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Review

Pollution Monitoring and Control in Rubber Industry in Nigeria

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The production activities of the rubber industry in Nigeria generate a large quantity of rubber (wastewaters) effluent most of which are often discharged untreated into nearby surroundings. A study carried out in 1994-1997 on the numbers and types of rubber processing factories and effluent generated and discharged in Nigeria and their modes of disposal/ control revealed that 41 rubber processing factories were located in 10 states of the country of which only 27 were still functional. Of these functional factories, 18.5% produced ribbed smoked sheets (RSS), 77.8% technically specified rubber (TSR) and 3.7% latex concentrate. Seventy-four percent (74%) had serious pollution problems while 18.5% had mild pollution problems. Fifty-five percent (55%) had received complaints from the residents living around the factories, of odour and pollution of their source of domestic water. Only 7.4% had good effluent treatment facilities in place while 11.1% had simple effluent treatment systems and 81.1% did not treat their effluent at all. While 66.6% of factories discharge their effluents into water bodies (rivers/streams), 33.4% send theirs to nearby waste/farmlands. However, recent investigation has shown that the number of the functional factories have reduced tremendously though some new ones have emerged, the overall pollution situation by the rubber industry is still bad. To improve the pollution levels caused by these processing factories, some efficient treatment systems in form of physical, chemical and biological processes can be used to reduce the pollution load of the effluent to tolerable limits.

Keywords: Rubber effluent, Pollution, Effluent treatment, Monitoring.

INTRODUCTION

Like in most Asian countries (Malaysia, India, Thailand, Sri- Lanka etc), Natural Rubber (NR) was one of Nigeria‟s most important economic tree crops, which in the past had earned the country a huge sum in foreign exchange and led to the emergence of many rubber-processing factories (Momodu, 1993; Anitha *et al.,* 2007). Apart from this, the employment of graduate and young school leavers, engagement of able youths (male and female) in the tapping of rubber latex with high financial benefits, hiring and leasing of rubber estates by native owners to rubber processing industries with attendant economic benefits are some of the associated positive effects linked with growing and processing of rubber (Ogiehor *et al.,* 2000). Most of these factories were located in the 10 states of the rubber growing zones of Nigeria with the majority of them in the South-South, a few in the South-West and others in the South-East geopolitical regions. However, there has been a decline in the national production of natural rubber which consequently led to the reduction in the number of rubber processing factories in Nigeria.

Nevertheless, the production activities of these factories generate a lot of waste water called effluent, much of which is discharged indiscriminately and untreated into nearby streams, rivers, ponds and even farmlands thereby causing pollution of the environment where it is being discharged (Ogiehor *et al*., 2000). Pollution is one of the greatest negative side effects of industrialisation and it is correlated with the degree of industrialisation and the volume of chemical materials used. Most industrial activities require a large volume of water for operations that eventually result in the production and discharge of a high quantity of waste waters (effluent) into the environment (Ghoreishi and Haghighi, 2003). The characteristics and complexity of wastes discharged by industries vary according to the process technology, the size of the industry and nature of the products. The majority of these industrial waste waters contain highly toxic substances such as heavy metals, organic and inorganic chemicals and salts, solids, colloids, oils, tars etc that are deleterious to the flora, fauna in and on the quality of the receiving bodies (Singh, 2001). The rubber industry like other industries in Nigeria has its own peculiar pollution characteristics that it contributes to the environment that needs to be thoroughly monitored and controlled.

RUBBER EFFLUENT GENERATION/PRODUCTION

During the processing of rubber, a large quantity of water (about 20 to 30 litres of water per kg of dry rubber) is used for washing, cleaning and dilution (Kumaran, 1988) and comes out as wastewater (effluent) that is often discharged untreated into nearby streams, rivers, ponds etc. It is estimated that on the average, about $1000m^3$ of effluent is discharged daily from a factory producing about 50tonnes dry rubber per day (Ahmad, 1983). This effluent consists of process water, uncoagulated latex washings and significant quantities of serum containing proteins, sugars, carotenoids, lipids, inorganic and organic salts (John and Mohd, 1977). The slightly acidic nature of the rubber effluent is as a result of the application of formic, phosphoric or sulphuric acids in the coagulation of skim latex with sulphuric acid coagulation leading to the production of a high level of sulphates. The organic matter when discharged into a stream or river decomposes as a result of the action of the bacteria which are its food and the dissolved oxygen present in the water is used up by these bacteria. With this diminishing oxygen supply, survival of the higher forms of life becomes difficult. Even after dissolved oxygen has been exhausted, the anaerobic bacteria are still able to survive by deriving its energy from the organic matter. This process leads to putrefaction and gives rise to obnoxious gases such as hydrogen sulphide (H_2S) and methane. The odours are detectable even at extremely low concentrations and make water unpalatable for several hundred miles downstream from the rubber processing factories (Rungruang and Babel, 2008). Another serious threat of rubber wastewater towards environmental protection is the high concentration of nitrogen and organic carbon in the effluent. The excess of nitrates produced as a result of this, contribute to undesirable eutrophication, methemoglobinemia in infants, increases oxygen and chemical demands and affects the paddy and other agricultural fields (Mohammadi *et al*., 2010).

The high level of ammonia also found in rubber effluent is derived from ammonia used as an anticoagulant and for the preservation of field latex. At low pH, ammonia can be harmless but as the effluent becomes more acidic, the ammonia tends to be very toxic and thus becomes dangerous to the aquatic animals and plants. This high level of ammonia and other plant nutrients makes it a good medium for algal growth. The rubber effluent also contains a fairly large amount of total solids - suspended, dissolved and settle-able. The dissolved solids play a significant role in the salinity of the effluent by affecting the mechanism regulating osmotic pressure which controls the availability of water to plants (RRIM, 1974).

Effluent properties

Generally, rubber effluent can be characterised on the basis of its physical, chemical or biological properties (Table 1). The physical and chemical properties are measured by temperature, colour, odour, turbidity or light permeability, suspended or settleable solids, excess acidity or alkalinity, large discharge of organic matters, excess saline matter, metallic or non-metallic contamination etc, while the bacteriological pollution which is normally caused by pathogenic organisms (bacteria and fungi) is indicated and measured by the presence of coliform, E. Coli, streptococci etc.

The quality and composition of rubber factory effluent (pollution load) usually depends not only on the type of natural rubber processing from which the effluent is discharged i.e. whether from a latex concentrate factory or a technically specified rubber (TSR) - block or crumb or ribbed smoked sheet (RSS) rubber factory (Table 2), but also on the product processing techniques adopted and effluent disposal methods. Of all, the effluent from the latex concentrate factory is the most polluting (because of the concentrating process that needs the addition of chemicals) whilst that from the crumb/block (TSR) rubber processing factory produces a large volume of less polluting effluent (Phang, 1987). However, effluent from sheet rubber (RSS) processing contains the highest amount of albuminoid nitrogen followed by that from latex concentrate, then block rubber and crepe factories respectively (Sethu *et al.,* 1977). The high toxicity of the latex concentrate effluent adversely affects the growth of bacteria and hence the bacterial population is comparatively

Table 1. Some characteristics of effluent from Natural Rubber processing

Parameters	Typical Range
pH	3.7-5.5
Conductivity (US/Cm)	11-300
Turbidity (NTU)	45-90
Acidity	1.0-3.5
Alkalinity	2.0-3.5
Total Dissolved Solids	80-200
Biochemical Oxygen Demand	1500-7000
Chemical Oxygen Demand	3500-14000
Suspended Solids	200-700
Total nitrogen	200-1800
Sulphate	0.20-0.70
Nitrate	1.5-7.0
Iron	0.1-3.0
Lead	0.1-0.8
TVC (bacterial)	$1.0x10^2$-$7.0x10^7$

All units are in mg/l, except pH, conductivity and turbidity
Source: Mohammadi *et al*., 2010; Momodu *et al.,* 2012.

Table 2. Properties of effluents from different natural rubber processing.

Properties	Source of Effluent			
	Centrifuged Latex	RSS	TSR	Crepe
pH	6.5	4.5	6.3	5.2
Total Solids	6000	2500	1500	750
Suspended solids	15000	500	600	400
COD	6000	3000	2500	1000
BOD	4500	2000	1500	750
Ammoniacal nitrogen	500	10	50	10
Total nitrogen	800	100	150	50

(All values except pH are in mg/l. RSS - Ribbed Smoke Sheet, TSR-Technically Specified Rubber.(Source: George and Jacobs, 2000).

low in that effluent. The near neutral pH values of crepe factory effluent make it more favourable for the proliferation and growth of bacteria than the others. The effluent composition is determined by the measurement of its physical, chemical and bacteriological properties which is usually done by analysing the effluent for parameters such as:

(a) pH
(b) Chemical Biochemical Oxygen Demand (BOD)
(c) Oxygen Demand (COD)
(d) Dissolved Oxygen (DO)
(e) Solids (Dissolved, Suspended etc)
(f) Heavy Metals
(g) Inorganic Salts (cations and anions)
(h) Nitrogen etc.

Analysis of these properties is important for the following reasons:

(i) To estimate the possible detrimental effect of the rubber factory effluent upon the quality of the receiving water (ponds, river, streams etc), which may be required for down stream use.
(ii) To evaluate the strength and characteristics of rubber factory effluent in order to apply proper treatment methods.
(iii) To satisfy various standards of regulating bodies such as Federal Ministry of Environment (FME) and National Environmental Standards, Regulatory and Enforcement Agency (NESREA).

Table 3. Natural rubber processing factories in Nigeria State.

States	No of factories	Functional factories
Anambra	1	1
Imo	1	1
Delta	13	10
Edo	12	7
Cross Rivers	6	3
Rivers	1	1
Ondo	1	1
Abia	1	1
Ogun	3	3
Akwa – Ibom	1	1
Total	41	27

Table 4. Summary of findings on the pollution levels of the NR processing factories.

	No of factories	Percent (%)
1) Number of rubber processing factories studied	27	
2) Types of rubber processing effluent		
a) RSS (Ribbed Smoke Sheet)	5	18.5
b) TSR (Technically Specified Rubber)	21	81.4
c) Latex concentrate	1	3.7
3) Factories with very serious pollution problems (No treatment facilities at all)	20	74
4) Factories with mild pollution problems	5	18.5
5) Factories with pollution complaints from surrounding dwellers.	15	55
6) Factories with good effluent treatment facilities.	2	7.4
7) Factories with simple treatment facilities	3	11.1
8) Factories without treatment facilities	22	81.4
9) Mode of effluent disposal (where effluent is discharged into)		
a) River or Stream	18	66.6
b) Wasteland	9	33.4

(iv) To determine and ensure that waste water complies with standards for water re-use, production control and disposal in municipal sewers.
(v) To ascertain the possible by-products that may be recovered from the rubber factory effluent.

Therefore treatment of rubber wastewater using effective methods for overcoming these problems becomes imperative.

Rubber effluent pollution in Nigeria

In 1994-1997, a survey/study was carried out in Nigeria to look at the number of rubber processing factories (functional/non-functional), types of effluent generated and discharged and their methods of disposal/control. A summary of the observations made during the study is shown in (Table 3).

From Table 3, a total of 41 rubber processing factories were located in 10 states of Nigeria out of which only 27 were still operational. Of the 27 functional ones (Table 4), 18.5% were producing ribbed smoked sheets (RSS), 77.8% produced technically specified rubber (TSR) also called crumb or block rubber and 3.7% latex concentrate. Seventy-four percent (74%) had very serious pollution problems being that most of them had no proper treatment systems in place which will often lead to the generation of effluent with heavy pollution load. The 18.5% of the factories that had mild pollution problems had some simple treatment systems in place that helped to reduce the pollution load. Fifty-five percent (55%) of the rubber processors had received complaints of unpleasant odour and pollution of the source of water supply for domestic use by residents leaving around the factories as most of them were located in residential areas of the cities. Sadly, only about 7.4% of the rubber factories treated their effluents properly with perfect effluent treatment systems while 11.1% had simple treatment facilities that did not treat their effluents thoroughly. About 81.4% of the rubber processors did not treat their effluents at all and discharged these effluents

Table 5. Some FME/NESREA limits for discharged effluent.

Parameters	Limits
pH	6-9
Temperature	20-30
Conductivity (Us/cm)	200
Total Dissolved Solid (mg/l)	2000
Total Suspended Solids (mg/l)	15-30
Dissolved Oxygen (mg/l)	5-20
Biochemical Oxygen demand (mg/l)	10-50
Chemical Oxygen demand (mg/l)	15-50
Phosphate (mg/l)	5-10
Sulphate (mg/l)	5
Chloride (mg/l)	20-600
Calcium (mg/l)	20
Magnesium (mg/)	50-200
Sodium (mg/l)	-
Potassium (mg/l)	-
Alkalinity (mg/l)	-
Acidity (mg/l)	-

All figures except pH, temperature and conductivity are in mg/l.

raw as produced into their disposal channels. Most of the rubber factories (66.6%) discharge their effluent into rivers and streams (which are mostly sources of domestic water in rural areas) while 33.4% send theirs onto waste/farm lands which are toxic to plants and clog the soils.

However, recent investigations have shown that the number of functional rubber processing factories have dropped in Nigeria. While most of the old ones were closed down, a few new ones emerged. Interestingly, only one of the new rubber processor has a good treatment system in place meaning that the pollution status of the rubber industry in Nigeria still remains as bad as it was in the period of rubber boom when there was a proliferation of rubber processing factories in the country.

Summary of effluent treatment

To reduce the pollutant levels of the rubber effluent discharged from the factories to tolerable and acceptable limits (Table 5), it has to be properly monitored and treated.

The result of the physicochemical and bacteriological analysis carried out on the effluent often determines the type of treatment methods to be used. Effluent treatments are carried out basically in three stages: Primary, Secondary and Tertiary.

Primary treatment

The purpose of primary treatment is to recover small pieces of rubber and remove inert materials that could hinder subsequent biochemical reactions. This treatment could either be physical or chemical or both.

Physical methods

The effluents generated from rubber processing factories may contain coarse, suspended and settleable solids that should be removed before effluent is subjected to secondary treatment. The physical methods of effluent treatment include screening, flotation and sedimentation. This often involves the use of rubber traps and equalisation or compositing tank.

Chemical methods

This involves the addition of appropriate chemicals to effluents so as to precipitate particulate and colloidal materials, thereby reducing oxygen demand of the effluent. Some of the known chemical methods of effluent treatment are neutralisation and chemical coagulation.

Secondary treatment

Secondary treatment involves the use of aerobic and anaerobic processes to remove the dissolved organic matter in the effluent and thereby reducing its BOD. The aerobic process requires the supply of oxygen. It is comparatively fast, produces higher sludge, it is energy consuming, generates CO_2 and has higher treatment cost. On the other hand, in the anaerobic process, digestion is done in the absence of O_2, it is comparatively slow, produces minimum sludge, energy yielding, generates methane gas (fuel value) and it is cost effective. All secondary treatments are biological processes and bacteria are the major organisms that carry out the oxidation. They consume the dissolved organic matter as food and thus remove it from the effluent. The effectiveness of this system depends on the bacteria population, pH, temperature and nutrients. Some of the common biological treatments of effluents are aerated lagoons, activated sludge process, oxidation ditch, oxidation ponds, anaerobic digestions etc. For some obvious reasons such as cost, limited land space and the production of biogas, the anaerobic process of effluent treatment is preferred to that of the aerobic process. Some recent anaerobic digestion processes that have been developed standardised and proved to be highly efficient are:

(I) 1st generation (1994) (Mathew *et al.*, 1998, 1997). – Simple Enclosed Anaerobic Digester (SEAD).
(II) 2nd generation (1998) – Anaerobic Immobilized Growth Digester (AIGD) (Mathew *et al.,* 1998)
III) 3rd generation (2008) - High Rate Anaerobic Reactor (HRAR) (Dorisamy *et al.*, 2007) with 80% reduction of the pollutants in the effluent.
IV) 4th generation (2012) – High Rate Methanogenic Reactor) (HRMR) with 95% reduction of the pollutants along with good biogas output.

Tertiary treatment

The effluent from secondary stage contains sludge and cannot be discharged directly into streams. This has to be clarified and filtered to obtain clear treated effluent that can be recycled and reused for factory or domestic purpose. This can be achieved by using the tertiary system of effluent treatment by passing the effluent through settling tanks, sand filters and sludge drying beds.

Conclusion

The environmental pollution caused by the rubber processing factories (rubber industry) is quite evident. The pollution of water bodies which are usually the sources of water for domestic use and farmlands/vegetations for agricultural purposes and the release of obnoxious gases into the atmosphere is disturbing. It is quite obvious that the rubber processors do not take monitoring and control of their discharge wastes/effluents seriously. This is because the various environmental regulatory bodies are not doing proper monitoring and enforcement to ensure that they comply with environmental safety standards.

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