

# Investigation of the Leachate Quality from Waste Dumpsite and Effects on Downstream Water Source

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## ABSTRACT

*This research was carried out on evaluating the quality of leachate from Akpayak waste dumpsite and the effects of its effluent on downstream of Iba Oku stream along Uyo Village Road, Uyo. Samples of leachate were collected using standard procedures at the waste dumpsite together with samples of water mixed with leachate at upstream and downstream of the adjoining stream. These samples were subjected to laboratory analysis using standard procedures for chemical and biological parameters at the University of Uyo Central Laboratory. The results from the laboratory were analyzed statistically. The statistical analysis showed that quality of leachate from waste dumpsite greatly affected the downstream quality of Iba Oku stream particularly, in Na, DO, and COD content of the downstream water. The results showed that mean of Na (27.46), DO (1.73) and COD (23.91) at waste dumpsite were significantly different from that of downstream water with mean of Na (20.79), DO (18.96) and COD (12.19) respectively. Their frequency calculated ( $F_{cal}$ ) values were as follows: Na (223.79), DO (156.52) and COD (426.39). Values for Coefficient of Determination ( $R^2$ ) were 1.00, 0.97, and 0.97 for Na, DO and COD respectively indicating that Na, DO and COD contents of downstream water were significantly different from Na, DO and COD at the waste dumpsite. Also, mean total heterotrophic bacteria was 6.4 while mean total coliform count was 126.7 indicating high faecal contamination of the downstream water which can cause serious health hazard like malaria, typhoid fever etc. As such, it was concluded that downstream water of Iba Oku stream is highly contaminated due to the influence of Akpayak waste dumpsite.*

## 1. INTRODUCTION

Leachate is a contaminated liquid emanating from the bottom of a waste dumpsite and which contains soluble organic and inorganic compounds as well as suspended particles. It can be formed through precipitation, through the waste itself, cover material, or reaction as the waste decomposes. Leachate varies widely in composition regarding the age of the dumpsite, type and content of the waste. It usually contains both dissolved and suspended materials. A typical environment consists of land, air and water, in each of these three components, there are living things (plants, animals and humans), which inhabit each component of the environment at different levels.

Apart from air which is among these three components of the environment, water is a very important resource to man. Akwa Ibom State is blessed with numerous networks of streams and rivers which play a major role in her development. They provide easy means of transportation, occupational activities, and means of waste disposal and source of food. They are also major sources of irrigation which aids in boosting agricultural yields. Its presence is accepted without question and its importance is only really appreciated when there is a shortage of it (Merit, 1996). It is only when we are deprived of it that we can truly appreciate its value (Dada, 1996). Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005). Water pollution is a major problem in the global context, and it has been reported that it is the leading worldwide cause of deaths and diseases (FAO, 1990). Water is life and if government is interested in securing lives and properties, then the provision of potable water should be paramount to any responsible government (Alierio, 2005).

According to Harmmer and Harmmer Jnr (1996), the amount of heavy metals contained in leachate is beyond the required limit in human system, which could lead to cancer, nervous disorder, lack of bladder control etc. Many towns and villages have suffered adversely from water pollution resulting from municipal waste discharged into the water bodies especially river and stream water. Poor quality of water affect both plant and soil and can lead to a decrease in crop yields and possible health hazards to the consumers of the produce (Oyedode, 1999). It was observed that leachate contributed a major pollution, comprising 90% of heavy metals, toxic chemicals like Lead (Pb), Iron (Fe), Calcium (Ca) etc in River Galveston in USA (Nwagozie and Ogele, 1996).

Chapman and Hall (1992) also observed that the health risk is greater when polluted water sprays directly on the crops rather than flooding around the base of the plants. Water related diseases sometimes, are the major causes of mobility and mortality. Malaria, diarrhoea and guinea worm, all contributed in posing serious threats to public health (APHA, 1995). In Nigeria, many deaths have been reported arising from cholera, typhoid and other epidemics, which are water-borne diseases, hence, increases the need for quality clean water (FEPA, 1991). FAO (1990) reported that the high bacterial counts recorded in leachate from waste dumpsite and eventually its effects on the river quality is attributed to the surface run-off and various human activities like faecal inputs into the water bodies. It was also stated that the high level of microbial pollution observed in some river water indicates that such river is likely to sustain high growth of pathogenic organisms that causes diseases.

The objective of this study therefore, is to investigate the quality of leachate from waste dumpsite and its effects on downstream water source. This is important in identifying the chemical and biological properties of this water source and through this, proper treatment of this water to suit its intending purposes before use could be recommended to save lives.

## 2. METHODOLOGY

### Study Site

The study was conducted at Akpayak waste dumpsite in Uyo Local Government Area, Akwa Ibom State, Nigeria. Its coordinates are Longitude  $7^{\circ} 56' 25.67''\text{E}$  to  $7^{\circ} 57' 0.34''\text{E}$  and Latitude  $4^{\circ} 56' 37.37''\text{N}$  to  $4^{\circ} 56' 26.89''\text{N}$  at an altitude 80 m. The site is used by Environmental Sanitation Agency as well as inhabitants of the area for waste disposal. Most of the wastes disposed are domestic and household wastes. This dumpsite has been receiving waste for a period of over twenty years and is operated as an open waste dumpsite. Leachate from this waste dumpsite is discharged through an outlet to Iba Oku Stream which the inhabitants of the area fetches water in the environment.

## Research Design

The research design involved investigation, fact finding and experimental analysis of the samples collected using laboratory equipment.

## Collection and Analysis of Samples

Samples for chemical and biological analyses were collected at three points to include waste dumpsite (S1), upstream (S2) and downstream (S3) for three months: August, September and October 2014. The samples were collected under aseptic conditions using 200ml screw-capped sterile bottles, corked and properly labelled and then transported to the laboratory for chemical and biological analyses. The samples collected were analyzed following quality control protocols for water quality analysis as recommended by APHA (1995). All field and laboratory determination were done according to standard methods for the examination of samples collected. The following parameters were analyzed; pH, Conductivity, TDS, DO, COD, BOD<sub>5</sub>, Sulphate, Chloride, Calcium, Alkalinity, Iron, Copper, Lead, Zinc, Sodium, Nitrate, Hardness, Acidity, Ammonium, Temperature, Total Heterotrophic Plate and Total Coliform Count.

## Statistical Analysis

Data collected were analyzed using descriptive statistics (range, mean, standard deviation) and Analysis of Variance (ANOVA) at 95% level of confidence. Also, simple regression analysis was employed to examine the effects of parameters from waste dumpsite on the quality of downstream water.

## 3. RESULTS AND DISCUSSION

### Chemical Properties of the Soil

The results of the analysis showing the range and mean of chemical parameters at various stations (S1, S2 and S3) are presented in Table 1 while the ANOVA table showing the chemical parameters at stations S1, S2 and S3 is shown in Table 2.

### Zinc Concentration

The downstream had the highest mean zinc, followed by dumpsite while upstream had the least. For downstream to have the highest zinc indicates that zinc content came from several sources other than the dumpsite alone (Table 1). Analysis of the variance (ANOVA) revealed that the  $F_{cal}$  for zinc was 704.83 greater than the critical value at  $P > 0.05$  indicating that the zinc content at dumpsite, upstream and downstream was significantly different from each other.

### Copper Concentration

Copper results revealed that the dumpsite had the highest copper content, followed by downstream while upstream had the least. The highest copper found in the dumpsite may be attributed to the copper content of the waste materials. It is an indication that high accumulation of waste especially solid waste increases the concentration of copper. Downstream had the second highest copper; this revealed that there was large volume movement of copper concentration from the dumpsite.  $F_{cal}$  for copper was 357.77, far greater than critical value even at  $P > 0.01$  confirming that copper of the three sample stations were significantly different from each other.

**Table 1: Range, Mean and Standard Deviation Values of the Chemical Parameters**

Parameters	Dumpsite (S1)	Upstream (S2)	Downstream (S3)
Zinc $\text{mg l}^{-1}$	0.270 – 0.290 $0.280 \pm 0.020$	0.096 – 0.099 $0.097 \pm 0.002$	0.290 – 0.300 $0.294 \pm 0.006$
Copper $\text{mg l}^{-1}$	0.086 – 0.098 $0.092 \pm 0.006$	0.014 – 0.025 $0.019 \pm 0.006$	0.046 – 0.068 $0.056 \pm 0.011$
Lead $\text{mg l}^{-1}$	0.225 – 0.244 $0.234 \pm 0.010$	0.091 – 0.104 $0.097 \pm 0.007$	0.323 – 0.347 $0.334 \pm 0.012$
Sodium $\text{mg l}^{-1}$	24.82 – 29.72 $27.45 \pm 2.471$	5.650 – 7.340 $6.577 \pm 0.857$	17.20 – 23.80 $20.70 \pm 3.340$
DO $\text{mg l}^{-1}$	1.633 – 1.834 $1.730 \pm 0.101$	5.675 – 7.320 $6.592 \pm 0.839$	16.30 – 21.30 $18.99 \pm 2.506$
COD $\text{mg l}^{-1}$	21.76 – 26.45 $23.95 \pm 2.361$	3.700 – 5.870 $4.680 \pm 1.100$	10.24 – 14.00 $12.19 \pm 1.884$
BOD <sub>5</sub> $\text{mg l}^{-1}$	26.29 – 29.47 $27.70 \pm 1.620$	4.580 – 6.330 $5.543 \pm 0.888$	11.43 – 16.40 $14.09 \pm 2.504$
Hardness $\text{mg l}^{-1}$	184.00 – 193.20 $188.73 \pm 4.606$	15.50 – 19.60 $17.63 \pm 2.055$	44.00 – 56.60 $50.51 \pm 6.317$
Acidity $\text{mg l}^{-1}$	1300 – 1395 $1355 \pm 49.24$	11.05 – 16.50 $13.58 \pm 2.745$	60.00 – 74.50 $66.90 \pm 7.275$
Chloride $\text{mg l}^{-1}$	21979 – 24470 $22933 \pm 13440$	121.5 – 129.5 $125.8 \pm 4.034$	271 – 285 $275.8 \pm 7.636$
TDS $\text{mg l}^{-1}$	3.330 – 5.300 $4.277 \pm 0.987$	0.100 – 0.600 $0.330 \pm 0.250$	0.330 – 1.320 $0.860 \pm 0.500$
Alkalinity $\text{mg l}^{-1}$	8400 – 8980 $8693 \pm 2900$	43.10 – 51.30 $47.20 \pm 4.100$	93.33 – 118.9 $106.8 \pm 12.84$
Iron $\text{mg l}^{-1}$	4.170 – 5.800 $5.057 \pm 0.824$	0.985 – 1.350 $1.157 \pm 0.183$	2.503 – 4.460 $3.471 \pm 0.979$
Sulphate $\text{mg l}^{-1}$	2.970 – 4.240 $3.580 \pm 0.636$	0.120 – 1.700 $0.710 \pm 0.863$	0.440 – 4.750 $2.080 \pm 2.332$
Nitrate $\text{mg l}^{-1}$	5.198 – 7.430 $6.288 \pm 1.117$	1.500 – 1.950 $1.717 \pm 0.225$	3.610 – 6.040 $4.800 \pm 1.216$
Ammonium $\text{mg l}^{-1}$	7.475 – 9.250 $8.360 \pm 0.888$	0.144 – 0.412 $0.303 \pm 0.141$	1.035 – 1.397 $1.236 \pm 0.184$
Calcium $\text{mg l}^{-1}$	1282 – 1374 $1329.5 \pm 45.77$	21.60 – 28.30 $25.10 \pm 3.360$	52.10 – 63.10 $57.94 \pm 5.528$
Temperature $^{\circ}\text{C}$	26.60 – 26.80 $26.70 \pm 0.115$	26.10 – 26.70 $26.30 \pm 0.320$	26.40 – 26.60 $26.50 \pm 0.115$
pH	9.100 – 11.40 $6.20 \pm 1.150$	6.700 – 8.300 $5.460 \pm 0.800$	8.400 – 13.60 $5.70 \pm 2.890$
Conductivity $\text{uscm}^{-1}$	1130 – 11980 $7997 \pm 6828$	42.00 – 48.00 $45.30 \pm 3.055$	96.00 – 105.00 $101.00 \pm 4.580$

### Lead Concentration

Lead results showed that, downstream had the highest lead content followed by dumpsite while upstream had the least. The lead content at downstream may be attributed to several sources other than dumpsite because the concentration of lead at dumpsite was lower than that at the downstream. F-ratio 2427.1 for lead confirmed that lead content of the three sampling stations was significantly different from each other.

**Sodium Concentration**

From Sodium results, the dumpsite had the highest sodium concentration followed by downstream while upstream had the least. The results revealed that the sodium content of the water situated closer to dumpsite might be influenced negatively by salinity level of the dump residue. As such, dump deposition near water source and farming land is not encouraging as it can result on high salt content of soils and water bodies. Analysis of variance also revealed that sodium content of one sample site was significantly different from that of the others ( $F_{cal} = 223.79$ ).

**Dissolved Oxygen Concentration**

Results of dissolved oxygen revealed that downstream had the highest dissolved oxygen followed by upstream while the dumpsite had the least. The least dissolved oxygen found at dumpsite may be due to the fact that dissolved is associated with liquid medium. As such, liquid media had higher dissolved oxygen than solid media.  $F_{cal}$  showed that there was significant difference in dissolved oxygen content of the three sampling stations.

**Table 2: ANOVA Table for Chemical Parameters**

Parameters	MSE	MST	LSD (0.05)	$F_{cal}$	SIG.
Zinc $\text{mg l}^{-1}$	3.431	0.024	0.0117	704.83	XX
Copper $\text{mg l}^{-1}$	8.222	0.003	0.0057	357.77	XX
Lead $\text{mg l}^{-1}$	1.181	0.029	0.0069	2427.1	XX
Sodium $\text{mg l}^{-1}$	1.072	239.91	0.0057	223.79	XX
DO $\text{mg l}^{-1}$	1.061	166.08	2.058	156.52	XX
COD $\text{mg l}^{-1}$	0.507	215.96	1.422	426.39	XX
BOD <sub>5</sub> $\text{mg l}^{-1}$	0.515	289.66	1.433	562.80	XX
Hardness $\text{mg l}^{-1}$	3.0703	18557	3.501	6043.9	XX
Acidity $\text{mg l}^{-1}$	501.5695	1289109	44.746	2570.2	XX
Chloride $\text{mg l}^{-1}$	450104.2	3880715	1340.43	862.18	XX
TDS $\text{mg l}^{-1}$	0.1232	10.426	0.7013	84.65	XX
Alkalinity $\text{mg l}^{-1}$	19830.46	55758	281.36	2811.7	XX
Iron $\text{mg l}^{-1}$	0.1268	8.3200	0.712	65.61	XX
Sulphate $\text{mg l}^{-1}$	1.0375	4.5545	2.035	4.39	NS
Nitrate $\text{mg l}^{-1}$	0.2050	11.9540	0.906	58.17	XX
Ammonium $\text{mg l}^{-1}$	0.1504	43.044	0.775	286.11	XX
Calcium $\text{mg l}^{-1}$	444.3326	1250206	42.116	2813.7	XX
Temperature $^{\circ}\text{C}$	0.0167	0.0875	0.258	5.25	X
Ph	1.1858	11.2367	2.176	9.48	X
Conductivity $\text{usc m}^{-1}$	11645375.9	471667	6818.12	4.05	NS

**Note:**

MSE	=	Mean Square of Error
MST	=	Mean Square of Treatment
LSD	=	Least Significant Different at 5% Level
$F_{cal}$	=	Frequency Calculated
$F_{cal}$ at 5%	=	5.41
$F_{cal}$ at 1%	=	12.10
NS	=	Non Significant
X	=	Significant at 1%
XX	=	Significant at 5%

## Chemical Oxygen Demand (COD) Concentration

Dumpsite had the highest mean COD followed by the downstream while upstream had the least. COD is associated with oxidation process, that is, energy needed in breaking down or decomposing material in the presence of oxygen. The energy is more at where the decomposition process is initiated by oxygen and this was found at the dumpsite. However,  $F_{cal}$  was 426.39 greater than the critical value confirming that even at higher probability; there was a significant difference in the distribution of COD among the three sampling stations.

## Biological Oxygen Demand (BOD<sub>5</sub>) Concentration

From the results, the dumpsite had the highest BOD followed by downstream while upstream had the least. Biological oxygen demand is associated with energy used in breaking down complex substance in the presence of microorganisms. BOD being highest at dumpsite is consistent with the prior expectation because microbes were found in higher quantity in dumpsite due to the waste dumped than in the other stations. For BOD being higher than COD is an indication that most of the decomposition process was carried out by microorganism than oxygen.  $F_{cal}$  for BOD was 562.80 highly significant at 1% level which implies that there was significant difference in the distribution of BOD in the three sampling stations.

## Temperature Concentration

The temperatures of the three points were almost similar. However, dumpsite had the highest temperature followed by downstream while upstream had the least.  $F_{cal}$  was 6.25 significant at 5% indicating that temperature of the three sampling stations were different.

## pH Concentration

pH is a major chemical property of a medium because it tells the degree of acidity or alkalinity of the medium. From the results, downstream had the highest pH followed by dumpsite while upstream had the least.  $F_{cal}$  was 9.48 significant at 5% level. The three sampling stations had their pH below 7 indicating they were acidic in nature. The level of pH can affect the rate of decomposition. Alkalinity may reduce the activities of microorganisms which are responsible for the decomposition process.

## Hardness Concentration

From the results, dumpsite had the highest hardness followed by the downstream while the upstream had the least. Hardness of water is as a result of the concentration of dissolved calcium salt in water. The highest hardness experienced at the dumpsite may be attributed to the highest concentration of the salt at the dumpsite followed by the downstream. It therefore follows that if the dump are exposed directly to water body or very close to it, the hardness level of such water will be so high and such water may not be good for domestic purpose like drinking and washing.

## Acidity Concentration

From the results, the dumpsite had the highest acidity followed by the downstream while the upstream had the least. This acidity is influenced by the concentration of microelement commonly referred to as "heavy metals" in a solution. The results is a reflection that much Zn, Cu, Al, Mn, and other heavy metals were found at the dumpsite compared to other stations, hence, the highest acidity is recorded at the dumpsite.  $F_{cal}$  was 2570.2 significant at 1% which implies that the Acidity at one point was much different from acidity at the next point.



## Conductivity Concentration

From the results, the dumpsite had the highest conductivity followed by downstream while upstream had the least.  $F_{cal}$  was 4.05 not significant at 5% level indicating that the conductivity of solution from one point was not different from conductivity solution from the other stations. Generally, the conductivity of the three stations was low. However, it shows that the solution from each station was not neutral but each of them could conduct the flow of electric current. It is also confirmation that those solutions were not pure solution of water only but a mixture. This is on the ground that pure water does not conduct electricity meaning that the conductivity depends on the state and type of liquid medium used.

## Chloride Concentration

From the results, dumpsite had the highest chloride content followed by the downstream while the upstream had the least. From  $F_{cal}$  862.18, there was a significant different in chloride of the three sampling stations.

## Alkalinity Concentration

From the results, dumpsite had the highest mean alkalinity followed by downstream while the upstream recorded the least. The high alkalinity of the dumpsite may be attributed to the high concentration of OH and other anions in the soil. It also reflected on the high pH of the waste dumpsite and other stations. The high pH implies low concentration of  $H^+$  in the solution. It can be concluded that the leachates from the dumpsite was more alkaline than others and such property may have negative effect on the health of those who drink or use the water in food preparation.

## Iron Concentration

The results revealed that dumpsite showed superiority over others while the downstream was the second highest with upstream having the least. Analysis of variance revealed that  $F_{cal}$  was 65.61 significant at 5% implying that iron content of the three stations was significantly different. Though iron helps in destroying germs in water, its toxicity increases at higher concentration. With the concentration shown in the results, there may be a problem in drinking water due to high concentration of these elements in the downstream.

## Sulphate Concentration

The results showed that the dumpsite had the highest mean sulphate followed by downstream while the upstream had the least. The presence of sulphate increases the alkalinity content of the leachate and this is not good in drinking water.

## Nitrate Concentration

The results further revealed that the waste dumpsite had the highest mean Nitrate followed by the downstream while the upstream had the least. Nitrate is needed in water for aquatic organisms but is not required in drinking water.  $F_{cal}$  was 58.17 significant at 1% level.

## Ammonium Concentration

Dumpsite had the highest ammonium content, followed by the downstream while the upstream had the least.  $F_{cal}$  was 286.11 highly significant at 1% level confirming that ammonium content of one sample station was different from that of another.

## Calcium Concentration

The results showed that the dumpsite had the highest calcium content followed by the downstream while the upstream had the least. Analysis of variance among the three stations revealed that  $F_{cal}$  of calcium was

84.65, highly significant at different stations. The high calcium content in the dumpsite may be attributed to the components of waste discharged or dumped in the area. Calcium is good for the soil but its concentration in water is the basis for hardness of water and that may reduce the quality of the water compared to standards.

### Total Dissolved Solid Concentration

From the results presented in Table 1, dumpsite had the highest TDS, followed by the downstream while the upstream had the least. The highest TDS observed at the dumpsite may be attributed to high solid found at the waste dumpsite and what was observed in other stations might have been influenced by TDS content of respective stations and not necessarily the TDS of dumpsite.

### Effects of Waste Dumpsite Leachate on Downstream Water

Table 3 shows the regression analysis of the chemical parameters of leachate from the waste dumpsite with chemical parameters of water at the downstream. The level of contamination of the downstream water depend on the concentration of the parameters stated compared to the WHO standards. The concentration of the parameters in the downstream was influenced by the parameters of the leachate from the dumpsite. This assumption is from the basis of the regression analysis. The regression analysis results revealed that 65% of twenty parameters examined in the downstream water were from the waste dumpsite leachate while the remaining proportion (35%) were from other sources like the downstream water itself, soil and atmosphere.

Zinc had a positive coefficient of 0.407 with  $R^2$  of 1.00. This implies that zinc content of downstream water increased as at the zinc content of waste dumpsite leachate increased whereas the coefficient of determination ( $R^2$ ) revealed that 100% (all) of the zinc content of downstream water was explained by the zinc content of the waste dumpsite. Copper also had a positive coefficient of 1.833 with  $R^2$  of 0.96 which was significant. Again, copper content of the downstream water increased as the copper content of the waste dumpsite leachate increased and 96% of the copper content of the downstream water was explained by the copper content of the waste dumpsite leachate whereas the remaining 4% was from other sources.

For lead, the coefficient was significant (0.704) with  $R^2$  of 0.83, which was not significant. The rate of change of sodium content of the downstream water with that of the waste dumpsite leachate given by the coefficient was 1.135 with  $R^2$  of 1.00 indicating that sodium content of the waste leachate had a direct relationship with that of downstream water with sodium content of downstream water being 100% explained by that of the waste dumpsite leachate. Furthermore, DO, COD and BOD contents of the downstream water had a direct relationship with those from the waste dumpsite with coefficient of 24.488, 0.785 and 1.470 for DO, COD and BOD respectively yielding  $R^2$  values of 0.97 for DO and COD respectively and 0.90 for BOD. The effect was significant between DO and COD but not significant in BOD. Temperature coefficient was unitary with  $R^2$  of 1.00 whereas pH had a positive coefficient of 2.050 with  $R^2$  of 0.66 indicating that only 66% of the pH of downstream water was attributed to pH of the waste dumpsite leachate while the remaining 34% was explained by other factors like the pH of the downstream soil and the concentration of other elements in the downstream water.

Alkalinity had a zero intercept (constant), a positive coefficient and  $R^2$  1.00 which was highly significant. Implication of the positive coefficient is that Alkalinity of the downstream water increased and the total (100%) alkalinity level of the downstream was explained by that of waste dumpsite. Similarly, Iron, Sulphate and Nitrate had positive coefficients of 1.171, 0.231 and 1.089 respectively with  $R^2$  values of 0.97, 0.004 and 1.00. The positive coefficient confirms a direct relationship among the three elements between the two variables that effect of sulphate of the waste dumpsite leachate on downstream sulphate was not significant ( $R^2=0.4\%$ ). Only 0.4% of the sulphate in the downstream was explained by sulphate content of



the waste dumpsite leachate while the greatest proportion (99.60%) was explained by other factors. Hence, it can be said that, waste dumpsite does not affect the sulphate content of the downstream river. For ammonium, calcium and hardness, coefficients were still positive indicating a direct relationship (0.204, 0.121 and 1.371 respectively) whereas  $R^2$  values were 0.96, 0.99 and 0.99 for ammonium, calcium and hardness respectively.

The three elements found in the downstream river were significantly explained from the concentration in the waste dumpsite confirming that waste dumpsite affected the ammonium, Calcium and hardness of the downstream water quality. Effect of acidity and chloride contents of the waste dumpsite compare to that of the downstream river was not significant ( $R^2 = 0.88$  and  $0.18$ ). Nevertheless, their coefficients were positive (0.139 and 0.00024). Conductivity on the other hand had a coefficient of 0.0006 with  $R^2$  of 0.90 not significant at 5% level. Total Dissolved Solid (TDS) had a coefficient of 0.495 and  $R^2$  of 0.96. The positive coefficient suggests a direct relationship while the  $R^2$  revealed that TDS of the downstream water was 96% explained by the TDS of the waste dumpsite. From the above results, it has been revealed that the dumpsite leachate affected the properties of the downstream water significantly in some parameters. Another interesting observation was the rate of change of the chemical parameters of the downstream water with that of the waste dumpsite. The coefficients were positive in all the parameters confirming that increase in their concentration in the downstream water where due to increase in their concentration in the waste dumpsite.

**Table 3: Regression Analysis of the Chemical Parameters**

Parameters	A	B	$R^2$
Zinc $\text{mg l}^{-1}$	0.1812	0.407	1.00xx
Copper $\text{mg l}^{-1}$	- 0.113	1.833	0.96xx
Lead $\text{mg l}^{-1}$	0.146	0.704	0.83
Sodium $\text{mg l}^{-1}$	- 16.283	1.135	1.00xx
DO $\text{mg l}^{-1}$	- 23.379	24.488	0.97xx
COD $\text{mg l}^{-1}$	- 6.596	0.785	0.97xx
BOD <sub>5</sub> $\text{mg l}^{-1}$	- 26.618	1.470	0.90
Hardness $\text{mg l}^{-1}$	- 208.220	1.371	0.99xx
Acidity $\text{mg l}^{-1}$	- 121.12	0.139	0.88
Chloride $\text{mg l}^{-1}$	330.870	0.00024	0.18
TDS $\text{mg l}^{-1}$	- 1.252	0.495	0.96xx
Alkalinity $\text{mg l}^{-1}$	0.00	1.00	1.00xx
Iron $\text{mg l}^{-1}$	- 2.450	1.171	0.97xx
Sulphate $\text{mg l}^{-1}$	1.253	0.231	0.004
Nitrate $\text{mg l}^{-1}$	- 2.044	1.089	1.00xx
Ammonium $\text{mg l}^{-1}$	- 0.467	0.204	0.96xx
Calcium $\text{mg l}^{-1}$	- 102.370	0.121	0.99xx
Temperature $^{\circ}\text{C}$	- 0.200	1.00	1.00xx
pH	- 9.249	2.050	0.66
Conductivity $\text{usc m}^{-1}$	95.918	0.0006	0.90

**Note:**

a	=	Constant
b	=	Coefficient
xx	=	Significant at 5% (0.95)
$R^2$	=	Coefficient of Determination

**Comparison of Downstream Water with World Health Organization Standards (2011)**

Table 4 shows the comparison of downstream water quality with World Health Organization Standard (2011). Out of fifteen parameters compared between WHO and water at the downstream, 73.33% was significantly different while 26.67% was not. Specifically, non-significant parameters were: copper with difference of 0.6670, lead with difference of 1.6131, temperature with difference of 0.0109 and pH with difference of 2.7720 all lower than the critical value of 3.841 at 5% level. As such, downstream water is not suitable for consumption.

**Table 4: Comparison of Downstream Water with World Health Organization Standard (2011)**

Parameters	WHO Standard	Downstream	Difference	Significant at 5%
Zinc $\text{mg l}^{-1}$	5.0 – 15	0.290 – 0.300 $0.294 \pm 0.006$	9.4026	XX
Copper $\text{mg l}^{-1}$	0.05 -1.50	0.046 – 0.068 $0.056 \pm 0.011$	0.6670	NS
Lead $\text{mg l}^{-1}$	0.05	0.323 – 0.347 $0.334 \pm 0.012$	1.6131	NS
Sodium $\text{mg l}^{-1}$	120 – 400	17.226 – 23.84 $20.789 \pm 3.337$	220.0842	XX
DO $\text{mg l}^{-1}$	6 – 8	16.324 – 21.30 $18.985 \pm 2.506$	20.5200	XX
BOD <sub>5</sub> $\text{mg l}^{-1}$	4.0	11.428 – 16.400 $14.089 \pm 2.504$	25.4470	XX
Hardness $\text{mg l}^{-1}$	100 – 150	44.00 – 56.60 $50.51 \pm 6.32$	44.3937	XX
pH	6.0 – 8.5	8.40 – 13.60 $11.73 \pm 2.89$	2.7720	NS
Chloride $\text{mg l}^{-1}$	200 – 600	271.00 – 284.60 $275.79 \pm 7.64$	38.5703	XX
TDS $\text{mg l}^{-1}$	500	0.33 – 1.320 $0.87 \pm 0.500$	498.2675	XX
Iron $\text{mg l}^{-1}$	0.1 – 1.0	2.50 – 4.46 $3.47 \pm 0.98$	15.5132	XX
Sulphate $\text{mg l}^{-1}$	200 – 400	0.44 – 4.75 $2.08 \pm 2.33$	295.8544	XX
Nitrate $\text{mg l}^{-1}$	20	3.610 – 6.040 $4.80 \pm 1.22$	11.5520	XX
Temperature $^{\circ}\text{C}$	24 -28	26.40 – 26.60 $26.50 \pm 0.115$	0.0109	NS
Conductivity $\text{usc m}^{-1}$	40	96.00 – 105.00 $101.00 \pm 4.580$	93.025	XX

**Biological Parameters of Leachate from Dumpsite and Water at Other Stations**

The results of the analysis of biological parameters of leachate from waste dumpsite and water from other stations are as presented in Tables 5, 6 and 7. Also, the statistical analysis of biological parameters of leachate from waste dumpsite as well as water from other stations is presented in Table 8. Then the comparison of total heterotrophic bacteria and total coliform count is as presented in Table 9.

**Table 5: Results of the Biological Parameters of Leachate from Dumpsite and Water at Other Stations for the Month of August**

BIOLOGICAL PARAMETERS	Dumpsite	Upstream	Downstream
Total heterotrophic plate count cfu/ml	$9.5 \times 10^3$	$5.0 \times 10^3$	$6.5 \times 10^3$
Total coliform count cfu/100ml	180	90	150

**Table 6: Results of the Biological Parameters of Leachate from Dumpsite and Water at Other Stations for the Month of September**

BIOLOGICAL PARAMETERS	Dumpsite	Upstream	Downstream
Total heterotrophic plate count cfu/ml	$8.2 \times 10^3$	$4.0 \times 10^3$	$4.5 \times 10^3$
Total coliform count cfu/100ml	160	50	70

**Table 7: Results of the Biological Parameters of Leachate from Dumpsite and Water at Other Stations for the Month of October**

BIOLOGICAL PARAMETERS	Dumpsite	Upstream	Downstream
Total heterotrophic plate count cfu/ml	$9.0 \times 10^3$	$6.0 \times 10^3$	$8.2 \times 10^3$
Total coliform count cfu/100ml	180	120	160

**Table 8: Statistical Analysis of Biological Parameters of Leachate from Dumpsite and Water from other Stations**

MONTHS	Dumpsite		Upstream		Downstream	
	Total Het. Bact. $\times 10^3$ (cfu/ml)	Total coliform count (MPN/100ml)	Total Het. Bact. $\times 10^3$ (cfu/ml)	Total coliform count (MPN/100ml)	Total Het. Bact. $\times 10^3$ (cfu/ml)	Total coliform count (MPN/100ml)
August	9.5	180	5.0	90	6.5	150
September	8.2	160	4.0	50	4.5	70
October	9.0	180	6.0	120	8.2	160
Mean	8.9	173.3	5.0	86.7	6.4	126.7
Standard Deviation	0.66	11.53	1.5	35.12	1.85	49.33

**Table 9: Comparison of Total Heterotrophic Bacteria and Total Coliform Count at various Stations**

Sample Points	Total Heterotrophic Bacteria	Total Coliform Count
Dumpsite	8.9	173.3
Upstream	5.0	86.7
Downstream	6.4	126.7

From the results in the analysis of biological parameters, the total heterotrophic plate counts of the samples collected from waste dumpsite, upstream and downstream were very high. Comparing these results with the World Health Organization Standards (2011), the coliform count indicate that the acid content is very high which in any case is hazardous to the plant and the environment. Also, the results showed that the bacteria content of the samples collected in September has reduced though treatment of the water. In

August, compared to other months, both the total heterotrophic plate count and that of total coliform count is highly concentrated. These results therefore suggest that the amount of rainfall has played a role in the high contamination in the environment. Finally, the water from these sources is not good for consumption. As such, appropriate treatment measures should be given before use.

## 4. CONCLUSION

In conclusion, the degree of contamination of Iba Oku River is high due to the presence of heavy metals, faecal contamination and other toxic chemicals which is traceable to the waste dumpsite. Specifically, the concentration of leachate in waste dumpsite was very high compare to that at the downstream water except in parameters like sulphate, chloride and pH. The concentration of leachate in downstream water was significantly explained by the concentration of leachate at the waste dumpsite. Again, quality of downstream water was far below the WHO standards implying that the downstream water is not suitable for consumption. Also, the high concentration of total heterotrophic bacteria and total coliform count in the downstream water is an indication that the water can cause serious health hazard like typhoid fever, bacillary dysentery, cholera, diarrhea and malaria.

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