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Solid Waste Disposal: A Potential Threat to Aquatic Environment

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The disposal of solid waste close to water bodies is becoming a threat to the potability of water and the survival of aquatic organism. This research work was carried out to assess the impact of solid waste disposal on Nwaorie River in Owerri, Imo State, Nigeria. This was to ascertain the level of some heavy metals and physico-chemical parameters that could affects the quality of the water. Three sampling stations were established along the length of the study area and water from untreated effluent discharged points, 50m upstream, 50m midstream and 50m downstream respectively from the point of discharge. The water sample collected was taken to the Laboratory for analysis. Parameters such as pH, turbidity, Temperature, Total Dissolved Solid, Electrical conductivity, Dissolved Oxygen, Zinc, Arsenic, Iron, Cadmium were measured in situ using a multi-parameter water quality monitor and flame absorption spectrometry. The results obtained revealed the concentration of dissolved Oxygen ranged 6.900-7.400mg/l, Biochemical Oxygen Demand ranged 0.250-0.540mg/l, mean of pH has the highest value of 5.30±0.0 at the downstream,

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electrical conductivity highest value was 98.00±0.0 at the downstream and temperature was found highest at the upstream with a value of 31.2±0.01 Zinc was less than 0.003mg/l in all sampling points, Iron, zinc and Arsenic were not detected while $CaCO_3$ ranged 13-29mg/l and turbidity was 0.00. When compared the results of the measured parameters with World Health Organization Standard, all the measured parameter fell within the permissible limit. The study therefore concluded that river Nwaorie is slightly impacted by untreated waste deposited within the vicinity of the river, which could have implications for people that depend on the river for domestic uses and also aquatic organism in the river. Measures should therefore, be taken to stop this unhealthy way of waste disposal.

Keywords: Solid waste; heavy metal; pollution; aquatic environment.

1. INTRODUCTION

The development in economic activity and population has led to an extraordinary rise in the production of solid waste in most metropolitan areas. All resources are under pressure from the growing population, particularly freshwaters, which are constantly being contaminated and depleted [1]. Humans have been disposing trash into their surroundings, especially water bodies, recklessly contaminating their environment and have continue to do so [2-3]. Food, paper, polythene bags, dyes, metals, and other harmful components are some of the contents of solid waste thrown into water bodies [4-5]. However, rivers have become susceptible to pollution as water bodies become dumping grounds of effluent and solid waste. Rivers have been used as sinks for urban effluent hence becoming a pathway for heavy metal translocation worldwide [6]. The health of people and ecosystems is at risk because aquatic creatures like fish collect these contaminants both directly from polluted water and indirectly through bioaccumulation in the food chain. Apparently, the natural processes of pathogen removal and reduction are insufficient to protect public health due to the high number of effluents emitted to the receiving waterways. when a result, when water flows downstream, certain rivers are unable to self-purify [7]. As effluent management deteriorates as a result of growing populations, urbanization, industry, and greater chemical usage in agriculture and homes, water pollution has generally become a significant global issue [8]. Uncontrolled effluent discharge affects the physical, chemical, and bacterial characteristics of water, interfering with essential and legal water usage, ecological processes, and human health. This makes it possible to define water pollution as the alteration of the physical, chemical, and biological characteristics of water quality that has a negative impact on living beings [9]. Water is a vital resource that sustains life and accounts for between 50 and 97 percent of the weight of plants, animals, and humans. Consequently, it is crucial that drinking water be clean and safe for consumption [10]. Water quality varies from place to place depending on seasonal changes, types of soils, rocks and surfaces through which it moves [11]. Additionally, human activities such as waste disposal, municipal effluent disposal, industrial discharges, urban activities, and inefficient agricultural techniques change the natural composition of water [12]. Waterborne illnesses including diarrhea, typhoid, dysentery, poliomyelitis, respiratory illnesses, meningitis, hepatitis, and cholera are all caused by harmful bacteria found in contaminated water. Additionally, several illnesses that are associated with water, such filariasis, yellow fever, and malaria, are spread by insects that have aquatic larvae [13]. Due to their impact on health, oxygen-demanding wastes like sewage are among the more significant contaminants in our natural environment. According to [14], water contaminated by sewage or sewage treatment plant effluents is linked to a high illness burden. The already skewed life expectancy of the local population might be further impacted by such unhealthy activity. Increased oxygen demand is a result of the introduction of high sewage levels into recipient water bodies. Most frequently, wastes are dumped into receiving water bodies with little to no consideration for their assimilation capabilities. The physio-chemical characteristics of the receiving water body are impacted by these discharges into the water body. Untreated infections with bacteria, viruses, and protozoa are the most frequent health risks associated with drinking contaminated water. The major source of these microbial contaminants in wastewater are human and animal [15].

Microbial infections are known to be responsible for many waterborne epidemics. Numerous microbial infections found in wastewater can lead to chronic illnesses with expensive long-term consequences, such heart disease and stomach ulcers. Among the most significant and possibly dangerous contaminants in wastewater are viruses. They often require fewer dosages to produce infections and are more contagious, harder to detect, and resistant to therapy [16]. Water source eutrophication may also provide environmental conditions that favor the growth of cyanobacteria that produce toxins. Animals may get gastroenteritis, liver damage, nervous system impairment, skin irritability, and liver cancer after being exposed to these poisons on a regular basis [15]. The volume of the discharge, the chemical makeup, and the concentrations in the effluent all affect the potential negative impacts of contaminants from sewage effluents on the receiving water quality of the coastal environment [17]. Throughout the world, rivers and streams are significant sources of freshwater for both home and industrial usage. They offer a means of subsistence, freshwater resources, water for irrigation, hydropower, and leisure activities. Therefore, significant attention must be shown to issues that affects its constituents. This study therefore, seek to examine the physico-chemical characteristics of the water in the Nwaorie River and also check for presence of heavy metal.

2. MATERIALS AND METHODS

2.1 Study Area

Nwaorie River flows in Owerri, Imo State of Nigeria. Owerri, the capital of Imo State of Nigeria lies between 04^{o}55'N and 05^{o}35'N, and between 06^{o}35'E and 07^{o}30'E parallels. It falls within the rainforest zone of 2290mm per annum, relative humidity of 55-85% and temperature of 270C. Two seasons, wet and dry, are observed in the year, the rainy season which begin in April to October, while the dry season ranges from November to March [18]. Owerri covers a land mass of 5200km2 and lies entirely within coastal plain sand stones. It lies within the humid tropics and is generally characterized by a high surface air temperature regime year-round. [18]. Nwaorie River flows through the Federal Medical Center (FMC), Owerri, and Holy Ghost College, Owerri. All these institutions discharge their untreated waste into Nwaorie River, which serves as a source of drinking water, fishing, and other domestic uses for the locals.

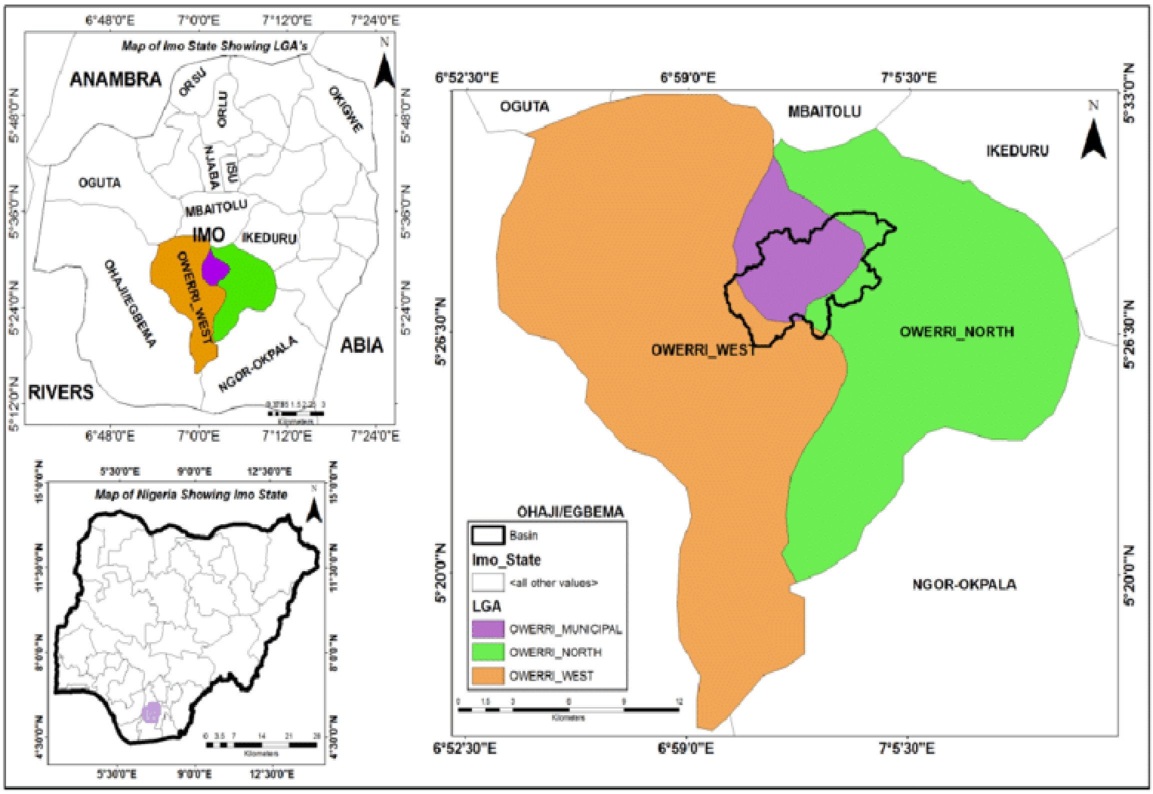

Fig. 1. Map of Nigeria showing Imo State and the study area

3. SAMPLING METHODS AND PROCEDURES

A trip was taken to Nwaorie River, in Imo State, Nigeria. Sterile bottles were used to collect water samples. Samples A (point of discharge), Sample B to D were collected 50m apart from each other, while sample E (control) was collected 1000m apart up stream where there is no hospital wastes.

Three sampling stations (A-C) were established along the length of the studied part of the Nwaorie River. Surface water samples were collected from the treated effluent discharge points. 50m upstream (Point A), 50m downstream (point B) and 50m downstream (point C) respectively from the point of discharge. The pattern of sampling was done in order to obtain a complete summation of pollutants distribution in the water body.

Water samples for physico-chemical parameters were collected in 1L plastic bottles while those for BOD analysis were collected in 250 ml narrow mouthed dark amber glass bottles. All containers were sterilized by washing with non-ionic detergents, rinsed with tap water, 1:1 hydrochloric acid and finally with deionized water.

Prior to sampling, the bottles were rinsed three times with sample water before being filled with the sample (in order to be familiarize with the sample water environment).

Sampling was carried out by dipping each sample bottle at approximately 10-20cm below the water surface by projecting the mouth of the container against the flow the direction. Preservatives were added as required in the specific test methods in order to avoid changes in chemical composition of the sample as a result of microbial degradation and inter-chemical reaction. Consequently, samples for BOD analysis were kept away from sunlight and incubated at room temperature for 5 days prior to analysis. Samples were then transported in cooler boxes containing ice to the laboratory for analysis.

3.1 Data Analysis

This section presents the results obtained from the field work in tables and the comparison with World Health Organization permissible limit for drinking water.

Table 1. Presents the coordinates and elevation of the selected points in Nwaorie River, Owerri, Imo State

S/N	Stations	Longitude	Latitude	Elevation
1	Up-stream	E 007°00'59.5"	N 05°30'53.3"	62m
2	Mid-stream	E 007°01'070"	N 05°30'11.7"	57m
3	Down-stream	E 007°01'39.2"	N 05°28'44.2"	55m

Table 2. Parameters and concentration in the Up-stream, Mid-stream and Down-stream of Nwaorie River, Owerri, Imo State

Parameter	Unit	Up-stream	Mid-stream	Down-stream
Dissolved Oxygen (DO)	mg/L	7.300	6.900	7.400
Biochemical Oxygen Demand (BOD)	mg/L	0.250	0.540	0.170
Zinc (Zn)	mg/L	0.003	<0.001	0.000
Iron (Fe)	mg/L	0.000	0.000	0.000
Cadmium (Cd)	mg/L	0.000	0.000	0.000
Lead (Pb)	mg/L	<0.001	<0.001	<0.001
Arsenic	mg/L	0.000	0.000	0.000
$CaCO_3$	mg/L	29	13	26
Turbidity	NUT	0.000	0.000	0.000

Source: Authors laboratory analysis

Table 3. Comparison of the parameters with the World Health Organization water quality guidelines

Parameter	Unit	Up-Stream	Mid-Stream	Down-Stream	Mean Conc.	W.H.O Standard
Dissolved Oxygen (DO)	mg/L	7.300	6.900	7.400	7.200	-
Biochemical Oxygen Demand(BOD)	mg/L	0.250	0.540	0.170	0.32	< 5.00
Zinc (Zn)	mg/L	0.003	<0.001	0.000	0.002	0.01-3.00
Iron (Fe)	mg/L	0.000	0.000	0.000	0.000	0.3
Cadmium (Cd)	mg/L	0.000	0.000	0.000	0.000	0.003
Lead (Pb)	mg/L	<0.001	<0.001	<0.001	<0.001	0.05
Arsenic	mg/L	0.000	0.000	0.000	0.000	0.01
$CaCO_3$	mg/L	29.000	13.000	26.000	22.667	150
Turbidity	NTU	0.000	0.000	0.000	0.000	5.00

Source: Authors laboratory analysis

Table 4. Shows the physio-chemical parameters of the Nwaorie River

Parameters	Up-Stream	Mid-Stream	Down-Stream	W.H.O Standard
pH				**6.5-8.5**
Pt. 1	5.3	5.3	5.8	
Pt. 2	5.3	5.3	5.7	
Pt. 3	5.2	5.3	5.7	
Electrical Conductivity (μs/cm)				**400**
Pt. 1	66	86	98	
Pt. 2	58	88	98	
Pt.3	58	86	98	
Turbidity (NTU)				**5.00**
Pt. 1	-	-	-	
Pt. 2	-	-	-	
Pt. 3	-	-	-	
Total Dissolved Solid (TDS)(mg/L)				**1000**
Pt. 1	33	44	49	
Pt. 2	35	44	49	
Pt. 3	34	43	49	
Temperature (°C)	**29.2**	**31.2**	**30.2**	**30**

Source: Authors laboratory analysis

Table 5. Results of the Concentration of Heavy Metals in mg/l in stream (up, down, mid)

Parameter	Unit	Up-stream	Down-stream	Mid-stream
Dissolved Oxygen	mg/L	7.300	7.400	6.900
Biochemical Oxygen Demand	mg/L	0.250	0.170	0.540
Zinc	mg/L	0.003	0.000	<0.001
Iron	mg/L	0.000	0.000	0.000
Cadmium	mg/L	0.000	0.000	0.000
Lead	mg/L	<0.001	<0.001	<0.001
Arsenic	mg/L	0.000	0.000	0.000

Source: Authors laboratory analysis

The concentration of Heavy metals in Nwaorie River varied at different levels. Dissolved Oxygen, Biochemical Oxygen Demand, Manganese, Zinc, and Lead were detected by the AAS, although concentrations of Iron, Cadmium, and Arsenic at three different points (up-stream, down-stream and mid-stream) were below the detection limit. The concentrations of heavy metals in the river is given in Table 5 and illustrated in Fig. 3.

Fig. 2. Shows that dissolved oxygen concentration in Down-stream was higher with mean concentration of 7.4 mg/L, Up-stream had a mean concentration of 7.3 mg/L and Mid-stream had the lowest concentration of 6.9 mg/l in Nwaorie River.

In Table 6, Parameters with standard deviation (SD) equals to zero (0) shows that data points are close to the mean. Meaning that there was not much variability in the data collected at different points of the river under consideration.

3.2 Hypothesis Testing

H0: There is no statistically significant variation in the mean values of the different variable
Hi: There is

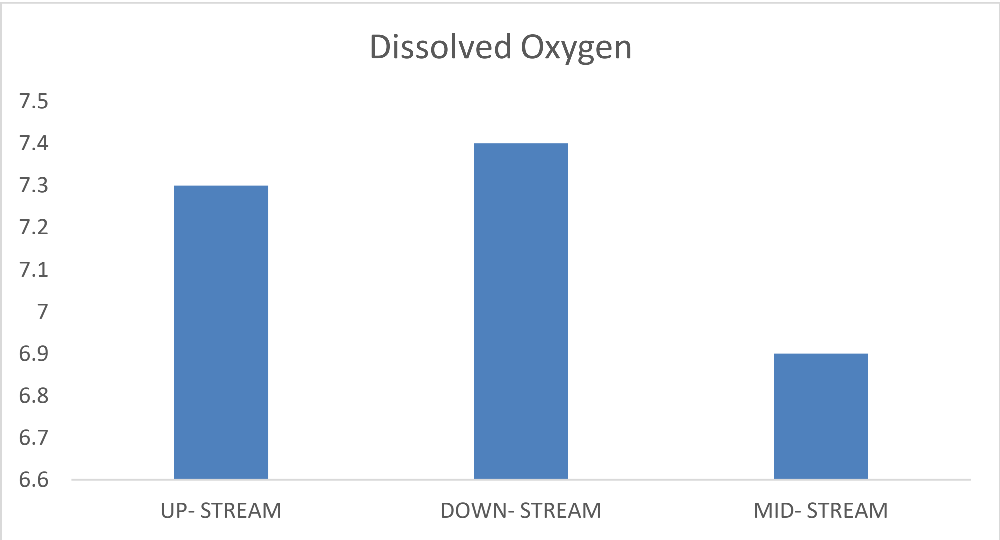

Fig. 2. Concentration of dissolved oxygen in Nwaorie River

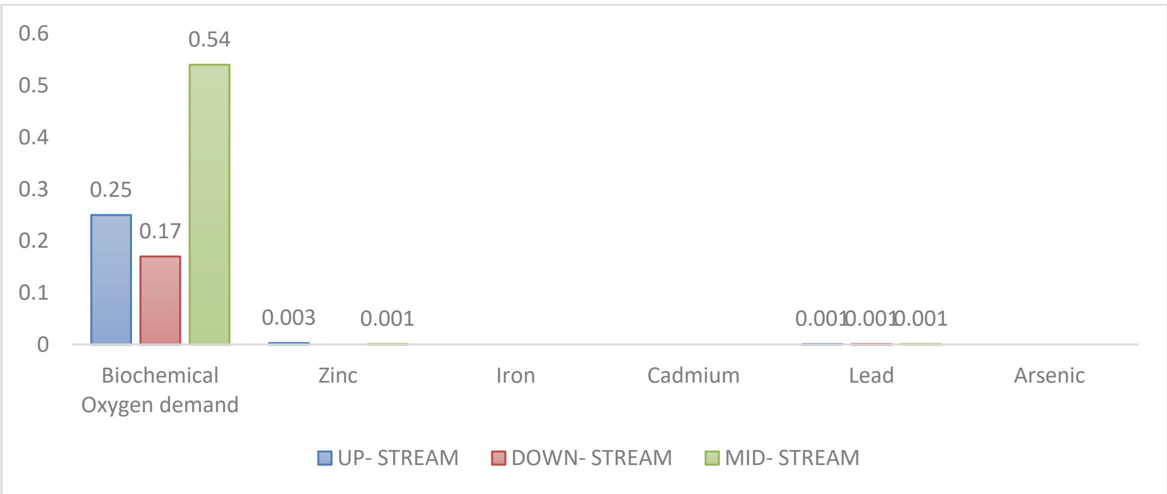

Fig. 3. Concentration of BOD, zinc, iron, calcium, lead and arsenic in Nwaorie River

Table 6. Mean and standard deviation of the concentration of heavy metals in water

Parameter	POINT 1 Mean±SD	POINT 2 Mean±SD	POINT 3 Mean±SD
pH	5.27±0.06	5.30±0.00	5.73±0.06
Electrical Conductivity	60.67±4.62	86.67±1.15	98.00±0.00
Turbidity	-	-	-
Total Dissolved Solid (TDS)	34.00±1	43.67±0.58	49.00±0.00
Temperature (°C)	29.2±0.02	31.2±0.01	30.2±0.0

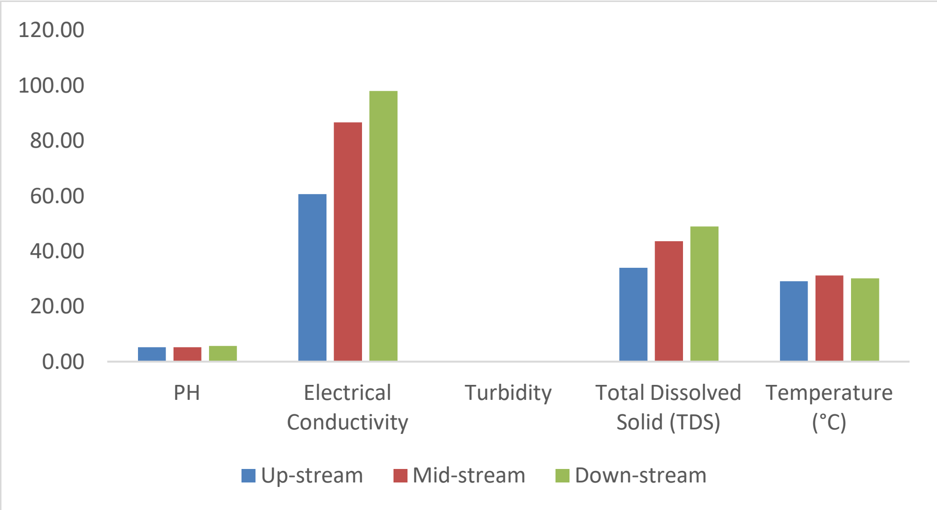

Fig. 4. The concentration of some selected parameter in Nwaorie River

Table 7. Analysis of variance (ANOVA) to compare the difference in concentration of parameter in Nwaorie river

			Summary ANOVA			
Source of Variation	**SS**	**Df**	**MS**	**F**	**P-value**	**F crit**
Between Groups	375.7222	2	187.8611	0.156718	0.857229	4.256495
Within Groups	10788.5	9	1198.722			
Total	11164.22	11				

Recall that a one-way ANOVA uses the following null and alternative hypotheses:

- ❖ H_0: All group means are equal.
- ❖ H_A: All group means are not equal.

We accept the null hypothesis of the one-way ANOVA because the p-value is greater than 0.05; as a result, we draw the conclusion that we have adequate evidence to claim that the means of all of the groups are the same. This means that there was no significant difference in the levels of heavy metals that were found at different points.

4. RESULTS AND DISCUSSION

4.1 Dissolved Oxygen

Dissolved Oxygen (DO) refers to an oxygen gas that is dissolved in the water. Aquatic species abundance is strongly associated with the DO concentrations. DO levels are often used to indicate the quality of freshwater, health of streams and rivers and the intensity of aquatic pollution. Furthermore, DO limits tastes, odors, discoloration and corrosion in drinking water. From Table 3, it is glaring that the Dissolved Oxygen value of Nwaorie River which ranges from 6.90 to 7.40 is within the permissible level for safe drinking water set by W.H.O hence poses no threat to aquatic lives. This shows that the river contains sufficient amount of oxygen which makes the survival of aquatic lives possible. However, if further monitoring is not done frequently, any slight increase in pollution as a result of indiscriminate dumping of waste materials could lead to a decrease in the Dissolved Oxygen hence pollution of the River.

4.2 (Biomedical) Oxygen Demand

The amount of dissolved oxygen that microbes consume while oxidizing reduced compounds in wastes and waterways is known as the biochemical oxygen demand, or BOD. Common sources of BOD include ammonia and easily degradable organic carbon (carbonaceous, CBOD) (nitrogenous, NBOD). These substances are typical components or metabolic by products of human activity, animal waste, and plant waste (domestic and industrial wastewaters). High BOD indicates water pollution while low BOD indicates a safe or good quality of water. Clean water or unpolluted river water would have a BOD value of less than 5 ppm whereas highly polluted water could have a BOD value of greater than 17 ppm. Hence, from the result above in Table 3, the BOD level for Upstream is 0.250, Mid-stream has a BOD level of 0.540 and Downstream 0.170 which all indicate low water pollution and it's safe for drinking.

4.3 Zinc

Zinc is a relatively common environmental pollutant; its presence may threaten the water ecological environment. Extreme zinc discharge pollutes groundwater and the subsurface environment. From Table 3, it shows that the Zinc concentration in Nwaorie River is minimal and it is below the permissible level of W.H.O. This is an indication that the river is not heavily polluted with Zinc heavy metals. Although the upstream part of the river which has a Zinc concentration of 0.003 mg/L of Zinc and it's the highest amongst the three parts (mid-stream and down-stream) should be properly monitored as continuous discharge of waste water from the Federal medical center and other sources could eventually lead to increase in pollution of the River.

4.4 Iron

Iron in drinking water is present as Fe^{2+} or Fe^{3+} in suspended form. It causes staining in clothes and imparts a bitter taste. It comes into water from natural geological sources, industrial wastes, and domestic discharge and also from byproducts. Excess amount of iron (more than 10 mg/kg) causes rapid increase in pulse rate and coagulation of blood in blood vessels, hypertension and drowsiness. In all the collected water samples and from the result as shown in Table 4, it is obvious that there is no trace Iron (Fe) in Nwaorie River in the three locations (up-stream, down-stream and mid-stream). The fact that there is no measurable trace of Iron in Nwaorie River could be as a result of self-purification of the River at the time of collection of the water sample. However, proper monitoring should be done as well to minimize indiscriminate dumping of solid hospital waste that could lead to pollution of the River.

4.5 Cadmium

The permissible limit of Cadmium in water according to WHO is 0.003 mg/L. However According to the result of this experiment, there was no record of any concentration of Cadmium in any points of the Nwaorie River. This indicates that the river is safe for drinking to an extent. It is important to safeguard the river from any activity that might lead to the accumulation of waste that could contain Cadmium heavy metals.

4.6 Lead

Lead is an industrial pollutants which have adverse effects on human and animal health. Lead accumulates in the organisms mainly the kidney and liver. The permissible limit in water recommended by WHO is 0.05 mg/L. From the result obtained, the value of Lead is comparatively low than the WHO Permissible limit. The result shows the concentration of Lead at less than 0.001 mg/L in all the three locations (Up-stream, Mid-stream and Down-stream). Thus, the river is safe from lead pollution and the water is safe for drinking and other domestic purpose. Further monitoring and inspection should be carried out regularly on the river to ensure that the Lead concentration does not increase.

4.7 Arsenic

The presence of Arsenic even at high concentrations, is not accompanied by any change in taste, or visible appearance of water. The presence of arsenic in drinking water is therefore difficult to detect analytical techniques. Long-term ingestion of arsenic in water can first lead to problems with kidney and liver function, and then to damage to the internal organs including lungs, kidney, liver and bladder. Arsenic can disrupt the peripheral vascular system leading to gangrene in the legs, known in some areas as black foot disease. The result obtained indicated that there was no trace of Arsenic in the three locations where samples were taken.

4.8 $CaCO_3$

$CaCO_3$ is a component of hard water, which causes it to be denser. Most typical way to measure hardness is in milligrams, where 120-180 mg/L is considered hard, more than 180 mg/L is considered very hard. Although cations are the cause of hardness, it can also be discussed in terms of concentrations. Concentrations between 60 and 120 mg/L of calcium carbonate are generally regarded as hard; concentrations below 60 mg/L are considered soft. Calcium carbonate-containing water that is hard (carbonate) and not hard (non-carbonate). Hard water can cause increased soap consumption and scale deposition in the water distribution system, as well as in heated water applications where insoluble metal carbonates are formed, coating surfaces and reducing the efficiency of heat exchangers. Excessively hard water can also have corrosion tendencies. A suggested explanation relative to hard water is that increased soap usage in hard water results in metal or soap salt residues on the skin (or on clothes) that are not easily rinsed off and that lead to contact irritation [19].

From the Table 3 above, the concentration of CaCO3 in Nwaorie river is between the ranges of 13.00 to 29.00 where the Up-stream tend to present a higher concentration than the other locations. Comparing these with the W.H.O guidelines, it is seen that Nwaorie River is considered to be soft water.

4.9 Turbidity

Turbidity is caused by particles suspended or dissolved in water that scatter light making the water appear cloudy or murky. High turbidity can significantly reduce the aesthetic quality of lakes and streams, having a harmful impact on recreation and tourism. It can increase the cost of water treatment for drinking and food processing. However, from the result obtained above in Table 3, the Nwaorie River appears not turbid. This may be as a result of self-purification or other factors as of the time of taking the sample.

4.10 pH

pH is the term to describe how acidic or alkaline a water sample is. The pH values of water samples from upstream, midstream and downstream points of Nwaorie River are displayed in Table 4. A pH range of 5.2-5.8 was obtained in all points. Upstream points have a pH values between 5.2-5.3 and indicated the most acidic amongst the three locations, midstream has a consistent values of 5.3 in all the three sampled points while the downstream points have a pH values ranging from 5.7-5.8. However, the standard pH values of W.H.O is 6.5-8.5 and this value is recommended for drinking water because it is not corrosive (W.H.O, 2010) Hence, it is evident that pH of Nwaorie River falls below the W.H.O standard and it's too acidic for drinking and for other purpose. This high acidity of the river is likely due to the presence of untreated waste materials dumped into the River. High pH value in water can cause skin to become dry, itchy and irritated.

4.11 Electrical Conductivity (EC), Total Dissolved Solid (TDS) and Temperature

Table 4 shows the conductivity values of the ground water samples taken from various locations. This is a measurement of the ionic component that has been dissolved in water, and as a result, its electrical characteristic. Electrical conductivity is a measurement that can be used to estimate the total number of dissolved substances in a liquid [20]. The values recorded varied from 58 to 98, with the upstream water sample having the lowest conductivity values with a range of 58 to 66 and the upstream water sample having the highest conductivity values with a consistent value of 98 in all sampled points. The conductivity values ranged from 58 to 98. The EC value in the River, on the other hand, was significantly lower than the World Health Organization's permitted limit of 400 µs/cm. These findings make it abundantly evident that the water in the area under investigation was not significantly ionized and had a lower degree of ionic concentration activity as a consequence of the presence of tiny dissolved materials.

Water has the ability to dissolve a wide range of inorganic and some organic minerals or salts such as potassium, calcium, sodium, bicarbonates, chlorides, magnesium, sulfates etc. These minerals produced un-wanted taste and diluted color in appearance of water. This is the important parameter for the use of water. The water with high TDS value indicates that water is highly mineralized. Desirable limit for TDS is 500 mg/L and maximum limit is 1000 mg/L which prescribed for drinking purpose. The concentration of TDS in present study was observed in the range of 33 and 49 mg/L. The concentration of TDS increases upstream to downstream with upstream value of 58-66 mg/L and midstream value of 86 mg/L and downstream value of 98 mg/L. The mean total dissolved solids concentration in Nwaorie River was found to be 81.6 mg/L, and it is within the limit of WHO standards. High values of Total Dissolved Solid in ground water are generally not harmful to human beings, but high concentration of these may affect persons who are suffering from kidney and heart diseases. Water containing high solid may cause laxative or constipation effects according to Sasikaran et al. [21].

The average temperature of water samples of the study area was 30.2 °C and in the range of 29.2-30.2 C. Temperature in this study was found to be slightly above the permissible limit of WHO (30 C). These suggest that the Nwaorie River temperature is generally ambient and good for consumers who prefer warm to cool water and for the specific reason of water quality since high temperature negatively impact water quality by enhancing the growth of micro-organisms which may increase taste, odour, colour and corrosion problems. Again, temperature affects biological, chemical and physical activities in the water [20] and increase in temperature of water decreases solubility of gases such as O_2, CO_2, N_2 and CH_4 [20].

5. CONCLUSION AND RECOMMENDATIONS

The presence of some concentrations of heavy metals in Nwaorie although in considerate levels shows that the pollutants could rise above the regulatory limits if no adequate measures are put in place to ensure proper monitoring of waste dumping especially hospital waste from various Hospitals and other sources near the water body. Based on the results of this research work, it has become very necessary for adequate monitoring stations to be located near the water body to ensure compliance of no dumping of untreated waste into the water body. Measures should be taken for continuous monitoring to be able to alert the government and other relevant authorities in cases of possible water pollution. Furthermore, adequate mechanism should be put in place to frequently test the water to check for any increase in concentration of some elements which may arise as a result of heavy metals present in those wastes discharged into the River to avert serious pollution of the River.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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