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Impact of industrial effluents on Alaro river in Oluyole industrial estate, Ibadan and its suitability for aquatic life

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Abstract

Human activities involving urbanization, agricultural development, overuse of fertilizers, inadequate management of land use and waste disposal can affect the quality of water and making it unfit for both aquaculture and domestic purposes. Thus, overexploitation and its attendant pollution is dangerous and threatening to spoil freshwater and aquatic ecosystems. Hence, this study was designed to evaluate quality of water around an industrial area in order to assess its suitability for aquatic life and to evolve policies for use and protection of water resources. A total number of thirty (30) water samples were collected from six (6) different sites and were subjected to hydrochemical analysis using various standard methods to determine their conformity to World Health Organization (WHO) maximum allowance concentration. As against the WHO recommendation of absence of colouration for drinking water, the water samples were not all colourless but had varying colours ranging from light green to greenish brown. The mean values of Conductivity (387.27uS), pH (7.38), Total Suspended Solids [TSS] (423.87mg/L) and Total Dissolved Solids[TDS] (212.97mg/L) fall within the WHO standard, those of Salinity (0.18%), Turbidity (149.00 NTU), Biochemical Oxygen Demand[BOD*]* *(*106.80mg*/L),* Chemical Oxygen Demand*[COD]* (187.10mg/L) and NH_4 (4.44mg/L) were higher than the WHO standard while Dissolved Oxygen[DO] (3.49mg/L) and Cl^- (39.48mg/L) fall below the standard. These parameters make Alaro river unsuitable for aquatic life (fish) and therefore recommended that government and other stakeholders should take overdue steps in the development and implementation of waste water and industrial effluent receiving facilities in order to prevent discharge of untreated effluents into water bodies.

Keywords: Fresh water, Hydrochemical, Pollution, Standard, Urbanization

Introduction

The importance of water to human beings and other natural systems cannot be overemphasized and there are numerous economic and scientific facts that shortage of water as well as pollution can cause rigorous decline in productivity and die-off of entire ecosystems (Garba *et al.,* 2008; Garba *et al.,* 2010). Pollution of the aquatic environment has been defined by UNESCO/WHO/UNEP as the introduction by man directly or indirectly of substances or energy into the marine environment which results in such deleterious effects as harm to the living resources (Schwarzenbach *et al*., 2010; Novotny, 2003; Harrington *et al*., 1985). Effluents generated from domestic and industrial activities constitute major sources of natural environmental pollution. This is a great burden in terms of wastewater management and can therefore lead to a point-source pollution problem, which considerably increases treatment cost as well as introduction of a wide range of both chemical pollutants and microbial contaminants to water sources (EPA, 1993, 1996; Eikelboom & Draaijer, 1999; Amir *et al.,* 2004). Presently, industrial waste is the most common source of water pollution due to the fact that industries are increasing as a result of global industrialization (Osibanio *et al.,* 2011), while most industrial areas are located near water sources due to large quantities of water usage for its overall processing (Osibanjo *et al.,* 2011). According to Olaniyi *et al. ,*2012, there has been increasing consciousness on effective treatment of industrial effluents before their eventual discharge into water bodies but in most developing countries, Nigeria inclusive, enforcement of effluent quality standards backed by legislation are occasionally easily flouted (Okereke, 2007).

Industrial waste discarded into natural water bodies constitutes a serious source of environmental pollution in Nigerian rivers, which has been shown to strongly affect the water quality, as well as the microbial and aquatic flora (Kanu & Achi, 2001).

Eutrophication of water bodies may also generate environmental circumstances that enhance toxin-producing cyanobacteria growth causing gastroenteritis, liver damage, nervous system impairment, skin irritation and liver cancer in animals (EPA, 2000; Eynard *et al.,* 2000) as well as dysentery, typhoid, hepatitis, cholera, etc in humans (Galadima *et al.,* 2011).Due to large quantity of effluents discharged into the receiving water bodies, the decreased processes of pathogen reduction might contribute to the spread of diseases.

Consequences of low dissolved oxygen levels include reduced survival of fish by increasing their susceptibility to diseases, retardation in growth, hampered swimming ability, alteration in feeding and migration, and, when extreme, lead to rapid death. Long-term reductions in dissolved oxygen concentrations can result in changes in species composition (Welch, 1992; Chambers & Mills, 1996; Environmental Canada, 1997). Temperature is another factor affecting aquatic ecosystems. An increase in the average temperature of a water body can have ecological impacts. Because municipal wastewater effluents are warmer than receiving water bodies, they are sources of thermal enhancement (Welch, 1992; Horner *et al.,* 1994). Also, industrial wastes altering water pH and providing excessive bacterial nutrients frequently compromise the ability of natural processes to inactivate and destroy pathogenic organisms (Gerardi & Zimmarman, 2005). In addition, suspended solids affect aquatic ecosystems in terms of reduced photosynthesis, physical harm to fish, and toxic effects of contaminants attached to suspended particles (Horner *et al.,* 1994).

Aquatic organisms, including fish, amass pollutants directly from contaminated water and indirectly through the food chain (Hammer, 2004; Mohammed, 2009). According to Galadima *et al.,* 2011, water pollutants are commonly pathogens, silt and suspended solid particles such as waste foods, soils, sewage waste materials, cosmetics, automobile emissions, construction rubble and eroded rivers and waterways banks. The degree of discharge of industrial and domestic effluents is such that rivers receiving untreated effluents cannot provide the dilution required for fish survival as good quality water sources. This study was therefore aimed at revealing the adverse effects of untreated industrial effluents on several parameters of water quality in Oluyole Industrial Estate, Ibadan, Oyo state.

Materials and Methods

Study site

The location of the five (5) selected sites (Paper Mill, Industrial Light Packaging Cartons [Interpak], Steel Mill, Block Molding Industry and Poultry Farm) was Alaro River along Oluyole Industrial Estate, Ring Road, Ibadan, Oyo state (North-east of Ibadan in the South-western part of Nigeria)

Description

The sample sites were considered to reflect different activities in the catchment area (upstream and downstream) which may affect the water quality situation of the river. Six points of sample selection were considered for each of the five (5) sites along Alaro river. The description of the sample collection points is shown in Table 1-5 as follows; P (PaperMills), I (Interpak (Industrial Light Packaging Cartons)), SM (SteelMill), B (Block Molding Industry), Z (Poultry Farm), T (Top Layer), B (Bottom Layer) while confluence is the point at which the effluent enters Alaro river.

The physico-chemical parameters considered include pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Salinity, Turbidity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), Nitrate,

Chloride, Phosphate, Ammonium, Conductivity and colour. The parameters were determined using Hach® water quality test kits, water quality meters and spectrophotometer.
Water samples were collected and analyzed within 24 hours using Hach® water quality test kits and spectrophotometer. Dissolved oxygen and total dissolved solids were measured on site.
Data obtained from the water sample was computed and presented as Means ± Standard Deviation using GraphPad Prism 6.0.

Results
The physico-chemical parameters of Alaro river vary depending on the nature of activities and quality of effluent discharged into it from the industrial estate. Due to inadequate public water supply to the people living in the area traversed by Alaro river, people within this area use the water for drinking, bathing and other domestic affairs. The colour of the water sample as shown in Table 6 where both Interpak and Steel mill empty their effluents were colourless, which is in conformity with WHO standard. Paper mill and Block Molding (289.34mg/L), DO (2.45mg/L) and Cl^- (54.98mg/L) are lower than the WHO maximum recommended industries were light green and poultry farm appeared greenish-brown indicating their non-conformity with WHO standard.
The pH at different point of sampling ranged between 6.78-7.72 (Table 7) and was thus within the recommended range (6.50-8.00) for both drinking purpose and aquatic animals. Conductivity around the Poultry Farm effluent point was the highest (610.50uS), however all the sampling points were within the

Table 1: Description of Paper mill water sample collection points

Sample	Code Description
P1T	Top layer of confluence between paper mill and Alaro river
P2B	Bottom layer of confluence
P2T	About 20m downstream of P1T
P2B	Bottom layer of P2T
P3T	About 25m downstream of P2T
P3B	About 25m downstream of P2T

Table 2: Code description of Interpak (Industrial Light Packaging Cartons) water sample collection points

Sample	Code Description
I1T	Top layer of confluence between Interpak and Alaro river
I1B	Bottom layer of confluence of I1T
I2T	About 30m downstream of I1T
I2B	Bottom layer of confluence of I2T
I3T	About 20m downstream of I2T
I3B	Bottom layer of I2T

Table 3: Code description of Steelmill water sample collection points

Sample	Code Description
SM1T	Top layer of confluence between steel mill and Alaro river
SM1B	Bottom layer of confluence of SM1
SM2T	About 20m downstream of SM1
SM2B	Bottom layer of confluence of SM2
SM3T	About 35m downstream of SM2
SM3B	Bottom layer of confluence of SM3

Table 4: Code description of block making industry water sample collection points

Sample	Code Description
B1T	Top layer of confluence between Block Molding industries and Alaro river
B1B	Bottom layer of confluence of B1T
B2T	About 35m away from B1T
B2B	Bottom layer of confluence of B2T
B3T	About 20m away from B2T
B3B	Bottom layer of confluence of B3T

Table 5: Code description of poultry farm water sample collection points

Sample	Code Description
Z1T	Top layer of confluence between Poultry Farmand Alaro river
Z1B	Bottom layer of Z1T
Z2T	About 20m away from Z1T
Z2B	Bottom layer of confluence of Z2T
Z3T	About 25m away from Z2T
Z3B	Bottom layer of Z3T

Table 6: Different water colouration of sample sites observed at Alaro river

Sample Sites	Colour Observation
Paper Mill	Light green
Interpak	Colourless
Steel Mill	Colourless
Block Molding Industries	Light green
Poultry Farm	Greenish

Table 7: Mean physico-chemical parameters of sample sites (Alaro river) and standards

Industries Discharging Effluents at Sample Site	pH	Conductivity (uS)	TSS (mg/L)	Salinity (%)	Turbidity (NTU)	TDS (mg/L)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	NH^4 (mg/L)	Cl^- (mg/L)
Paper Mill	7.20 ± 0.16	19.00 ± 7.88	220.33 ± 71.66	0.14 ± 0.05	50.83 ± 27.11	164.17 ± 9.67	3.35 ± 0.68	61.50 ± 57.28	112.34 ± 94.28	3.57 ± 1.64	37.50 ± 17.69
Interpak	7.55 ± 0.00	15.50 ± 4.00	447.00 ± 56.57	0.15 ± 0.03	192.17 ± 5.89	161.00 ± 2.83	3.94 ± 0.19	25.67 ± 0.47	53.50 ± 0.71	4.10 ± 0.37	37.45 ± 20.03
Steel Mill	7.63 ± 0.14	48.34 ± 0.74	503.84 ± 56.34	0.15 ± 0.03	200.17 ± 55.39	289.34 ± 12.25	4.13 ± 0.28	68.83 ± 65.76	127.00 ± 103.70	4.98 ± 1.09	42.47 ± 27.08
Block Molding industries	7.72 ± 0.14	43.00 ± 4.71	280.00 ± 9.43	0.17 ± 0.00	84.67 ± 1.41	161.00 ± 2.83	3.57 ± 0.47	20.67 ± 16.97	45.17 ± 27.58	3.25 ± 1.31	25.00 ± 4.70
Poultry Farm	6.78 ± 0.09	10.50 ± 8.99	668.17 ± 286.85	0.30 ± 0.00	217.17 ± 155.33	289.34 ± 12.25	2.45 ± 0.21	357.33 ± 79.20	597.50 ± 129.87	6.28 ± 1.65	54.98 ± 2.35
Overall Mean	7.38	387.27	423.87	0.18	149.00	212.97	3.49	106.80	187.10	4.44	39.48
WHO Standard for Drinking Water	6.50-8.50		500		5	500	6	10		0.03	200
Standard for Aquatic Animals (Bhatnagar & Devi, 2013)	6.50-8	00-1500	150	0.05-0.1	5	10-500	>5	3-6		< 0.03	60

WHO standard (300-1500uS). It should be noted that Poultry Farm effluent's Conductivity (610uS), TDS values while TSS (668.17mg/L), Salinity (0.3%), Turbidity (217.17 NTU),BOD (357.33mg/L), COD (597.50mg/L) and NH_4 (6.28mg/L) were higher than the recommended values. The Overall mean physico-chemical properties of the Alaro river (Table 1) revealed that pH (7.38), Conductivity (387.27uS), TSS (423.87mg/L), T (mg/L)DS (212.97mg/L) and Cl- (39.48mg/L) were within the recommended range (Figure 1). Salinity (0.18%), BOD (106.80mg/L), Turbidity (149 NTU) andNH4 (4.44mg/L) were higher than the recommended range values while DO (3.49mg/L) was lower (Figure 2).

Discussion

All aquatic organisms have endurable limits of physico-chemical properties of water within which they perform optimally. Exceeding these limits can have unfavorable effects on their body performances (Davenport, 1993; Kiran, 2010). In this study, mean values of conductivity (387.27uS), pH (7.38), TSS (423.87mg/L) and TDS (212.97mg/L) were within the WHO standard, those of Salinity (0.18%), Turbidity (149.00 NTU), BOD (106.80mg/L), COD (187.10mg/L) and NH_4 (4.44mg/L) were higher than the WHO standard, while DO (3.49mg/L) and Cl^- (39.48mg/L) were below the standard.

The high mean turbidity (149.00 NTU) make Alaro river inappropriate for aquatic life, because of interference with sunlight penetration which hinder photosynthesis and eventual reduction of oxygen production for fish and aquatic life. High turbidity also creates large amounts of suspended matter which clog the gills of fish and shellfish, eventually causing death.

High mean BOD (106.80mg/L) and COD (187.10mg/L) denote high degree pollution of the river with organic matter due to untreated discharge of municipal and domestic waste. This makes the water body unsuitable for aquaculture. According to Bhatnagar *et al.* (2004), the BOD level between 3.0-6.0mg/L is optimum for normal activities of fish, 6.0-12.0mg/L is sublethal to fish and above 12.0mg/L can usually cause death to fish due to suffocation. The mean value of Ammonia found in this study was markedly high (4.44mg/L) as compared to the recommended range (0.0-0.03mg/L). Ammonia is toxic to fish and aquatic organisms, even in very low concentrations. According to Santhosh & Singh (2007), Ammonia concentrations greater than 0.1mg/L cause gill damage, destroy mucous producing membranes, produce "sub- lethal" effects like poor feed conversion, reduced growth and disease resistance, and at concentrations lower than lethal concentrations can cause osmo-regulatory imbalance and kidney failure. When ammonia levels reach 0.06 mg/L, fish can suffer gill damage. At 0.2 mg/L, sensitive fish like trout and salmon may die, while ammonia-tolerant fish like carp may tolerate concentrations below 2.0 mg/L. Ammonia levels above approximately 0.1mg/L usually indicate polluted water and/or water source. Maximum tolerance of ammonia concentration for aquatic organisms is 0.1 mg L -1 (Meade, 1985).

The mean DO value of Alaro river (3.49mg/L) is less than recommended value (>5mg/L), though, Santhosh & Singh (2007) opined that catfish and other air breathing fishes can survive in low oxygen concentration of 4.0mg/L. This however does not apply to non-air-breathing fish species. Minimum concentration of 1.0mg/L DO is important to sustain fish for long period and 5.0mg/L is adequate in fishponds (Ekubo & Abowei, 2011).

In conclusion, the biological, chemical and physical aspects of water quality are interwoven and must be considered together. For instance, higher water temperature reduces the solubility of Dissolved Oxygen (DO), and may cause shortage of DO that kills more sensitive fish species. The rotting fish carcasses may subsequently contribute to bacterial growth which might promote the spread of disease e.g. in human swimmers or boaters (Barnes *et al.,* 1998). This study shows significant deviation of Alaro river from WHO recommended standard values for aquatic life, thus there is high need for government and other stakeholders like Environmental Health Officers, Veterinary Public Officers and regulatory agencies to take a bold step in the development and implementation of waste water and industrial effluent receiving facilities before they are channel to the water bodies.

We demonstrate the pressing need of strict regulations in disposal of solid wastes, waste oil and biological waste including fish offal. There should be proper monitoring programmes to identify water pollution sources which discharge pollution into the water bodies directly or indirectly. Furthermore, education efforts should be made to sensitize the

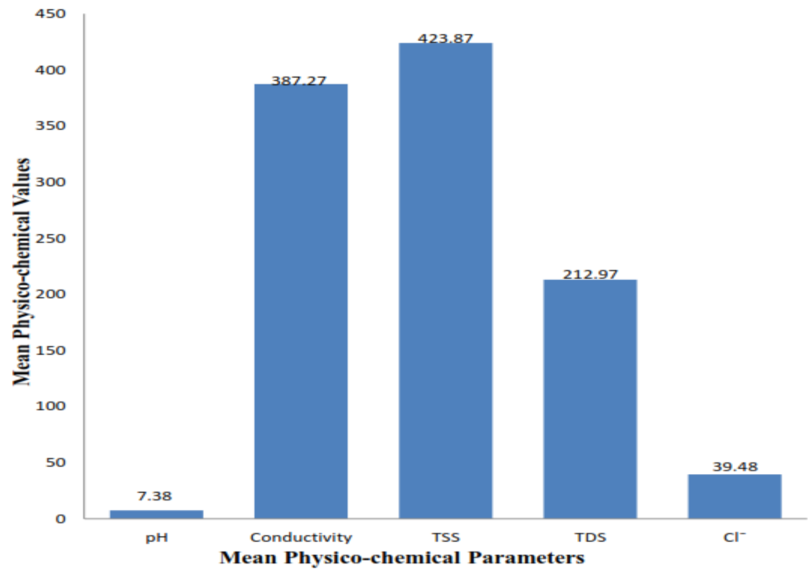

Figure 1: Distribution of overall mean physico-chemical parameters of water samples that fall within WHO and aquatic standard parameters

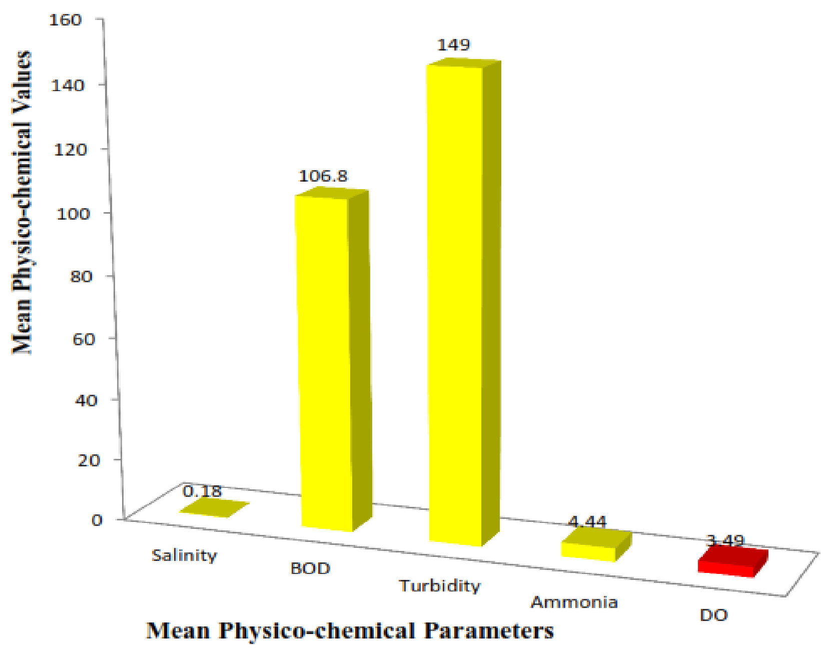

Figure 2: Distribution of overall mean physico-chemical parameters of water samples that fall outside WHO and aquatic standard parameters

local population regarding the adverse effect of river pollution on both human and animal life.

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