

"CHARACTERISTICS OF RUBBER EFFLUENTS AND ITS IMPACT ON THE WATER QUALITY OF UPPER CALABAR RIVER, NIGERIA

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ABSTRACT

Water quality investigations of the upper Calabar river was conducted between November 1997 and July 1998. The study revealed marked changes occurring in color (96.3 ± 35.70 Pt Co units), NH_4^+ (3.4 ± 5.4 mg/l) and turbidity (15.7 ± 4.9 FTU) which were above WHO (1984) and FEPA (Federal Environmental Protection Agency, 1989) permissible limits for inland waters (15.0 Pt Co units, 0.5 mg/l and 5.0 FTU respectively). These observations were attributed to effluents discharged into the river from a nearby rubber factory. The rubber effluents were characterized by high ionic content (conductivity, 3380 ± 1285.0 $\mu\text{s/cm}$), moderate acidity (pH 5.0 – 6.4) have marked total hardness ($2164.3 - 2372.7$ mg/l as CaCO_3), high NO_3 (64.72 ± 16.5 mg/l), high SO_4 (1700 ± 263.0 mg/l) and were totally devoid of dissolved oxygen (zero value). The effluents also impacted the surrounding sediments as high levels of Mn (426.7 ± 179.5 ppm), Fe (790.8 ± 136.6 ppm) and Cu (4.5 ± 0.9 ppm) were measured during the investigation. The effluents were more concentrated and toxic in the Low Production Season, LPS (November – February) than the High Production Season, HPS (May – September), ascribed to the preferential sorption or higher uptake of drainage water by rubber trees for latex generation in the HPS. The poor quality of effluents contributed significantly ($P < 0.05$) to the pollution load of the river. Management procedures on the control of organic/inorganic pollution emanating from the factory are highlighted.

Key words: Effluent impacts, water quality, WHO/FEPA limits, heavy metals, effluent management, Calabar river, Nigeria

INTRODUCTION

Environmental pollution problems are a global issue due to the devastating effects of toxic pollutants on both non-living and living environments. Rubber latex production in similarity with most industrial

production, involves series of sequential processes that must be followed before the final materials or products are ready for the market. Tapped latex consists of a suspension of rubber particles in a liquid serum. The rubber portion (35.62%) contain substances like hydrocarbons, protein and phospholipids while the serum phase is mainly water (59.62%) with small amounts of soluble compounds including carbohydrates, amino acids, proteins, inorganic anions and metal ions (Webster & Kwill, 1989).

In Nigeria, the high production season (HPS) for rubber tapping lies between May and September which corresponds to the wet season, while the low production season (LPS) exist between November and February corresponding to the dry season. Processing of rubber into dry and ribbed smoke sheets involve acid washing with formic or acetic acid, drying and machining. No doubt, these processes leave behind toxic and concentrated aqueous solutions with high obnoxious odors. Several products are made from the natural rubber and these processes lead to pollution company if the effluents are not properly treated.

Industrial effluents constitute 95% of total waste discharged into the sea (Asuquo, 1998). The discharge of untreated rubber effluents to the river can cause outright damage to aquatic life and/or adversely affect the growth rate of both plants and animals. Poor industrial waste disposal practices can contribute significantly to the deterioration of both surface and ground water quality. Reports on water quality of some Nigerian rivers are available (Adebisi, 1981; Adeniji & Mbagwu, 1983; Ajayi & Osibanjo, 1981; Akpan, 1984; Asuquo, 1989, 1999). This investigation presents the results of the effect of rubber effluents discharged on the water quality of the Calabar river, the observed environmental problems and management methods for controlling such wastes in future.

METHODS:

Investigating the impact or effect of a particular outfall or discharge on the receiving system are difficult to design and carry out because of the small areas involved and the frequency with which changes in the effluent or outfall are expected to occur. For this report, five stations were chosen as follows: Station 1, Factory effluent pit; Station 2, Drainage channel; Station 3, Effluent discharge point, Station 4, 5km upstream and Station 5, 5km down stream of discharge point (Fig.1). The "T" Model sampling was adopted in order to access effectively the influence of the discharge on the upstream and downstream segments of the river (Fig.1). Invariably, the upstream location served as a control site since the river is unidirectional in the study area.

Water samples were collected monthly using steel bucket and sub-sampled into glass containers. Surface sediments from the factory waste pit (Station 1), Effluent Discharge point (Station 3), 5 km downstream (Station 4) and 5 km upstream (Station 5) were also collected with hand auger for heavy metal analysis. Water temperature, Dissolved oxygen and pH were measured insitu using portable DO and pH (WTW) meters. Conductivity was determined with HACH conductivity meter. All other parameters were determined as described by APHA (1989) except alkalinity, which followed titrimetry with 0.1M HCL. Chloride (Argentometric method with 0.1N AgNO₃ solution) and heavy metals (Cu, Mn, Fe) using Atomic Absorption Spectrophotometer after digestion of sediments in a mixture of 2:3 hydrochloric/perchloric acid solution (Forstner & Wittmann, 1983). Duplicate analyses were done to ensure reproducibility of results.

RESULTS:

The set of water quality parameters measured during the LPS and HPS are presented in Tables 1 and 2, while Table 3 shows the levels of Cu, Mn and Fe in the sediments contaminated by the rubber effluent discharge. Fig. 2a - d present the spatial trends of some measured parameters with marked differences between effluent (station 1) and water samples in LPS and HPS. Dissolved oxygen (DO) was totally absent in the effluent samples during both periods. DO levels in water varied from 4.9 - 6.6 mg/l in LPS and from 6.7 - 6.8 mg/l in the HPS. Conductivity in effluents dropped from 3380 μ S/cm to 76.7, 71.4 and < 38.8 μ S/cm during the LPS, HPS and at upstream locations respectively. Similarly, total dissolved solids (TDS), total hardness, nitrates, SO₄, salinity and TSS of effluents decreased to lower levels during both periods. On the other hand the magnitude of color (3300 and 2020 Pt Co Units) in effluents changed to 96.3 and 93.7 Pt Co units, turbidity from 320 and 260 FTU to 15.7 and 22.6 FTU in water, while ammonium concentrations varied from 191.1 and 224 mg/l in effluents to 3.4 and 1.53 in water for LPS and HPS respectively. The observed changes in color, turbidity and ammonium concentrations were above the WHO (1984) permissible limits of 15.0 Pt Co units, 5.0 FTU and 0.5 mg/l.

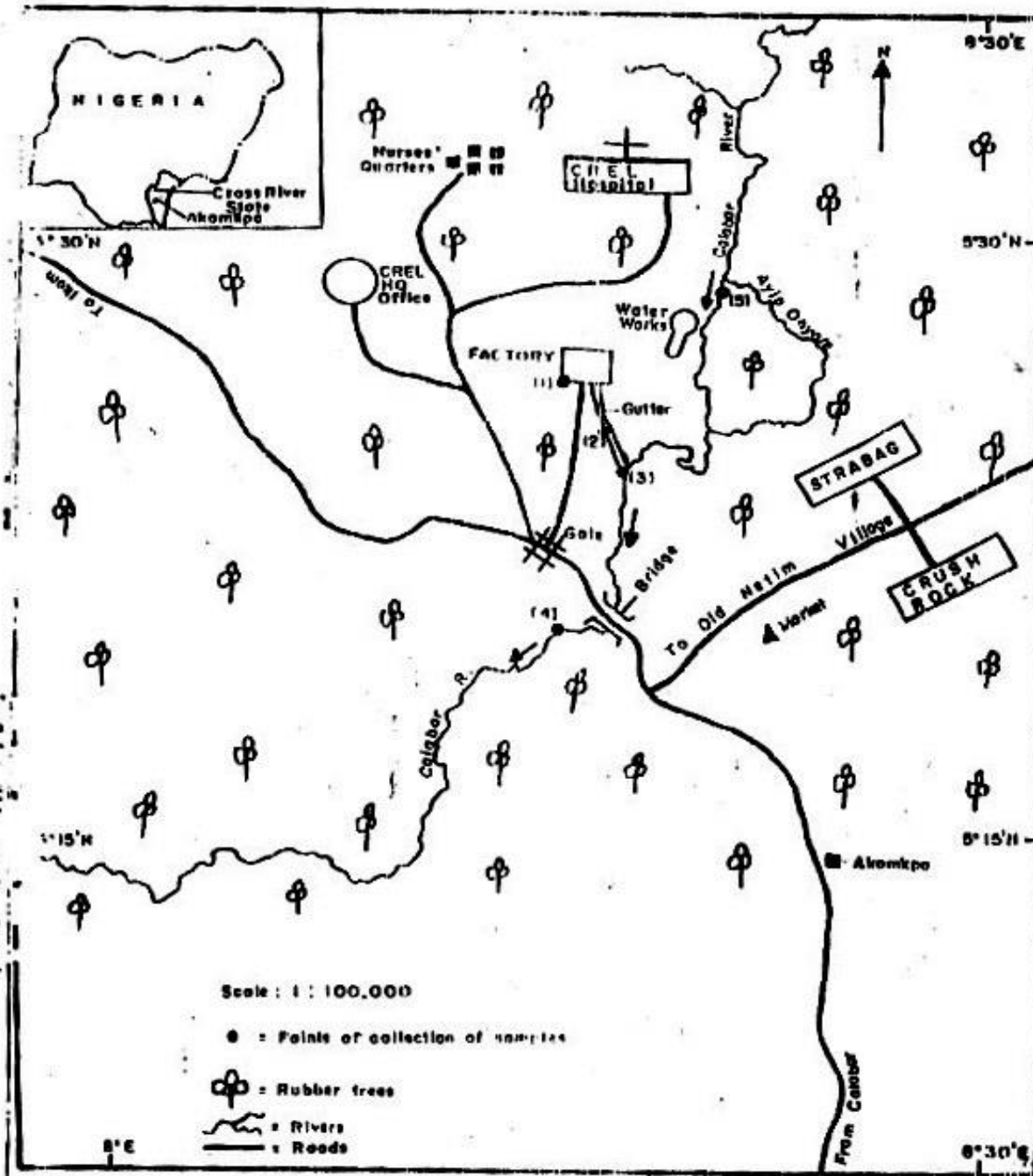


Fig. 1 . Map of the study area showing sampling locations.

DISCUSSION

Changes in water quality are expected to deviate from normal levels whenever an aquatic system receives effluent discharge from an outfall. Such changes can be very significant if the effluents were discharged raw or untreated. In Fig. 2 a - d, there is a drastic drop in the levels of color, turbidity, conductivity and ammonium during the period. It is observed that while color and turbidity were high in the LPS, conductivity and ammonium levels were low and when conductivity and ammonium were high in the HPS, color and turbidity were low in the HPS. Generally, the raw effluents contained relatively high concentrations of measured parameters (Fig. 2, Station 1). The BOD₅ distributions indicate that levels were lower in the LPS

TABLE 1: Comparison of water quality of effluents and river with WHO (1984) and FEPA (1989) limits. (Low season)

Parameters	Effluent	Water	Control 5 km	WHO (1984)	FEPA (1989)
Temp. °C	33(2.4)*	30.7(1.2)	33(2.0)	25	30-35
DO mg/l	0	6.4(1.3)	4.9(0.6)	>5.0	NL
pH	5.0(0.4)	6.5(0.2)	6.9(0.2)	6.5 - 8.5	6.5 - 8.5
Conductivity µS/cm	3,380(1285)	76.73(57)	38.7(0.1)	2000	4000
TDS mg/l	1,690(1125)	38.0(28.6)	19.3(0.1)	1000	NL
TSS mg/l	320(128.0)	14.7(3.1)	12(0.1)	-	30
Color Pt Co	3300(1341)	96.3(35.70)	72(20.6)	15.0	NL
Turbidity FTU	320(80.7)	15.7 (4.9)	8.0(0.3)	5.0	NL
Tot. hardness mg/l	2,372.7(105)	31.01(13.0)	22.5(10)	500	NL
NO ₃ mg/l	64.72(16.5)	0.64(0.34)	0.53(0.2)	45.0	NL
NH ₄ mg/l	191.12(63.0)	3.4(5.4)	0.45(0.01)	0.5	NL
NO ₂ mg/l	0	0	0	0.1	NL
SiO ₂ mg/l	21.1(8.1)	141.44(0.4)	1.47	-	NL
SO ₄ mg/l	1,700(-263)	3.6(3.7)	1.1(0.1)	400	NL
PO ₄ mg/l	106.2(0.85)	0.92(1.6)	0.01(0.01)	-	NL
Cl mg/l	1,215.7(101)	27.6(20.4)	14.20(6.7)	250	600
Salinity mg/l	1,319.0(148)	29.95(7.6)	15.41(4.2)	-	600**
Ca ²⁺ mg/l	448.9(148.0)	9.6(3.2)	3.2(0.01)	100	NL
Mg ²⁺ mg/l	469.4(148.0)	5.21(3.3)	4.7(2.1)	50	NL
Total Alk mg/l	100(20.2)	46.7(115)	40(8.6)	-	NL
BOD ₅	0	0	0	0	10

* Standard Deviation values are in parentheses

** Salinity as Chloride

NL - No limit

TABLE 2: Comparison of effluent and water quality parameters with WHO (1984) and FEPA (1989) limits. (High Season)

Parameters	Effluent	Water	Control	WHO (1984)	FEPA (1989)
Temp. °C	31(1.6)*	27.3(1.3)	26(0.8)	25	30-35
DO mg/l	0	7.27(2.3)	4.7(0.5)	-	NL
pH	6.4(0.05)	6.7(0.1)	6.8(0.1)	6.5 - 8.5	6.5 - 8.5
Conductivity µS/cm	20,300(118)	71,4 (88)	30.1(19.8)	2000	4000
TDS mg/l	10,180(142)	28.1(30.1)	15(2.6)	1000	NL
TSS mg/l	260(54.1)	13.3(1.5)	12(0.4)	-	30
Color Pt Co	2,020(189.0)	93.7(335)	65(16.1)	15.0	NL
Turbidity FTU	260(15.6)	9(2.6)	6(0.5)	5.0	NL
Tot. hardness mg/l	2,164.3(174.1)	22.6(9.9)	19.2492.9	500	NL
NO ₃ mg/l	13.1(2.5)	1.0(0.16)	1.0(0.4)	45.0	NL
NH ₄ mg/l	224(48)	1.53(2.2)	0.18(0.02)	0.5	NL
NO ₂ mg/l	0	0	0	0.1	NL
SiO ₂ mg/l	13.1(2.8)	0.9(0.2)	1.0(0.02)	-	NL
SO ₄ mg/l	1,022(96.5)	2.76(3.0)	1.47(1.3)	400	NL
PO ₄ mg/l	27.1(0.5)	0.035(0.04)	0.01(0.01)	-	NL
Cl mg/l	7,302(244)	20.3(22.2)	10.64(2.8)	250	600
Salinity mg/l	7,922.7(5841)	22.03(23.1)	11.54(1.6)	-	600**
Ca ²⁺ mg/l	108.2(44)	12.3(6.7)	2.4(0.6)	100	NL
Mg ²⁺ mg/l	501.6(70)	2.48(2.9)	4.10(1.6)	50	NL
Total Alk mg/l.	0	25.0(0.2)	25(0.5)	-	NL
BOD	0	0	0	0	10

* Standard Deviation values are in parentheses

** Salinity as Chloride

NL - No limit

TABLE 3: Levels of Cu, Mn and Fe in the rubber effluents and sediments

Parameters	LPS		HPS		FEPA (1989)
	Effluent*	Sediment**	Effluent*	Sediment**	
Cu (ppm)	5.2 ±0.1	3.9 ±0.8	6.2 ±0.3	4.5 ±0.9	1.5
Mn (ppm)	930 ±230	426.7 ±179.5	980 ±410	537 ±221	NL
Fe (ppm)	1194.8±640	742.6 ±205.3	1289.6 ±623	790.8 ±136.6	20

* sediments from waste pit

** sediments from stations 3 and 4

LPS = Low Production Season . HPS = High Production Season .

(3.5 ± 2.4 mg/l) than the HPS 3.9 ± 2.9 mg/l). Low BOD values with a corresponding high DO concentrations indicate that the effluents contain very low amount of biodegradable material . In order words, the coagulants composition were mostly of plastic-like material resistant to decay and decomposition by aquatic microbial community. The Calabar River has been reported to have turbidities lower than 12 FTU (Asuquo, 1999). Increased turbidity is attributed to the rubber effluent discharge. High turbidity as observed during the investigation can be particularly dangerous to the aquatic fauna. Apart from increasing the particulate load of the river, enhanced turbidity can cause the smothering of fish eggs during breeding periods (Asuquo, 1997). Additionally, high turbidity can clogg the gills of fish, hinder respiration and photosynthetic activities of aquatic living forms.

Variation in pH occurred between the effluent and water samples. The acidic effluents (pH 5.0 - 6.4 units) have indicated that the rubber factory is a source of severe organic pollution to the Calabar river. The acidity is contributed by the quantity of formic and acetic acids applied during acid coagulation of the rubber latex. The effectiveness of the acid application is evident in the huge amount of coagulated materials produced as particulates during the primary treatment process. These could be very detrimental to fish population.

All conductivity movements in effluents were markedly higher than those of the water samples. The increased ionic content of the effluent is attributed to the conversion of the rubber latex into dry (smoked) rubber which involves a series of processing steps. The very high levels of major ions (Chlorides, 7302 mg/l in HPS; SO_4 , 1700 mg/l in LPS; Ca, 448.9 mg/l in LPS and Mg, 501.6 mg/l in HPS) could cause a significant alteration in the ionic stability of the fresh water system. These on a sustained basis may lead to destruction of benthic species and may result in the migration of motile species from the area of impact to less impacted areas thereby contributing to low fish catch by fishermen. Also induced saline environment can alter the physiological activity of fish such as increased dehydration rate – resulting in environmental stress and subsequent death of fish.

Particulate concentrations were relatively higher in the effluents than the water samples. Large amounts of particulates in the effluent were mainly rubber particles from the acid coagulation process. These were easily perceptible but most often than not form a colloidal solution. They contribute to increase turbidity and a highly colored effluent observed. The high particulate concentrations in the effluent did not seem to have effect on the concentration of oxygen in the river water . This suggest that most of the particulates are non-biodegradable and could not be oxidised by micro-organisms in the river system. The non-biodegradable (particulate rubber) could contribute significantly to food poisoning through the consumption of contaminated fish. This is possible since fish species can ingest particulates as food (Horn *et al* ,1970, Asuquo, 1997).

Measurements of the degree of hardness (total hardness) showed marked deviation between the effluent stream and the river water. The presence of calcium and magnesium contributed significantly ($P < 0.05$) to the effluent hardness. The assimilative capacity of the river for self-purification seem to depress the effect of hardness on the receiving water. This is evident at 5km down stream, where normal levels of Ca and Mg were measured during the period. High nutrient (NH_4 , NO_3 , PO_4 , SiO_2) levels in the effluents were observed (Fig 2d, 3a-d). This suggest that the raw effluent could be a source of nutrient loading to the river, particularly the N and silicon nutrients. There is an immediate uptake of nutrients by the river microbial biomass as depicted by a significant ($P < 0.05$) decrease in nutrient concentrations of water samples collected 5km downstream.

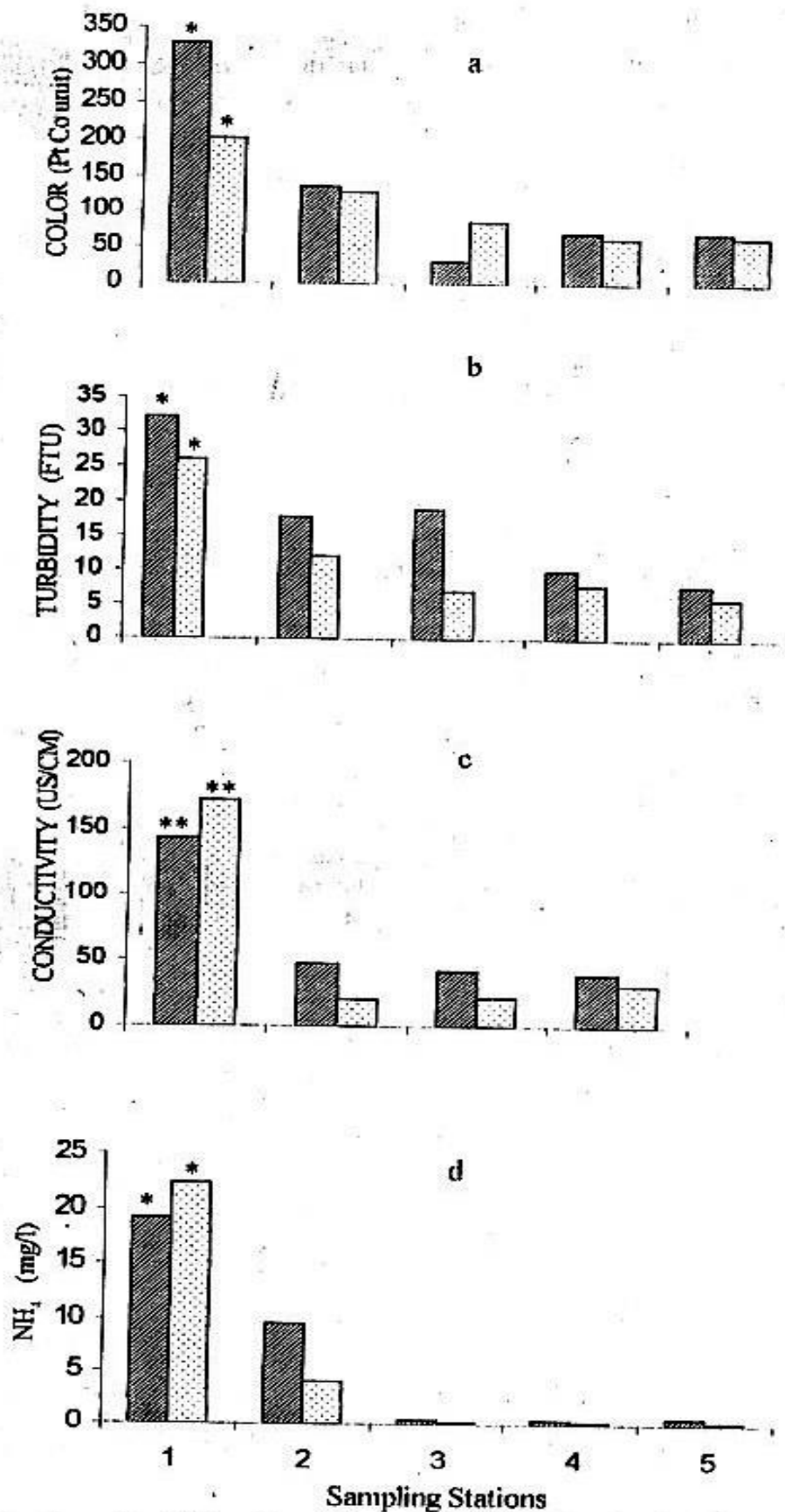


Fig. 2a - d Spatial trends of Color, Turbidity, Conductivity and Ammonium showing marked differences between effluent (station) and water samples in Low Production (LPS) and High Production Season (HPS)
 * = effluent value x 10. ** = effluent value x 100
 Station 1 - Factory waste pit (raw effluent). Station 2 - concretized channel
 Station 3 - Effluent Discharge Point (EDP). Station 4 - 5 km downstream
 Station 5 - 5 km upstream (control station)

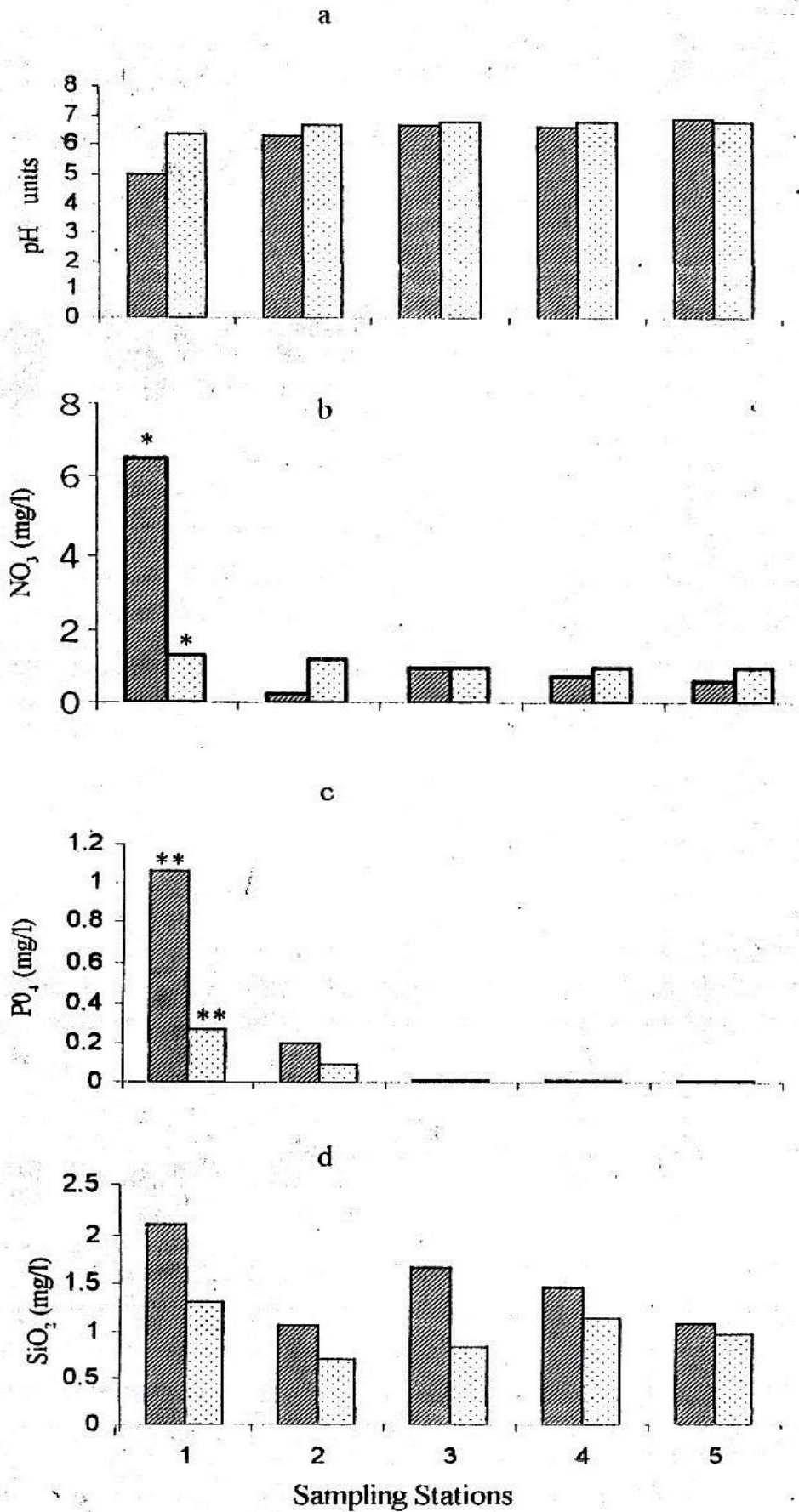


Fig. 3a - d Spatial trends of pH, NO₃⁻, PO₄⁻ and SiO₂ showing marked differences between effluent (station) and water samples in Low Production Season (LPS) and High Production Season (HPS)

* = effluent value x 10. ** = effluent value x 100

(Station 4). Information is required on the uptake of each of the primary nutrients (N, P and silica in case of diatoms) that could be used for generating predictive models of nutrient uptake for the contaminated system. Nutrient availability suggests a positive impact on the environment due to the effluent discharge provided it is intermittently released into the river. On the other hand, high ammonium levels are undesirable in aquatic systems as it can strongly inhibit the uptake of nitrate by phytoplankton (Dugdale *et al.* 1970).

The concentrations of toxic metals especially Cu, Mn and Fe were markedly higher in the sediments from the waste pit than sediment samples from the river. Although Cu levels were lower than the other metals, the observed concentrations suggest contribution from the effluent discharge. The measured concentrations were above Federal Environmental Protection Agency (FEPA) (now Federal Ministry of Environment) limits of 20 and 1.5 ppm for Fe and Cu in inland waters respectively. The remarkably high levels of Fe >600 ppm and Mn > 400ppm are indicative of a polluted environment arising from the effluent discharge. Accumulation of heavy metals in biological tissues is dangerous to man and other organisms. High doses could result in acute toxicity and for Cu may cause severe mucosal irritation, intestinal cramps, depression and narcotic changes in liver and kidney (WHO, 1984).

The Calabar River at the upper reaches is characterized by intermittent rocky outcrops. The drastic reduction in concentration of the effluent parameters is enhanced by the river flow (current speed 5 - 24 cm/sec, Asuquo, 1999) vis-à-vis its ability to transport and disperse pollutants. In other words, inputs of fresh water from upstream seem to counteract the effect of discharges due to efficient mixing of the fresh water with effluent stream thereby lowering the levels of the pollutants in water compared to the concentration in the effluents. The dilution effect is more pronounced in the HPS when there is increased fresh water discharge due to additions from surface run-off and inland drainage.

CONCLUSION

Presently, the aquatic environments of most developed and developing countries are constantly being impinged by considerable outflow from industrial wastes. Regrettably, some industries carry out only primary and secondary treatments of their produce waters (effluents) without recourse to tertiary while most do not treat the effluents at all before discharge into the aquatic systems.

This investigation showed that the effluent stream from the rubber factory was acidic and highly ionic in nature. It contained high amounts of non-degradable matter (plastic-like materials), high Fe and Mn concentrations, highly colored and turbid with high nutrient concentrations. Such discharges could have serious impact on the river water quality in addition to the metals being bioaccumulated by fish and shellfish (eg *Typanotonus* sp, *Portunus* sp etc) found in the precincts of the industry.

The control of wastes from the rubber factory should start with the reduction of the organic load of effluents in sedimentation tanks. Decolorizing process should form the main stream of the treatment process. A dark coloured effluents greatly hinders biological production by aquatic plants. Toxic metals must be removed by passing effluent stream through anionic resin beds for metal adsorption before discharge. The release of produce waters into the aquatic systems should be first certified by regulatory agencies located in the city or area. By this approach, the quality of waste discharged can be ensured or guaranteed.

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