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Physicochemical Changes in the Quality of Surface Water due to Sewage Discharge in Ibadan, South-Western Nigeria

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Abstract

Sewage discharge is known to degrade the quality of receiving water bodies. This study assesses the impact of black water discharge on the physico-chemical parameters of River Zik in the University of Ibadan. Water samples were collected from five sampling sites along the stream located at progressive distances from the discharge point. Sampling was done three times over a period of three months (May to July 2012). The physico-chemical parameters tested were: pH, Biochemical Oxygen Demand (BOD_5), Dissolved Oxygen (DO), Electrical Conductivity (EC), Total Suspended Solids (TSS) and Nitrate. The overall mean values of the measured parameters were as follows: BOD_5 (381.1 mg/L); DO (3.9 mg/L); SS (1825.4 mg/L); pH (6.1); EC (618.5 µs/cm) and Nitrates (59.8 mg/L). The highest concentrations of BOD_5, SS, EC and Nitrates were obtained at the point of sewage discharge into the stream. One-way ANOVA showed significant deviation from WHO standards for BOD_5, SS, DO, EC and Nitrates ($p < 0.05$). This study showed that sewage discharge into River Zik have seriously contributed to the pollution of the stream to levels which pose health and environmental hazards to those using it downstream for domestic and agricultural purposes. This environmental hazards has been attributed to the little or near none existence of regulatory bodies responsible for regulating the strenght of black water discharge into sewers and/or recieving water bodies.

Keywords: sewage, receiving water body, environmental hazards, down-stream pollution and South-Western Nigeria

1. Introduction

Wastewater is referred to as any water that has been previously used by domestic or industrial activity and because of the usage now contains waste products. This waste products due to anthropogenic influence and natural processes such as precipitation, weathering and sediment transportation affects the water quality (Qadir, Malik, & Husain, 2008) which comprises of discarded domestic solid or liquid, industrial, agricultural and commercial gaseous chemical and radioactive wastes (Ekhaise & Omavwoya, 2008; Al-Ghamdi, 2011). The major components of water pollution are wastewater discharged from sewer systems and the industries. Wastewater from sewer systems contribute to increased oxygen demand and nutrient loading of the water bodies thereby promoting toxic algal blooms which usually leads to a destabilized aquatic ecosystem (Morrison, Fatoki, Persson, & Ekberg, 2001; Igbinosa & Okoh, 2009).

Sewage discharge leading to water pollution has become an issue of considerable public and scientific concerns in the light of evidence of their extreme toxicity to human health and ecosystems. Pollution is caused when a change in the physical, chemical or biological condition in the environment harmfully affect quality of human life including other animals' life and plant (Okoye, Enemuoh, & Ogunjiofor, 2002). Industrial, sewage, municipal wastes are been continuously added to water bodies hence affecting the physicochemical quality of water making them unfit for use of livestock and other organisms (Pandey, 2003).

According to previous research works (Qadir et al., 2008; Pandey, 2006); uncontrolled domestic wastewater discharge into the streams without any form of treatment has resulted in eutrophication of the water bodies as evidence by substantial algal bloom; dissolve oxygen depletion in the subsurface water leads to large fish kill and other oxygen requiring organisms. Sewage discharge into the environment with enhanced concentration of nutrients, sediments and toxic substances may have a serious negative impact on the quality and life forms of the receiving water body when discharge untreated or partially treated (Miller & Siemmens, 2003; Schulz & Howe, 2003).

Water associated diseases which are associated with ingestion of contaminated water with human or animal faeces are the major source of faecal microorganisms, including pathogens and microbial intestinal infections such as cholera, typhoid fever and bacillary dysentery (Cabral, 2010). These diseases caused by bacteria, viruses and protozoa are the most common health risks associated with contaminated water sources (WHO, 2008). These contain wide varieties of viruses, bacteria, and protozoa that may get washed into drinking water supplies or receiving water bodies (Kris, 2007). Virus concentrations present in raw water receiving fecal matter from humans are often high, although these viruses cannot reproduce in water; however, they are still capable of causing diseases when ingested even at low doses (Okoh, Sibanda, & Gusha, 2010). Many microbial pathogens in wastewater can cause chronic diseases with costly short and long-term effects, such as degenerative heart disease and stomach ulcer (Akpor & Muchie, 2011). Bacteria cause a wide range of infections, such as diarrhea, dysentery, skin and tissue infections. Disease-causing bacteria found in water include different types of bacteria, such as E. coli, Listeria, Salmonella, Leptospirosis, Vibrio and Campylobacter (Absar, 2005). The most common and widespread health risks associated with drinking poor quality water in developing countries are of biological origin and diarrhoeal disease globally has been attributed to unsafe water, sanitation and water hygiene (Suthar, Chhimpa, & Singh, 2009). Other impacts of discharging untreated or inadequately treated wastewater into the environment according to Okoh, Odjadjare, Igbinosa and Osode (2007) include increased nutrient levels (eutrophication), often leading to algal blooms; depleted dissolved oxygen, sometimes resulting in fish kills; destruction of aquatic habitats with sedimentation, debris, and increased water flow; and acute and chronic toxicity to aquatic life from chemical contaminants, as well as bio-accumulation and bio-magnification of chemicals in the food chain. This study was therefore conducted to assess the impact of sewage discharge on the physico-chemical parameters of river Zik in university of Ibadan, Nigeria.

2. Methodology

2.1 Study Site

This study was carried out in university of Ibadan, Ibadan which is located in south-western Nigeria between longitude 3°58'E and latitude 7°22'N. The altitude generally ranges from 15 to 21 m above mean sea level (Oyediran & Adeyemi, 2012). The stream flows from Sango in Ibadan town through the institution and empties in Awba dam of the university. The dam is used for fishing and irrigation while, water is abstracted from the dam by the university water treatment plant for treatment and distribution to the residence on campus.

2.2 Sampling Design

Water samples were collected at five different points along the stream using random grab sampling. Sampling was done three times from each of the points and all samples were collected in triplicate to improve reliability of data. Water samples were collected from the mid-width of the stream using one-litre plastic bottles that had previously been cleaned, soaked in 10% nitric acid and rinsed thrice with distilled water. Three one-litre samples were collected at each of the sampling points designated A – E. The full description of sampling locations is shown in Table 1.

Table 1. Sampling location description

Designation	Sampling points
A	10 m upstream with respect to sewage discharge point.
B	Point of discharge.
C	10m downstream from point of discharge.
D	50m downstream from point of discharge.
E	100m downstream from point of discharge.

2.3 Physico-Chemical Properties of the Wastewater Samples

Samples were analyzed for the following physico-chemical parameters: Hydrogen ion Concentration, Temperature, Total Dissolved Solid (TDS), Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD) and Electrical Conductivity. The pH value of the samples were determined with a pH meter (Unicam 9450, Orion model No. 91-02). Temperature was measured with mercury thermometer immediately after sample collection. Gravimetric method involving filtration and evaporation were used to measure the total dissolved solids. Methods recommended by APHA (1998) were followed for the measurement of DO, BOD_5 and COD. The Electrical Conductivity was determined using a conductivity meter (Metrohm 640, Switzerland).

2.4 Statistics

The results of laboratory analysis were subjected to data analysis using SPSS, version 12. To analyze changes in the levels of BOD_5, TSS, DO, pH, EC and Nitrates that might be attributed to sewage discharge into River Zik. One-way Analysis of Variance (ANOVA) at 95% level of significance was used.

3. Results and Discussion

A summary of the results collected over a period of three months, between May to July 2012 is presented in the following set of tables which also compare each of the parameters with the acceptable levels. A discussion of each parameter follows the tables.

At point A, 10m upstream, the BOD_5 value was 36 ± 1.8 mg L^{-1} (Table 2). The BOD concentration went higher to 955 ± 16.7 mg L^{-1} at the point B. This was because of the sewage discharged on the stream at this point and therefore not completely mixed. At point C, 10m downstream from the point of discharge, the mean value of BOD_5 was reduced to 733 ± 35.2 mg L^{-1}. This can partially be attributed to dilution due to mixing and partially as a result of settling along the stream course and dilution. Also, some part of BOD_5 may decrease due to microbial degradation during course of flow from B to C. However, the time required for water to travel this distance is too small to get any significant degradation. The flow of the water in the stream may increase the amount of dissolved oxygen in water that subsequently increased the microbial degradation of organic matter. At points D (50m upstream) and E (100m upstream), the mean BOD_5 values further decreased to 416 ± 36.3 and 237 ± 15.8 mg L^{-1} respectively. This, again, may be due to extensive dilution occurring in the stream during flowing of the effluent as it moves away from point A. Nevertheless, the mean values of BOD_5 at points D and E remained higher and may be partly due to other non-point pollution sources or that the microbial load far exceeds the self-purification capacity of the stream.

Table 2. Biochemical Oxygen Demand (BOD_5) in River Zik (Means and Standard errors of the means) compared with WHO standard

Sample station	BOD in the Stream (mg/L)	Acceptable WHO levels	WHO standards exceeded by (mg/L)
A	36 ± 1.8	20	16
B	955 ± 16.7	20	935
C	733 ± 35.2	20	713
D	416 ± 36.3	20	396
E	237 ± 15.8	20	217

Results (Table 2) from all the sampling points indicate that BOD_5 levels far exceed the acceptable levels of 20 mg L^{-1} as stipulated by World Health Organization (WHO, 1984). The low levels of BOD_5 at point A indicate that the stream is not heavily polluted before the discharge of raw sewage. There was, however, a marked increase at the point of discharge indicating a substantial impact and degradation of water quality.

The DO concentration from the study (Table 3) ranged from 1.6 ± 0.1 to 5.8 ± 0.2 mg L^{-1}. DO is the measure of the degree of pollution by organic matter, the destruction of organic substance as well as self-purification of the water bodies. It reflects interaction with the overlaying air because oxygen from the atmosphere is dissolved in the water (Chiras, 1998) and it is one of the most significant tests for measuring the quality of water. The standard for sustaining aquatic life is stipulated to be 5 mg L^{-1} (Horne & Goldman, 1994). Concentration below 2 mg L^{-1} adversely affects aquatic and biological life while the concentration below 2 mg L^{-1} may lead to death of fish. The lowest mean value of 1.6 ± 0.1 mg L^{-1} was detected at B (a point where the effluent is discharged into the stream). There is a decrease in concentration from 3.6 ± 0.1 mg L^{-1} found at C. The low DO concentration at point B could be due to high organic load of BOD_5 and suspended solid values (Table 2). At point C, the mean DO level increased to 3.6 ± 0.1 mg L^{-1} probably due to mixing and re-aeration along the stream.

Table 3. Dissolved Oxygen (DO) in River Zik (Means and Standard errors of the means) compared with standard to support aquatic life

Sample station	DO in the Stream (mg/L)	Standard for Sustaining Aquatic Life (mg/L)	Standard for Sustaining Aquatic life exceeded by (mg/L)
A	4.5 ± 0.2	5	0.5
B	1.6 ± 0.1	5	3.4
C	3.6 ± 0.1	5	1.4
D	4.1 ± 0.1	5	0.9
E	5.8 ± 0.2	5	Not exceeded

Table 4. Suspended Solids (SS) in River Zik (Means and Standard errors of the means) compared with WHO standard

Sample station	SS in the Stream (mg/L)	Acceptable WHO levels (mg/L)	WHO standards exceeded by (mg/L)
A	1510.6 ± 217.2	30	1480.6
B	2476.9 ± 21.2	30	2446.9
C	1838.8 ± 81.4	30	1808.8
D	1766.9 ± 48.0	30	1736.9
E	1534.0 ± 33.6	30	1504

Table 5. Electrical Conductivity (EC) in River Zik (Means and Standard errors of the means) compared with WHO standard

Sample station	EC in the Stream (μS/cm)	Acceptable WHO levels	WHO standards exceeded by (mg/L)
A	435.5 ± 3.2	400	35.5
B	905.3 ± 9.4	400	505.3
C	741.1 ± 5.1	400	341.1
D	588.0 ± 3.2	400	188
E	422.7 ± 3.7	400	22.7

The mean value of DO concentration continued to improve down the stream to 4.1 ± 0.1 and 5.8 ± 0.2 mg L^{-1} at points D and E, respectively. This could be attributed to both the flow and recovery capacity of the stream. At C, it may be suggested that the stream recovered from the organic load and could have been a better status to support aquatic life.

Electrical conductivity (EC) values (Table 5) ranged from 422.7 ± 3.7 to 905.3 ± 9.4 µS cm^{-1}. WHO recommends 400 µS cm^{-1}. At point A, an average of 435.5 ± 3.2 µS cm^{-1} was recorded. The high value could be due to the discharge of gray water few meters upstream, leading to concentration of salts from detergents. The value rose to 905.3 ± 9.4 µS cm^{-1} at point B as a result of the sewage discharge. At point C, the recorded conductance value was 741.1 ± 5.1 µS cm^{-1} and decreased to 588.0 ± 3.2 and 422.7 ± 3.7 µS cm^{-1} at points D and E respectively.

The reduction may be due to little amounts of dissolve solids in water due to dilution. Electrical conductivity is used to indicate the dissolved solids in water because the concentration of ionic species determines the conduction of current in an electrolyte (Hayashi, 2004). The high value of electrical conductivity therefore suggest that river Zik has a considerable loading of dissolved salts, and is unsuitable for irrigation, having exceeded the minimum acceptable levels as stipulated by WHO.

Hydrogen ion concentration or pH is the indicator of acidity or alkalinity of water. It is a measure of the effective concentration (activity) of hydrogen ions in water. Water having a pH range of 6.5–8.5 will generally support a good number of aquatic species. Only a few species can tolerate pH values lower than 5 or greater than 9 (Harrison, 1999). The mean values of pH obtained (Table 6) ranged from 6.0 ± 0.2 to 6.2 ± 0.1. These pH values were slightly below the recommended ranges (6.5–9.5) as stipulated by WHO. However, it falls within the EU standard pH limits of 6.0 to 9.0 for protection of fisheries and aquatic life (Chapman, 1996).

The most highly oxidized form of nitrogen compounds is commonly present in surface and groundwater because it is the end product of aerobic decomposition of organic nitrogenous matter. Unpolluted natural waters usually contain only minute amounts of nitrate (Jaji, Bamgbose, Odukoya, & Arowolo, 2007). Usually, nitrate levels of streams polluted by human and animal wastes are high. In this study, the nitrate-N concentrations was generally high and ranged between 17.6 ± 0.2 to 97.3 ± 1.2 mg/L. It is important to note that nitrate level in the stream could be a source of eutrophication for receiving water. The obtained values exceeded the recommended limit for WHO except for points A and E, 10 m upstream and 100 m downstream from the point of sewage discharge respectively. The nutrient levels in the upstream discharge point of the receiving water may be as a result of diffuse sources from settlement and agricultural runoff, while the reduced level of nitrate in the downstream point could be as a result of conversion of nitrates to nitrites along the length of the stream.

Table 6. The pH in River Zik (Means and Standard errors of the means) compared with WHO standard

Sampling stations	pH in the Stream (mg/L)	WHO Recommended Range
A	6.1 ± 0.2	6.5–9.5
B	6.0 ± 0.2	6.5–9.5
C	6.0 ± 0.2	6.5–9.5
D	6.1 ± 0.1	6.5–9.5
E	6.2 ± 0.1	6.5–9.5

Table 7. Nitrate in River Zik (Means and Standard errors of the means) compared with WHO standard

Sampling stations	Nitrate in the Stream (mg/L)	Acceptable WHO levels	WHO Maximum Limit exceeded by (mg/L)
A	17.6 ± 0.2	25 - 50	Not exceeded
B	97.3 ± 1.2	25 - 50	47.3
C	85.9 ± 0.3	25 - 50	35.9
D	65.8 ± 0.6	25 - 50	15.8
E	32.6 ± 0.8	25 - 50	Not exceeded

One way ANOVA test showed that only BOD_5, SS, DO, EC and Nitrates had significant difference ($P < 0.05$). This implies that BOD_5, DO, SS, EC and Nitrates were the parameters of water quality of the stream that had been significantly affected by pollution.

Similar studies done in Tanjero River (Mustapha, 2002) and in several other streams and rivers found that sewage discharge in surface water is contributing greatly to the degradation of ecosystem health.

4. Conclusion

This study showed that most of the parameters assessed in river Zik are above limits recommended by WHO. The study showed that although the stream was already polluted from upstream activities, there was a significant increase in the levels of BOD_5, SS, DO, EC and Nitrates at the raw sewage discharge point, thereby, contributing to the pollution of river Zik and endangering ecosystem and the health of the people who rely on the stream for livelihood water source. The management of sewage wastewater should be improved to minimize danger to the environment and to people. Relevant authorities should embark on regular monitoring activities of streams and rivers to ensure the safety of human and animal population and the environment. It is recommended that further research should be carried out in the low flow season where minimum or near zero flows are observed as the river is ephemeral in nature.

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