 1984b). Dried latex crepes are examined for defects and the selected grades are laminated to produce sole crepe of the required dimensions.

Discolouration of the latex crepe during manufacture and on storage is a serious problem in many manufacturing units. Nadarajah and Muthukuda (1974) suggested the use of oxalic acid as coagulant and to avoid addition of sodium bisulphite for eliminating discolouration. Nadarajah and De Silva (1983) have shown that use of boric acid in the range of 0.05 to 1.0% on DRC of latex in place of sodium bisulphite can control discolouration to some extent. Various factors causing discolouration of latex crepe and its remedial measures have been described by Nadarajah (1983). Nadarajah and Perera (1983) have shown that processing conditions and volatile matter present in latex crepe also affect mould growth and discolouration.

EFFLUENT FROM PROCESSING FACTORIES

A large quantity of effluent emerges from all types of rubber processing factories. It is to be treated properly before being discharged into the normal water ways. Different types of treatments for the effluent are described in literature (Ahmed, 1978, 1980; Ahmed et al. 1979; Nordin and Mohamed, 1989; Zaid and Sing, 1980).

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