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Concentration level of phosphate and nitrate in Ikpoba River of Edo State, Nigeria

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Water is vital to the existence of all living organisms, but its value is increasingly being threatened as human populations grow and demand more water of high quality for various activities. This has led to water deterioration in quality and quantity for consumption by humans and has also impacted in the aquatic ecosystem. The aim of this paper is to access the vulnerability of Ikpoba River to eutrophication through the determination of phosphate and nitrate concentration. Eighteen water samples were collected from six stations in triplicate at an interval of two weeks throughout the duration of sampling. Temperature, pH, and conductivity were recorded in-situ and there was significant difference between nitrate and phosphate concentration together with majority of the other parameters recorded at the various stations. Comparison of results obtained from this study with those of other studies indicated that increased concentration of nitrate and phosphate in Ikpoba River are probably caused by discharge of pollution load from Guinness Nigerian Brewery's domestic sewage, agriculture, and slaughter house which have further accelerated the occurrence of eutrophication.

Key words: Eutrophication, nutrients, phosphate, nitrate.

INTRODUCTION

Water is vital to the existence of all living organisms; however, of all renewable resources of planet, water has the unique place. It is essential for sustaining all forms of life, food production, economic development and for general well-being. But this valued resource is increasingly being threatened as human populations grow and demand more water of high quality for domestic purposes and economic activities which leads to deterioration in water quality and quantity that impact not only the aquatic ecosystem, but also the availability of safe water for human consumption (Carr and Neary, 2008).

Three-quarter of the earth surface is covered by water which exists as surface and ground water. While surface water is the one seen on the surface of the earth (e.g. rivers, lakes and streams etc.), the one beneath the surface of earth is referred to as ground water (e.g borehole, well and aquifers water). 97% of the world's water is found in the ocean, with only 2.5% of the world's water being non-saline or non-salty. However, while 75% of all fresh water is bound up in glaciers and ice caps, only1% of fresh water is found in rivers, lakes and soils; the remaining 24% is present as ground water (Radojevik and Bashkin, 1998).

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Water is said to be polluted when pollutants are discharged directly or indirectly into water bodies (e.g. lakes, rivers, oceans and groundwater) without adequate treatment to remove harmful compounds (Carr and Neary, 2008). A water pollutant is any biological, physical or chemical substance present at excessive levels capable of causing harm to living organisms, including man (Radojevik and Bashkin, 1998). When a water body is polluted it affects plants and organisms living in it. In almost all cases the effect is damaging not only to individual species and populations, but also to the natural biological communities.

Historically, water pollution was not a major problem until large centres of human population developed. Rivers and seas have their own self-purification ability, but water pollution becomes a problem when it exceeds the self-purification capacity of a water body (Radojevik and Bashkin, 1998). Water pollution can be a serious health hazard to the ecosystem and humans that come in contact with it through drinking, washing or swimming in polluted water or through food chain.

The health of rivers and their biological diversity are directly related to health of almost every component of the ecosystem (Ramesh et al., 2007). In freshwater bodies, nutrients play a major role as their excesses lead to eutrophication. Phosphorus and nitrogen are nutrients that are essential for aquatic plant and algae growth. Most waters naturally contain enough of these nutrients to support native aquatic life. However, an over-abundance of these nutrients can over-stimulate plant and algae growth such that they create water quality problems. Monitoring of water quality is the first step that can lead to management and conservation of aquatic ecosystems. It is also true that the management of any aquatic ecosystem is aimed at the conservation of its habitat by suitably maintaining the physico-chemical quality of water within acceptable levels.

Industrial wastes and domestic sewage are the major urban sources of nutrient overload, responsible for 50% of the total amount of phosphorus unloaded into lakes from human settlements (Smith et al., 1999.). Other sources that contribute to cultural eutrophication include the use of fertilizers, faulty septic systems, and erosion into the lake. Industrial agriculture, with its reliance on phosphate-rich fertilizers, is the primary source of excess phosphorus responsible for degrading rivers and lakes (Carpenter, 2008).

The routine application of chemical fertilizers and phosphorus-laden manure has resulted in the gradual accumulation of phosphorus in soil, which washes into lakes of the watershed where it is applied. On a global basis, researchers have demonstrated a strong correlation between total phosphorus inputs and algal biomass in lakes (Anderson et al., 2002). Since 1950, phosphorus inputs to the environment have been increasing as the use of phosphate-containing fertilizer, manure, and laundry detergent has become more common (Litke, 1999). Consequently, humans release 75% more phosphorus to the soil than would be naturally deposited by weathering of rock (Bennet et al., 2001). Even increases in minute amounts of the nutrient can stimulate tremendous growth and productivity (Addy and Green, 1996). According to an estimate, 400 g of phosphates could potentially induce an algal bloom to about 350 tons (Sharma, 2009). Therefore, this study was aimed at monitoring the nitrate and phosphate levels in Ikpoba River, Edo State to keep a check on 'eutrophic' conditions. In identifying sources of eutrophication, studies have shown that, if too much phosphate is present in the water body, algae and weeds will grow rapidly, thereby choking the waterway, and using up large amounts of precious oxygen which may result to the death of many fish and aquatic organisms.

METHODOLOGY

Study area

This study was conducted in Ikpoba River, which originates from Ishan plateau and flows through Benin City within latitudes 6.5°N and longitude 5.8°E situated in the rainforest belt of Edo State, southern Nigeria. The climate of Benin City is tropical with two major seasons: Wet (April - October) and Dry (November - March). Rainfall is bimodal, with peak usually observed in July and September, and a brief stop in August. The mean annual rainfall is 2,300 mm, while the average temperature is 32°C. The mean relative humidity is about 70%. The ancient city is urban and had witnessed an overwhelming influx of people from the rural areas in the last decades thereby resulting in a tremendous increase in population of about 1,147,188 (National Population Commission (NPC), 2006). There are two brewery factories, furniture factories, small-scale pharmaceutical production factories, petroleum storage depot and oil pipeline, art metal workshops, motor spare parts shop and colour photo laboratories.

The river is dendritic in the upper reaches with significant domestic, industrial and agricultural wastes accumulating in the river through flood run-off water.

Sampling

The water samples were collected in triplicates at two weeks intervals from five stations of Ikpoba River from May 2013 – January 2014. Plastic, glass and amber bottles were respectively used to collect samples for nutrients, dissolved oxygen and BOD determination. The bottles were rinsed with surface water, dipped into the river and after being filled, were capped tightly inside the river water itself. Sampling bottles were kept in a cooler filled with ice blocks and transported to the laboratory for further analysis. Water temperature was measured in-situ using mercury-in-glass thermometer. Hydrogen-ion concentration (pH) and conductivity of the water sample was measured in-situ, using a multiple meter, model U-10 micro (Horiba limited, Japan). Dissolved oxygen in the water was fixed during the sample collection, by the addition of 1 ml of Manganese Sulphate (Winkler's solution I) and another 1 ml of Potassium iodide - Sodium Hydroxide (Winkler's solution II) was added to the sampling bottle using a syringe. The bottle was closed and thoroughly shaken to ensure proper mixing. Consequently, a brown precipitate was formed at the bottom of the bottle. Thereafter, the bottle was transported to the laboratory for further analysis.

Water analysis

Phosphate and nitrate content of the water samples was estimated spectrophotometrically using ALPA 4500 method.

Quality assurance / Quality control

1) Nutrients analyses (e.g. nitrogen and phosphorus) were promptly carried out after sampling to prevent metabolic conversion of the components which would lead to unrepresentative results if analysis was delayed.
2) Samples were stored in a refrigerator at 4°C before analyses were carried out, which further slowed down bacterial and chemical reactions.
3) The UV spectrophotometer was calibrated before readings were taken.
4) Precautions was taken to prevent contamination of the sample and to ensure the concentration of the substance being determined do not change between sampling and analysis, by capping the bottles tightly inside the river water and placing them in a cooler filled with ice blocks and transported to the laboratory for experimentations.

RESULTS AND DISCUSSION

From Appendix Table 1 and Figure 1, the pH range of Ikpoba River is between 6.17 - 6.5, which falls within WHO and Nigerian drinking water standard (6.5 - 8.5) except for Station 5 with an average pH of 6.17. The observed pH range is lower than the lowest range and higher than the highest range earlier observed and reported by Bello-Osagie and Omoruyi (2012) in the same river (6.35 - 7.05). The temperature of the water samples from all the sampling points ranged from 27 to 30°C, and there was statistical significant difference at $p<0.05$ among locations. The water temperatures are similar to those reported in Otamiri River, Owerri, Imo State (Akubugwo and Duru, 2011).

Total dissolved solid ranges from 6.67 - 17.83 mg/l in Ikpoba River with Station 5 having the highest TDS. From literature, the value of electrical conductivity increases with increase in the amount of total dissolved solids (TDS) that are present (Macgill Environmental Research Laboratory (MERL), 2006; Ademoroti, 1996) and this is reflected by Station 5 of Ikpoba River having the highest electrical conductivity of 35.83 µS/cm. Total dissolved solid is a measure of inorganic salts, organic matter and other dissolved materials in water. Changes in TDS levels in natural water often result from industrial effluent or salt-water intrusion.

The values for total suspended solid (TSS) observed ranged between 13.67 - 26.50 mg/l, and these values are lower than those reported on River Benue (12.55 - 49.57 mg/l) by Anhwange et al. (2012). Turbidity ranged from 2.33 – 5.83 mg/l, which does exceed the WHO and Nigerian drinking water standard of 5 mg/l only at Station 5. The highest TSS value (26.50 mg/l) was also recorded at Station 5 which have the highest turbidity value of 5.83, because the greater the amount of suspended solids in water the higher the measured turbidity. The higher TSS at these points may be due to the continuous discharge of effluents from the Brewery industry and the abattoir which carries many materials from the upper land into the river. Also, there was significant difference among stations at $p<0.05$.

The average phosphate range in Ikpoba River for this study is from 0.01 - 0.20 mg/l, which is lower than the values (0.28 – 3.52 mg/l) reported for Osse River by Omoigberale and Ogbeibu (2007). High phosphate values at Stations 3 and 5 may be due to wastes emanating from homes, abattoir, cars and motorcycles washing activities. From literature, phosphates concentration range of 0.029 - 0.245 mgl $^{-1}$ and nitrate concentration range of 1.38 – 2.9 mgl^{-1} are in sufficient quantities for the growth of algal blooms (Kaur and Singh, 2012); thus, algae blooms may not likely occur in both rivers based on this but with time it may occur when the concentration is increased. Station 5 of Ikpoba River with phosphate concentration of 0.2 mg/l had visible algae bloom but the phosphate was not the highest; and this can be explained by the fact that we do not expect to find a high phosphate reading if the algae are already blooming, as the phosphates will already be in the algae, not in the water. The recommended maximum level of phosphate for rivers and streams had been reported as 0.1 mg/l, while 0.025 mg/l is found to accelerate eutrophication process in rivers and lakes (EPA, 1983).

The average concentration for nitrate ranges from 0.50 - 0.67 mg/l in Ikpoba River with Station 5 having the highest nitrate concentration of 0.67 mg/l. Rodhe (1969) suggested that phosphate concentration in excess of 0.015 mg/l and nitrate concentrations above 0.3 mg/l are sufficient to cause algal blooms and thus algae bloom can occur in Ikpoba River. This higher concentration of nitrate can be attributed to industrialization and the discharge of household wastes as well as discharge of fertilizers and pesticides into the rivers during agricultural activities. A higher value of 3.80 mg/l was reported in Ogun River by Jaji et al. (2007) and this observed high concentration of nitrate was as a result of human activities. Human activities observed along the study area include agricultural landuse, anthropogenic activities such as improper disposal of human wastes and industrialization. Farming operations around the area were said to have contributed immensely to elevated values of ammonia and phosphate (Akubugwo and Duru, 2011).

From Appendix Table 1, the average values for dissolved oxygen (DO) in all stations are low, and Station 5 recorded the lowest (4.67 mg/l). These low concentrations of dissolved oxygen in Ikpoba River may be attributed to the discharges of domestic and effluents containing reduction agents. When the DO concentrations of this study was compared with those obtained from the study reported in Otamiri River, Owerri, Imo State (12.59 mg L^{-1}), it was found to be less.

Among the five sample sites examined for this study, only Station 5 showed dissolved oxygen concentrations below the value established by the WHO drinking water standards of 5 mg/l. The low concentration of dissolved oxygen (4.67 mg/l) at Station 5 in Ikpoba River can be explained by the fact that this sample was collected close to a brewery industry. In Stations 1 and 4 of Ikpoba River, the cattle manure, waste water from slaughter house as well as vegetal material degradation could be the sink of the dissolved oxygen. Impact of continual discharge of wastes from such kind of industry on the water quality has also been investigated in the Ikpoba River, Nigeria (Benka-Coker and Ojior, 1995). The authors reported that the DO content of the receiving river water dropped from 7.2 to about 2.4 mg/l on mixing with slaughter house waste water. The reduction in the dissolved oxygen value can be attributed mainly to the presence of high divalent iron concentrations, which were present in the stream water contaminated with industrial effluents. The oxidation to iron (III) is obtained with consumption of oxygen dissolved in the water.

Biochemical oxygen demand (BOD) is a measure of the quantity of oxygen used by micro-organisms (e.g., aerobic bacteria) in the oxidation of organic matter. The relative high level of BOD recorded at Station 5 of Ikpoba River (10.33 mg/l) may be due to the effluents discharged into the river at this point. The river can be said to be highly polluted and cannot self-purify itself since BOD is greater than 4 mg O_2/l (Radojevik and Bashkin, 1998).

Chemical oxygen demand (CO) is the oxygen required for chemical oxidation of organic matter with the help of strong chemical oxidant. Chemical oxygen demand is an indicator of organic pollution, which is caused by the inflow of domestic, livestock and industrial waste that contains elevated levels of organic pollutants (Garg et al., 2010). The COD values obtained from Ikpoba River for this study ranges from 7.00 – 15.67 mg/l, and falls below the WHO standard.

Conclusion

This study showed that Ikpoba River receives pollution load from Guinness Brewery, domestic sewage, agriculture and slaughter house and this has accelerated the occurrence of eutrophication. There was visible growth of algae in Ikpoba River, accompanied with a murky appearance of the water and thus penetration of light into the water was diminished. Eutrophication has thus decreased the value of Ikpoba River for fishing, drinking, recreation and aesthetic enjoyment.

RECOMMENDATIONS

i) There should be improved monitoring of brewery effluents discharged into the river.

ii) The relevant government authority should make policies to control point sources of nutrients such as ensuring that industries establish an effluent treatment facility and provide alternative farmlands for farmers. This will reduce the nutrients, domestic and chemical pollutants being discharged into the river and thus control eutrophication.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Appendix

Table 1a. Mean physicochemical parameters of the river water samples for the months of May to July.

Ikpoba River	Mean±S.D					p-value	Level of significance
	Station 1	Station 2	Station 3	Station 4	Station 5		
pH	6.50±0.55	6.50±0.55	6.50±0.55	6.50±0.55	6.17±0.41	p>0.05	NS
Temp (°C)	27.33±1.51	27.00±1.26	28.50±1.38	29.17±1.72	30.00±1.90	p<0.05	Significant
Ec (uS/cm)	9.33±3.61	14.67±5.79	18.83±9.35	16.83±3.13	35.83±8.18	p<0.05	Significant
TDS (mg/l)	6.67±1.97	8.67±2.50	11.33±4.63	8.67±1.97	17.83±3.31	p<0.05	Significant
TSS (mg/l)	17.33±6.12	13.67±4.76	20.67±7.23	16.33±8.31	26.50±7.23	p<0.05	Significant
Turbidity (mg/l)	2.33±0.52	3.00±0.63	3.83±1.60	3.50±1.05	5.83±2.32	p<0.05	Significant
PO_4^{3-}(mg/l)	0.01±0.00	0.15±0.03	0.20±0.50	0.10±0.02	0.20±0.02	p<0.05	Significant
NO_3^- (mg/l)	0.50±0.55	0.50±0.55	0.50±0.55	0.50±0.55	0.67±0.82	p<0.05	Significant
COD (mg/l)	7.00±1.67	7.83±2.04	12.50±2.35	9.50±2.59	15.67±4.93	p<0.05	Significant
DO (mg/l)	5.83±0.41	6.50±0.55	5.83±0.75	5.00±0.00	4.67±0.52	p<0.05	Significant
BOD (mg/l)	2.83±0.41	2.83±0.41	3.33±1.37	7.50±2.81	10.33±0.52	p<0.05	Significant
Coliform (cfu/ml)	4.00±0.00	5.33±0.52	7.00±0.63	7.83±0.41	8.00±3.10	p<0.05	Significant

*Significantly different means ($p < 0.05$). *NS means not significant. *One way ANOVA was used to determine the level of significance at 95% confidence interval.

Table 1b. Sampling stations of Ikpoba River.

Location code	Location name	Activities
Station 1	UNIBEN, Capitol	Cow grazing, agriculture and construction work.
Station 2	Upper mission	Abstraction of water for irrigation, construction works and religious ritual. Vegetations include bamboo, banana and palm trees etc.
Station 3	Temboga	Agriculture and animal grazing.
Station 4	Ikpoba Slope	Cassava mailing
Station 5	Guinness Brewery	Discharge of brewery effluent, washing of bikes, laundry, open defecation and canoeing.

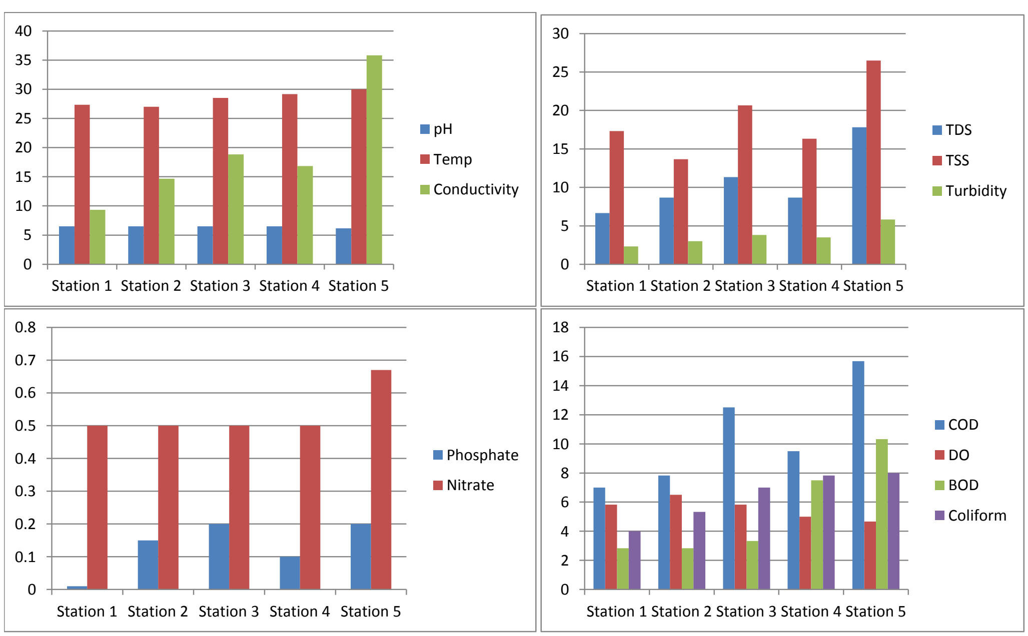

Figure 1. Graphical representation of the mean physicochemical parameters of the river water samples for the months of May to July.