Effluent Discharge and Stream Pollution by a Rubber Factory: A case study of Field 20 stream in Odukpani, Cross River State

Efiong, J.

Department of Geography and Regional Planning, University of Calabar, Calabar-Nigeria

and

Eze, B. E. (PhD)

Department of Geography and Regional Planning, University of Calabar, Calabar-Nigeria

Abstract

Increases in socio-economic activities worldwide have been accompanied by a faster growth in pollution stress on especially the aquatic environment. In Nigeria, there are many cases of aquatic pollution that have not been documented. Water quality investigation of Field 20 Stream in Pamol (Nigeria) Limited Estate, Odukpani, Cross River State, was conducted weekly between April and June 2004 spanning a period of 10 weeks. The study revealed that the stream has been heavily polluted by effluents discharge into it. The investigation revealed marked changes between the control point and the downstream station with respect to parameters such as turbidity (from 4+0.7 to 19+ 0.9 F.T.U.) and colour (from 42 + 1.4 to 148 + 1.16 Pt-Co Units), which were above the WHO (1984) permissible limits for inland waters (5.0 F.T.U. and 15.0 Pt-Co Units respectively). Also the variation in dissolved oxygen between the upstream station (5.3+ 0.18 mgl-1) and downstream station (4.4 + 0.08 mgl-1) was below the WHO (1984) limit of>5.0 mgl-1 of dissolved oxygen in water for domestic purposes. Hence the water was considered to have been polluted by the effluents discharged into it. Variations in some other measured parameters between the upstream and the downstream stations though still within the WHO (1984) permissible limits were noticed. The rubber effluents were also analysed and were found to be high in turbidity (68+0.9 F.T.U), low in dissolved oxygen (1.7 + 0.7mgl-1), high again in total hardness (512 +3.2mgl-1), moderate in acidity (6.41+0.6) and very high in colour (510+7.8 Pt-Co Units). Mitigation procedures on the control of the pollution resulting from the rubber factory, for example the decolourization of the highly coloured effluents before the discharge were recommended.

Introduction

The world has entered a period of unprecedented environmental change as evidenced in the rapid growth of natural and man-made changes in the biosphere in recent times. Environmental pollution causing changes in environmental quality is just one issue raising widespread alarm. An increase in socio-economic activities worldwide has been accompanied by an even faster growth in pollution stress, especially on the aquatic environment. This is because the majority of human needs can only be met with goods and services provided by industries. Industries have the capacity to improve as well as degrade the environment. Raw materials, which have been taken from the natural resource base are converted into products by the industry. Láng (1993) noted that during the production process pollutants are often released into the environment.

Industrial effluents as pollutants contain a large number of both known and unknown substances formed during the production process. Rubber latex processing for example, involves sequential immersion in various chemicals before the final products are ready for the market. This process leaves behind toxic and concentrated aqueous solution with obnoxious odour (Webster and Kwill, 1989). The discharge of such mixture may give rise to various types of harmful effects or outright pollution in the receiving environment (Nyholm, 1992). The situation is worse where the receiving environment is a water body and the effluents untreated.

Industrial effluents constitute 95% of total waste discharge into the sea (Asuquo, 2000). Almost all industries in Nigeria and particularly Cross River State (including the rubber factory of Pamol (Nigeria) Limited discharge their effluents into rivers, streams, estuaries, lagoons or sea. Changes in the quality of rivers, streams, lagoons etc. as a result of industrial activities has been reported in Nigeria (Ajayi and Osibanjo, 1981; FEPA, 1991; Ntekim *et al.,* 1993; Asuquo, 1999; 2000). However, the extent to which pollution have occurred in Nigeria hinterland aquatic systems including the Field 20 Stream where rubber effluents are discharge into is yet to be scientifically investigated. Indeed, it is taken for granted in so far as a multinational companies are concerned. This investigation therefore determines the effects of the effluent discharged by Pamol (Nigeria) Limited, Odukpani, Cross River State on the Field 20 Stream that drains the area. Its attendant environmental implications and the pollution abatement measures for mitigating the effect of such effluent discharges in the future are discussed.

Literature Review and Conceptual Framework

Gardener (1977) noted that some of the most serious modifications of streams result from the intentional or unintentional wastes disposal in them. Water quality may be degraded to the extent that pollution becomes obvious and is a major public concern. These modifications, he further noted results primarily from the concentration of people, cities, industries etc. on land adjacent to streams. Hence, the concept of the river basin as a hydrological unit is most applicable here. Under this concept, More (1969) noted that the results of the divers human activities taking place in the river basin are reflected in the river. For instance, water pollutants discharge at one point will flow downstream and adversely affect the water use down the river (or stream)

Jain *et al* (1981) defines pollutions to mean, the impairment of water quality by man's activity causing an actual hazard to public health or impairment of beneficial use of water. Also, the Group of Experts on the Scientific Aspects of Marine Pollution, GESAMP (1988), defines the pollution of aquatic environment to mean, the introduction by man, directly or indirectly, of substances or energy which result in such deleterious effects as (1) harm to living resources (2) hazard to human health, (3) hindrances to aquatic activities, (4) impairment of water quality with respect to its use and, (5) reduction of amenities.

Some researchers have done water quality studies. Imevbore (1970) noted that some water quality data exist for a number of rivers and lakes in Africa, but are largely confined to the major cations (Na, Ca, K, and Mg) and anions (Cl^- and PO_4^{3-}). Such data are normally collected during surveys of the productivity of the water body concerned or to explain some unusual biological effects. Ajayi and Osibanjo (1981) observed that with the intentions of such studies, data relevant to pollution of the water bodies, such as indices of gross organic pollution (e .g BOD) or levels of toxic micro pollutants (e. g trace heavy metals and trace organic substances) are seldom, if ever, collected. Pollution data on African rivers are therefore very sparse. This situation was first noted by Zoeteman (1973), and there has been little improvement since then (Ajayi and Osibanjo (1981).

Osibanjo (1996) writing on the present water quality status in Nigeria decried a situation where the country is abundantly endowed with freshwater resources with coastal and marine water resources on its southern border located on the Atlantic Ocean has sparsely and un-coordinated water quality data of her fresh and marine waters. That is, the extent and variety of foreign substances in water are sparse and un-coordinated. This is noted as the reason behind the non-existence of Environmental Quality Objective (EQO) and Water Standards in the country.

However, twenty – six (26) Nigerian rivers were sampled during the dry season periods of 1977 and 1978 as reported by Ajayi and Osibanjo (1981). The samples were analysed for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), pH, dissolved oxygen, ammonia, nitrate and phosphate. Seventeen of the rivers examined were found to be more or less unpolluted, six of them being of high quality and the remaining nine were found to be polluted naturally.

Dauda (1998) gave the summary of results obtained from the analyses of twenty (20) surface water samples collected from some parts of the Federal Capital Territory (FCT), Abuja between 1995 and 1996. In any case, the samples were analysed for the water potability. The results showed that most of the water samples were not polluted. This was possibly due to the low industrial activities and urbanization in the Federal Capital Territory, Abuja.

NEST (1991) noted in a recent study of the effects of the thick black effluent from two breweries in Ikpoba River in Benin City an increase in pH; a decrease in dissolved oxygen; an increase in BOD; a massive increase in COD and an equally massive increase in total suspended solids all of which had adverse effects on the aquatic life. The same team noted that in the 1960s, Rivers Iya Alaro and Shahsa, which drains the Ikeja industrial estate, were used as recreation spots and as sources of water for domestic uses. Today, industrial effluents especially from textile mills, has turned their colour permanently bluish – green. The waters are also characterized by high pH, high level of sodium compound, and a high lead content. These changes, together with substantial heat pollution (the temperature of the effluent is sometimes as high as 50^0C) have made the water unattractive for recreation and definitely unsafe for domestic use. The vegetation on the edges of the rivers is dying off and there is no trace of fish life for some 3km downstream from the effluent discharge point.

FEPA (1991) published the effects of paper mill effluent on the River Niger and textile wastewater on the affected streams. The effect of the effluent on the River Niger was localized to a short stretch near the river band as reflected visually in the colouration of the water and chemically in increased settleable solid and dissolved solids. The character of the riverbed in the affected area must have been completely altered over the years

In Calabar, different researchers have carried out water quality analysis on different water bodies and water sources for different purposes. Ntekim *et. al.* (1993) reported high levels of heavy metals (Fe^{2+}, Cu^{2+}, Zn^{2+}) in the riverine sediments of the Calabar River. These facts were collaborated by Asuquo (1999) when researching on the physicochemical characteristics and anthropogenic pollution of the surface waters of the Calabar River.. These were attributed to the industrial activities within the area.

Researchers like Esu and Amah (1999) also observed a high level of quality degradation of the coastal waters in Calabar, which they attributed to poor wastes disposal systems, and increase in industrialization especially with the new status of Calabar as a Free Trade Zone in the country.

Moreover, Asuquo (2000) researched on the characteristics of rubber effluents and its impact on the water quality of the upper Calabar River. The investigation revealed marked changes in colour, NH_4 and turbidity which were above the WHO (1984) and FEPA (1989) permissible limits for inland waters. These observations were attributed to effluent discharged into the river from a nearby rubber factory of the Cross River Estates Limited (CREL) in Uyanga. The rubber effluents were characterized by high ionic content (conductivity, 3380 ± 1285.0 μscm^{-1}), moderate acidity (pH 5.0 – 6.4) and were totally devoid of dissolved oxygen (zero value). The poor quality of the effluent contributed significantly to the pollution load of the river.

Study Area

Figure 1 is the map of Odukpani L.G.A. showing the Pamol (Nigeria) Limited area of operation and figure 2 is the map of the study area showing sampling locations. The area under investigation is located off km 18 along Calabar-Ikom highway in Cross River State, between latitudes 5^0 05´ N and 5^0 08´ N and longitudes 8^0 18´E and 8^0 22´E, near Calabar, the Cross River State Capital.

A double maxima rainfall averaging 1830mm annually characterizes the area. Most of the original vegetation has been replaced by rubber trees. The detailed geology of the area has been described by Reyment (1965), Murat (1972), etc. to be part of the Niger Delta sedimentary basin. According to Edet (1993), the area has 'good to excellent aquifer rating' and CREBA (1982) gave the transmissivity value as varying between 202.9m2/day to 43300.5m2/day. The major inhabitants of the area are the employees of Pamol (Nigeria) Limited Company.

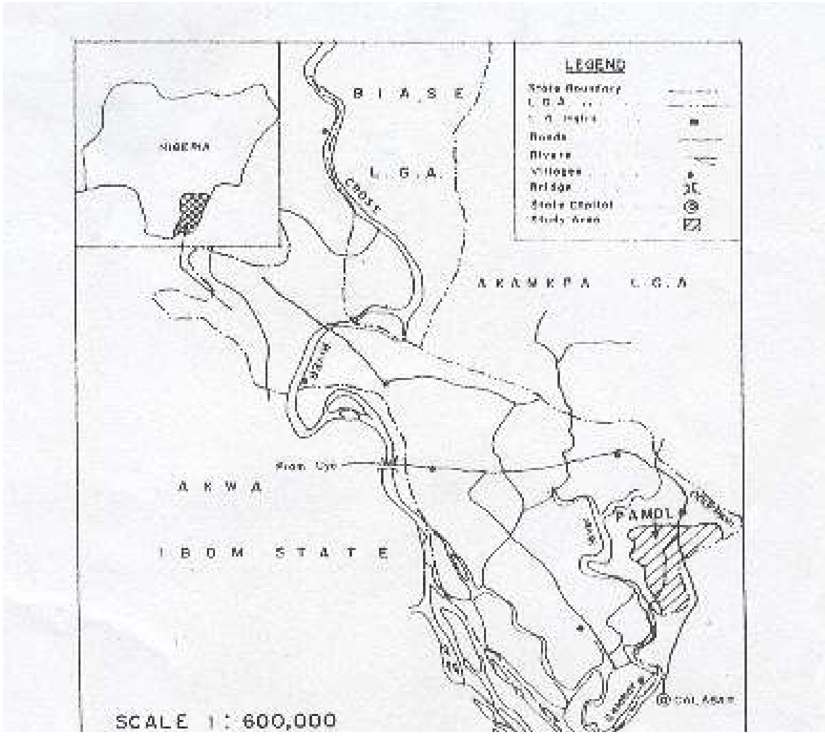


Figure 1 **Map of Odukpani L.G.A. showing the Pamol (Nigeria) LTD area**

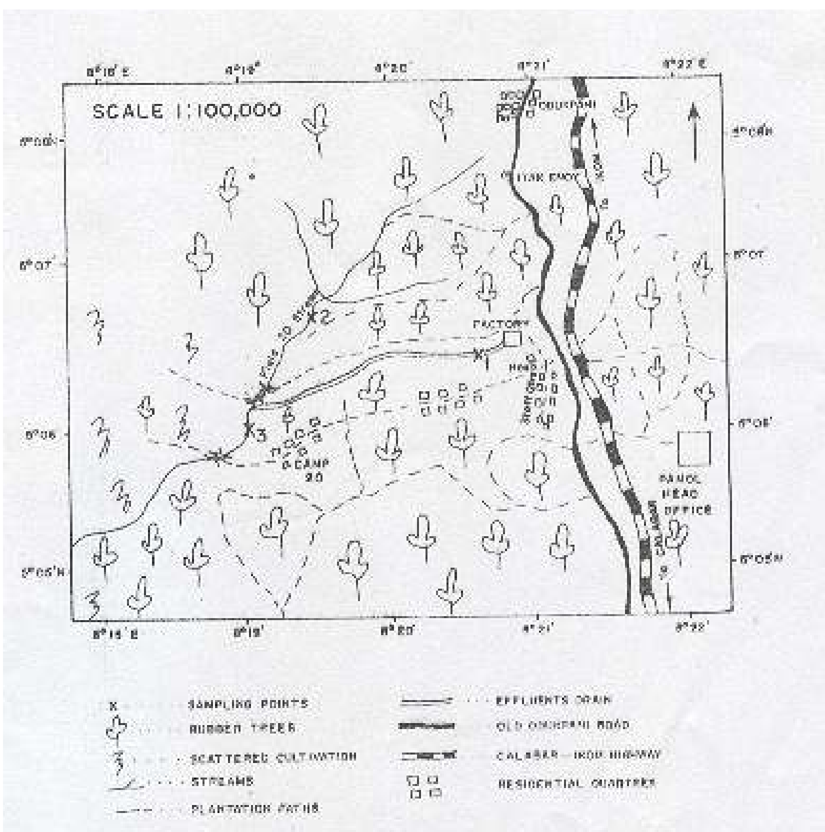


Figure 2 Map of the study area showing sampling locations

Method of Data Collection

Data collection involves the collection of 30 water samples at three (3) different points along the effluent drain and the Field 20 Stream as shown in fig. 2.

The three sampling stations were chosen for this study as follows:

Station 1 Effluent drain, 50m, away from the factory;

Station 2 1000m, upstream of the effluent discharge point;

Station 3 100m downstream of the effluent discharge point. (see Fig 2).

The global positioning system (GPS 12) was used to locate the sampling positions on the globe (See table 1). The "T" model sampling technique (Asuquo 2000) was adopted. The upstream station (Station 2) served as the control based on this model as the stream is unidirectional in the study area.

Eleven (11) water quality parameters were investigated during the study. Five (5) were investigated in-situ. They include temperature and specific conductance which were determined using the HACH conductivity meter, model 44600; potency of hydrogen (pH), using the pH meter, Lutron 201 model; dissolved oxygen (DO) using portable DO meter, model 5509; and turbidity using the secchi disc. The other six (6) water quality parameters: colour, total suspended solids (TSS), total dissolved solids (TDS), total hardness and biochemical oxygen demand (BOD) were determined as described by APHA (1989) and alkalinity, which followed titrimetry with 0.1M hydrochloric (HCl) acid. All laboratory analyses were performed at the Institute of Oceanography, University of Calabar, Nigeria.

Results and Discussion

Table 1 presents the range (minimum and maximum), mean and standard deviation values of the water quality parameters measured at the three (3) sampling stations with the sampling size.

From table 1, dissolved oxygen (DO) in the effluent samples (station 1) was as low as 1.7 $\pm$0.07 mgl^{-1} while those for stations 2 (the control) and 3 (downstream station) were 5.3$\pm$0.18 mgl^{-1} and 4.4$\pm$ 0.08 mgl^{-1} respectively. Dissolved oxygen is used to indicate the degree of pollution by organic matter. (Chapman and Kimstach 1992). The low dissolved oxygen status of the effluent affected the quality of the water downstream hence the reduction of the value of the DO from 5.3$\pm$ 0.18 mgl^{-1} at the control station to 4.4$\pm$ 0.08 mgl^{-1} at the downstream station (Fig 3.1). This value is also below the WHO (1984) minimum permissible limit (>5.0mgl^{-1}) of dissolved oxygen in water for domestic purposes.

The students' "t" test for dissolved oxygen between the control and the downstream station indicated significant differences at both 95 per cent and 90 per cent confidence level between the means of the two data sets (see table 2). Dissolved oxygen is essential to the respiratory metabolism of most aquatic organism. It affects the solubility and availability of nutrients, and therefore the productivity of aquatic ecosystem (Chapman and Kinstach, 1992). The measurement of dissolved oxygen can be used to indicate the degree of pollution by organic matter.

Table 1 Water quality data for the Field 20 stream at the indicated locations.

Parameter	Sampling size	Station 1: Effluent drain 50m away from the factory. GPS: N 05^{0} 06.387´ E008^{0} 20.646´		Station 2 (Field 20 Stream): 1000m, upstream of the effluent discharge point. (Control) GPS: N 05^{0}06.582´ E 008^{0}19.652´		Station 3 (Field 20 Stream): 100m, downstream of the effluent discharge point. GPS: N 05^{0}06.081´ E 008^{0}19.093´	
		Range	Mean & SD	Range	Mean & SD	Range	Mean & SD
Temperature ^{0}C	10	29.0-2.5	29.2 (0.12)*	29.3-29.5	29.4 (0.07)	29.5-29.7	29.6 (0.07)
Dissolved oxygen DO (mgl^{-1})	10	1.6-1.8	1.7 (0.07)	5.2-5.8	5.3 (0.18)	4.2-4.5	4.4 (0.08)
Turbidity (F.T.U)	10	67-70	68 (0.94)	3-5	4 (0.67)	18-21	19 (0.88)
Total Suspended Solids (TSS) mgl^{-1}	10	48-50	49.2 (0.79)	1-3	2(0.67)	10-12	11 (0.67)
Total dissolved Solid (TDS) mgl^{-1}	10	300-310	307.5 (2.84)	11.6-13.0	12.2 (0.36)	19.0-22.0	20.1 (0.86)
Biochemical oxygen demand (BOD) mgl^{-1}	10	1.4-1.6	1.5 (0.07)	0.4-0.6	0.6 (0.07)	0.7-0.9	0.8 (0.07)
Alkalinity (mgl^{-1})	10	180.0-210.0	199.0 (8.45)	15-25	20.0 (2.36)	15.0-25.0	20.0 (2.36)
Total hardness (mgl^{-1})	10	508.6-517.4	512.8 (3.21)	31.9-32.3	32 (0.12)	110.0-117.3	112.1 (2.13)
Potency of hydrogen (pH Units)	10	6.00-8.21	6.41 (0.64)	6.12-8.30	8.00 (0.63)	7.18-7.80	7.64 (0.18)
Apparent colour (Pt-Co)	10	500-520	510 (7.82)	41-44	42 (1.35)	147-150	148 (1.16)
Conductivity (µScm^{-1})	10	614.2-618.0	615.7 (1.18)	23.8-24.8	24.3 (0.3)	38.2-42	40.5 (1.00)

SD = Standard deviation
*Values in parenthesis are standard deviation

High levels of turbidity increase the total available surface area of solids in suspension upon which bacteria can grow. High turbidity can reduces light penetration and impair photosynthesis of submerged vegetation and algae. This in turn reduces plant growth and may suppress fish production. It also interferes with dis-infection of drinking water and is aesthetically unpleasant (Jain *et al.,* 1981; Chapman and Kinstach, 1992). The result of the investigation shows that turbidity was 68$\pm$ 0.94 F.T.U. in the effluent samples against 4$\pm$ 0.67 and 19$\pm$ 0.88 F.T.U. in the control and downstream samples respectively (Fig. 3.2). The high value of turbidity of the effluents was particularly because of the plastic-like material, resistant to decay released in the processing process. The Student's 't' test also showed significant differences at both 95 per cent and 90 percent confidence level between the means of the two data sets (Table 2).

The value of 19± 0.94 F.T.U. was of course higher than the WHO (1984) 5.0 F.T.U. permissible limits for inland waters.

Table 2: Showing the differences between the calculated t-values and the critical t-values for some measured water quality parameters between the control and the downstream.

Water quality Parameter	Pooled standard deviation	Calculated t-test values	Degree of freedom	Critical t-values* At 95%	At 90%
Dissolved oxygen	0.13	34.6	18	2.10	1.73
Turbidity	0.85	39.22	18	2.10	1.73
BOD	0.065	7.63	18	2.10	1.73
TDS	0.66	26.5	18	2.10	1.73
Colour	1.26	186.9	18	12.0	1.73

* Percentage points of the t-distribution from t-table.

The effect of the colour of the effluent on the stream was very clearly indicated. The effluent with a characteristics colour unit of 510± 7.82 Pt-Co units impacted the water and increased the colour from 42± 1.35 Pt-Co units at the control station to 148± 1.16 Pt- Co units at the downstream station (see also fig. 3.6). The maximum permissible unit of colour is 15Pt- Co units (WHO 1984), even though colour in natural waters could range from 0-300 Pt-Co units (Recourses Inventory Committee 1998). The case of Field 20 Stream in the study area is that of pollution from the effluent discharge by the nearby rubber factory. This is because the upstream sample recorded a value of 42±1.35 Pt-Co, which is also statistically different from that of the downstream (Table 2). Colour in regarded as a pollution problem in terms of aesthetics and increase colour may interfere with the passage of light, thereby impeding photosynthesis.

Potency of hydrogen (pH) ion concentration was 7.64± 0.18 units at the downstream station against 8.0± 0.63 units at the upstream (control station). This variation was attributed to the acidic effluents (6.41±0.64 units) indicating that the rubber factory is a source of organic pollution to the stream. The acidity is contributed by the quantity of the acetic and formic acids applied during acid coagulation of the rubber latex (Asuquo, 2000). This acidic effluent could be dangerous to the aquatic community.

Total suspended solids (TSS), total hardness and conductivity were all higher in the downstream samples than in the upstream ones as follows:

TSS was 11± 0.67 mgl^{-1} at the downstream station against 2± 0.67 mgl^{-1} at the upstream station (Fig. 3.3). TDS was 20.1± 0.86 mgl^{-1} at the downstream station against 12.2± 0.36 mgl^{-1} at the upstream station (Fig 3.5). Also total hardness was 112.1± 2.13 mgl^{-1} at the downstream station against 32±0.12 mgl^{-1} at the upstream station (Fig. 3.4), and conductivity was 40.5±1.00 μScm^{-1} at the downstream station against 24.3± 0.3 μScm^{-1} at the upstream station.

FIG: 3.1 Spatial trends in dissolved oxygen (DO) between sampling stations

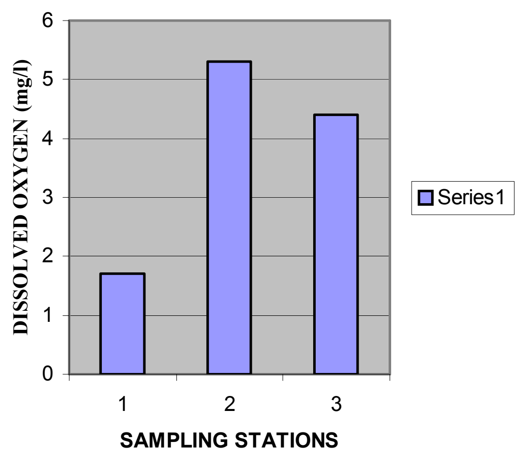


FIG. 3.2: Spatial trends in turbidity between sampling stations

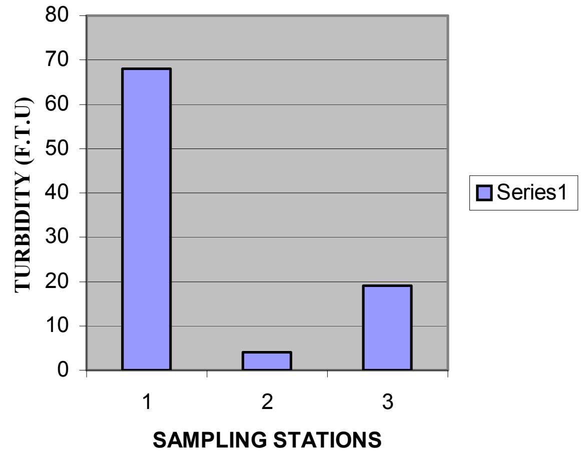


FIG. 3.3: Spatial trends in total suspended solids (TSS) between sampling stations

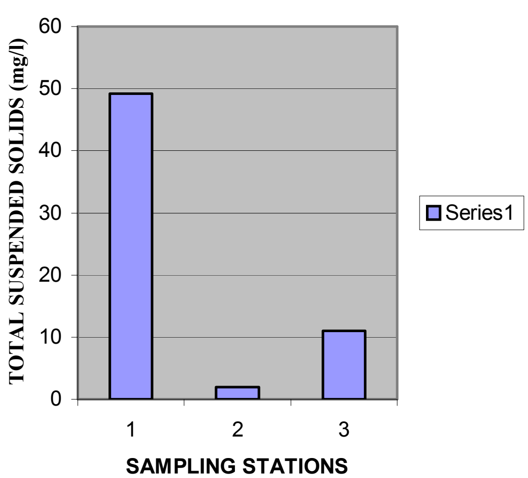


FIG. 3.4: Spatial trends in total hardness between sampling stations

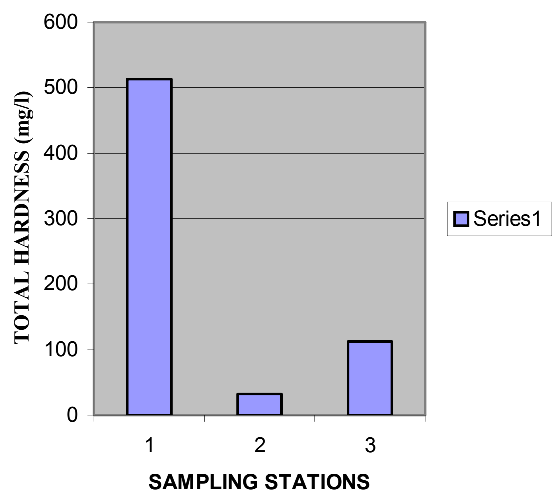


FIG. 3.5: Spatial trends in total dissolved solids (TDS) between sampling stations

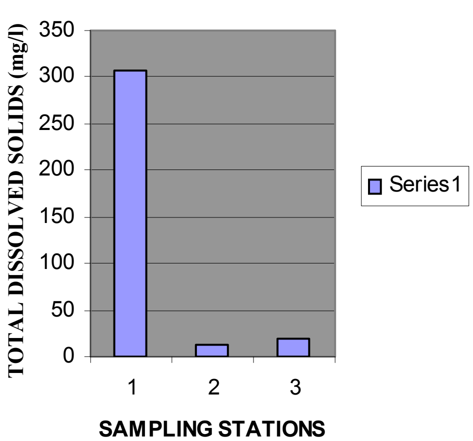
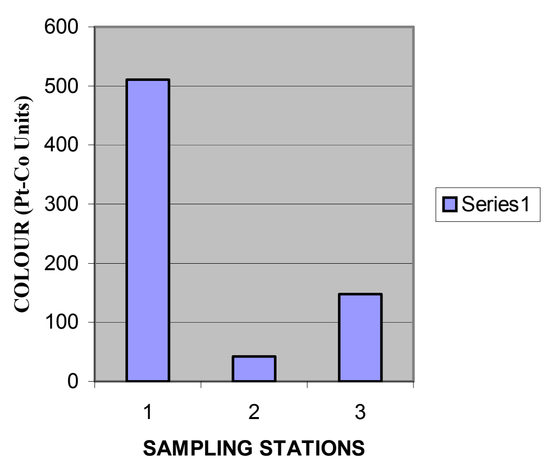


FIG. 3.6: Spatial trends in colour between sampling stations



All these variations were as the result of the reception of effluent discharges with the characteristics of 49.2 $\pm$ 0.79 mgl^{-1} of TSS; 307.5 $\pm$ 2.84 mgl^{-1} of TDS; 512.8$\pm$321 mgl^{-1} of total hardness and 615.7 $\pm$ 1.18 μScm^{-1} of conductivity.

The effluent discharged into the stream also slightly increased the BOD of the water from 0.6$\pm$ 0.07 mgl^{-1} at the control station to 0.8 $\pm$ 0.07 mgl^{-1}.

From the above findings and discussion it was observed that the Field 20 Stream in the Pamol (Nigeria) Limited Estate, Odukpani, Cross River State has been polluted. This pollution is due to the rubber processing effluents discharged into it by the rubber factory.

Conclusion

This study has revealed that the Field 20 Stream in Pamol (Nigeria) Limited Estate, Odukpani, Cross River State has been polluted by the effluents from the Pamol Rubber Factory. This has greatly affected the use of the water for domestic purposes by the local people. The turbidity was quite high and colourization and the odour unbearable. No doubt the aquatic life forms have been disturbed.

The control of this waste should begin with the decolourization of the highly coloured effluents, which is aesthetically unhealthy, and of great hindrance to biological productivity by aquatic plants. There should be a reduction and recycling of the acid used in the initial treatment process of the rubber latex. There is need (in the interim) to enlighten the people living around the area about the danger of using water from this stream for domestic purposes. There is also need for certification by regulatory agencies of the quality of the effluents discharged by Pamol into this stream. Moreover, there is need for Pamol (Nigeria) Limited to carry out a post-impact assessment of their factory on the project site.

References

Ajayi, S. O and Osibanjo, O. (1981). *Pollution Studies of Nigerian Rivers. II: Water Quality of Some Nigerian Rivers*. England: Environmental Pollution Series B. Applied Science Publishers, 87 – 95.

APHA (1989). *Standard Methods for the Examination of Water and Wastewater.* (7th Ed). Washington D. C: American Public Health Association, 1134.

Asuquo, F. Emile (1999). Physicochemical characteristics and Anthropogenic Pollution of the Surface Waters of Calabar River, Nigeria. Nigeria: *Global Journal of Pure and Applied Sciences*, Bachudo Science. 5 (4),595 – 600.

Asuquo, F. Emile (2000). Characteristics of Rubber Effluents and its Impact on the Water Quality of Upper Calabar River, Nigeria. *Tropical Journal of Environmental Research*. Greenlab. Intern. Scientific (GIS) Publishers. 2 (1&2), 136 – 145.

Chapman D. and Kimstach V. (1992). The Selection of Water Quality variables. In Deborah Chapman (Ed.), *Water Quality Assessments. A guide to the* *use of biota, sediments and water in Environmental Monitoring***.** London: Chapman and Hall, 51 – 117.

Cross River Basin Development Authority (1982). Inventory of Natural site condition – soil, slopes, hydrology, land use and vegetation throughout the area of operation of the Authority. *Progress Report. (4).*

Dauda, M. S. (1998). Quality Parameters of Some surface water samples from Federal Capital Territory (FCT), Abuja – Nigeria. ZUMA*: Journal of Pure and Applied Sciences. 1 (1),* 37 – 43.

Edet, A. E. (1993). *Hydrogeology of Parts of Cross River State. Evidences from Aerogoelogical and Surface Resistivity Studies*. Unpublished Ph. D Thesis, University of Calabar, Nigeria, 316.

Esu, E. O. and Amah, E. A. (1999). Physico – Chemical and Bacteriological Quality of Natural Waters in Parts of Akwa Ibom and Cross River States, Nigeria. Nigeria*: Global Journal of Pure and Applied Sciences,* Bachudo Science, 5 (4), 525 –534.

Federal Environmental Protection Agency – FEPA (1991). *Guidelines and Standards for Environmental Control in Nigeria*, Lagos.

Gardener, J. S. (1977). *Physical Geography*. New York: Harper's College Press, 166 – 167, 192 – 193.

GESAMP(Group of Experts on the Scientific aspects of Marine Pollution) (1988*). Report of the Eighteenth Session, Paris,* 1988. *GESAMP Reports and Studies 33,* United Nations Educational Scientific and Cultural Organization, Paris.

Imevbore, A. M. A. (1970). The Chemistry of River Niger in the Kaiji Reservior area*. Arch. Hydrobiol. 67,* 412 – 413.

Jain, R. K, Urban, L. V. and Stacey, G. S. (1981). *Environmental Impact Analysis. A New Dimension in Decision Making.* New York: Van Nostrand Reinhold.. 209 – 228.

Láng, István (1993). Environmental Management and Sustainable Development. In Nath, B., Hens, L. and Devuyst, D (Eds.),. *Environmental Management, Vol. 3. Instruments for Implementation* Brussels: VUB University Press

More, R. J. (1969). The Basin Hydrological Cycle. In: Chorley, R. J.(Eds.), *Water Earth and Man.* London: Maltuen, 67 – 76.

Murat, R. C. (1972). Stratigraphy and Paleogeography of the Cretaceous and Lower Tertiary in Southern Nigeria. In Dessauvagie, T. F. and Whiteman, A. (Eds.), *African Geology.* Ibadan: University of Ibadan Press, 251 – 266.

NEST (Nigerian Environmental Study / Action Team) (1991). *Nigeria's Threatened Environment. A National Profile.* Ibadan, pp.60 – 99.

Ntekim, E. E. U., Ekwere, S. J. and Ukpong, E. E. (1993). Heavy Metals Distribution in Sediments from the Calabar River, Southeastern Nigeria. *Environ. Geology 21*, 237 – 241.

Nyholm, N. (1992). Environmental Impact Assessment and Control of Marine Industrial Wastewater Discharges. *Water Science Technology.25 (11),* 449 –456.

Osibanjo Oladele (1996). Present Water Quality Status in Nigeria. In Aina, E. O. A. and Adedupe, N. O. (Eds.), *FEPA Monograph on Water Quality Monitoring and Environmental Status in Nigeria,* Abuja: FEPA.

Resources Inventory Committee (1998). *Guidelines for interpreting Water Quality Data in Province of British Columbia*, British Columbia

Reyment, R. A. (1965*). Aspects of Geology of Nigeria*. Ibadan: Ibadan Press, 122.

Webster, C. C. and Kwill, B. W. J. (1989). Rubber. *Tropical Agricultural Series.* Plenum Press.

WHO (1984). Guidelines for drinking water Quality. *Health criteria and supporting information*. Geneva: WHO, 62-315