Impact of Municipal Dumpsite on Neighbouring Boreholes

ABSTRACT

This study was carried out to assess the impact of a municipal dumpsite on the quality of nearby boreholes. The dumpsite waste was characterized to ascertain the individual components. Leachate sample was taken from the bottom of the dumpsite and analysed for relevant physicochemical parameters. Water samples were collected from seven selected boreholes and analysed for relevant water quality parameters. Water quality index was calculated for the monitored boreholes to reveal the quality status of the water. The result of the characterization of dumpsite waste revealed the following: plastic (40%), food waste (14%), tin/can (5%). rubber (4%), textile (4%), yard waste (10%), paper (11%), ash/dirt (2%), leather (0.5%), glass (5%) and wood (4.5%). The leachate analysis gave the following results: pH (9.7), ammonia (3.07mg/l), alkalinity (674.3mg/l), DO (3.9mg/l), total hardness (235.8mg/l), iron (9.08001mg/l), zinc (4.28947mg/l) and BOD_5 (7.2mg/l) that were above WHO and NSDWQ permissible limits, indicating potential for groundwater contamination. Computed water quality index (WQI) for the borehole water samples (with values ranging from 105.17 to 603.58) indicated that the groundwater around the dumpsite is extremely poor and unsuitable for drinking. The developed multiple linear regression model for WQI has an excellent fit to the measured data. The one-way multivariate ANOVA carried out showed no significant variation in water quality with increasing distance from the dumpsite. Therefore, it is concluded that leachate from the municipal dumpsite impacted on the water quality of the underlying neighbouring groundwater.

Keywords: Municipal dumpsite, Borehole, Groundwater, Contamination, Leachate, Water quality index

1. INTRODUCTION

Water of good drinking quality is of basic importance to human physiology, and man's continued existence depends very much on its availability. An average man (of 53kg – 63kg body weight) requires about three litres of water in liquid and food daily to keep healthy (Onweluzo and Akuagbazie, 2010). This fact accounts for why water is regarded as one of the most indispensable substances in life and like air, it is most abundant (Okonko *et al.*, 2008). Increase in human population has exerted an enormous pressure on the provision of safe drinking water, especially in developing countries (Umeh *et al*, 2005). Unsafe drinking water is a global public health threat, placing persons at risk for a host of diarrheal and other diseases as well as chemical intoxication (Hughes and Koplan, 2005). Most of the fresh water bodies all over the world are getting polluted, thus decreasing the portability of water (Chandra *et al*, 2012).

Groundwater is one of the major sources of domestic, agricultural and industrial water supply. In the last few decades, there has been a tremendous increase in the demand for fresh water due to rapid growth of population and the accelerated pace of industrialization. According to WHO, about 80% of all the diseases in humans are caused by poor quality water. Groundwater, which is in aquifers beneath the earth surface, is considered the most important natural resource to mankind. In the past few decades, due to population growth, rapid urbanization and industrialization, groundwater quality has witnessed deterioration, especially in developing countries. As groundwater is an important part of the hydrological cycle, it is more prone to various sources of contamination (Soujanya, 2016). In general, the quality of groundwater varies with the location, geology, type, and quantity of dissolved ions present in it. According to Fatta et al. (1999), dumpsites have been identified as one of the major threats of groundwater resources, thus, groundwater located near a dumpsite is likely to be polluted due to the leachate produced from it.

Dumpsite is a widespread land disposal area generally known for its common features being exposed directly to the atmosphere or covered improperly with soil layer and without proper bottom liner support. These features could significantly contribute to pollution and contamination of the total environment. Dumpsite could adversely affect the general condition of our atmosphere, exosphere and hydrosphere. Interestingly, an open dumpsite attracts flies and other insects that would cause diseases and considerably affect people's health. Individuals who stay in close proximity to the dumpsite, especially the scavengers who often come in contact with dumped waste, are prone to develop health disorders. Dumpsites receive a mixture of municipal, commercial and mixed industrial wastes. Studies on the effects of unlined waste dumps on the host soil and underlying shallow aquifers have shown that soil and groundwater system can be polluted due to poorly designed waste disposal facilities (Amadi et al., 2012).

Waste disposal management remains one of the major challenges in the developing countries. Wastes, if not properly disposed of, could lead to contamination of surface water and groundwater in its immediate environment. The most important issue today is groundwater contamination, and among the wide diversity of contaminants affecting water resources, heavy metals are of particular concern, considering their high toxicity even at low concentration. In recent times, the impact of leachates on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental importance. Groundwater is the most economic source of potable water for urban, semi-urban and rural areas in Nigeria because of its known advantages over surface water. The progressive degradation of groundwater quality via human activities particularly from waste dumpsites, if unchecked, will greatly affect it usability. Therefore, this study was designed to determine the significant impact of dumpsite on selected boreholes within the vicinity of a dumpsite and beyond in order to determine the quality of the groundwater in the area.

2. MATERIALS AND METHODS

2.1 Study Area

The study area was Igbogo Road situated between latitude 4^{o}53´37.272´´ N and longitude 6^{o}54´46.236´´E along Port Harcourt East West Road in Obio-Akpor Local Government Area of Rivers State, Nigeria (Figure 1). Due to the presence of the federal university in the surrounding area, the population of Igbogo is gradually increasing and this has resulted in high demand for sundry uses of water. Boreholes are preferred to surface water by the people and this has led to uncontrolled abstraction of groundwater resources in the area. Consequently, the large population and industrialization has resulted to increased waste generation. The official dumpsite for commuters in this area is a piece of bare land off the highway at the entrance of the road. This piece of land has served this purpose of dumpsite for some years now.

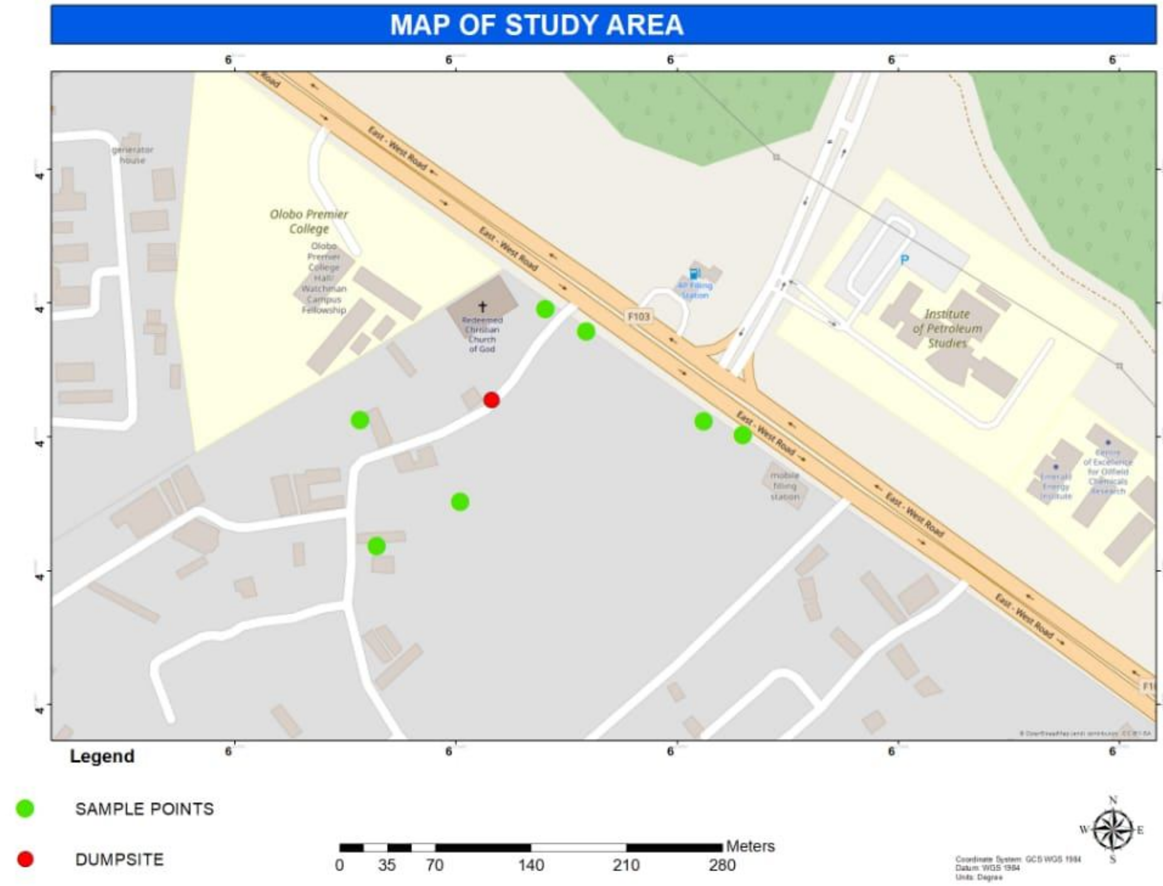

Figure 1: Map of Igbogo Road dumpsite showing sample points

2.2 Dumpsite Waste Characterization

Samples of municipal solid wastes from the waste stream at Igbogo Road dumpsite was manually and randomly collected, identified, sorted, characterized and weighed. For the classification of waste, eleven waste components were considered. These are food, paper, tin/can, glass, rubber, plastic, textiles, yard waste, ash/dirt, leather and wood. Sorting and weighing of collected waste was done at the dumpsite. The materials and resources used at the dumpsite for data generation were sorting platform, an electronic scale for weighing the waste, bins for all sorted categories, gloves, and a calculator. The determination of the individual component of the solid waste in the dumpsite was carried by Quartering method.

2.3 Dumpsite Leachate Analysis

Leachate sample was obtained from the bottom of the dumpsite. Plastic container of 200 ml was used to collect leachate sample. Before the collection of the sample, the container was washed with acid water in order to sterilize it, and thereafter thoroughly rinsed with distilled water. The collected sample was tightly closed and well labelled. The sample was preserved at 4ºC and thereafter taken to the laboratory for analysis. It was analyzed for relevant physicochemical parameters following the internationally accepted procedures and standard methods of American Public Health Association (APHA) and American Standard Testing Method (ASTM). The leachate sample was also analyzed for total coliform.

2.4 Collection of Borehole Water Samples

Groundwater samples were obtained from existing surrounding boreholes close to and far away from the dumpsite. The samples were taken north, south, east and west of the dumpsite. A total of seven borehole water samples were collected. Plastic containers of 200ml were used to collect the groundwater samples. Before the collection of the samples, the containers were washed with acid water in order to sterilize them, and thereafter thoroughly rinsed with distilled water. The collected samples were tightly closed and well labelled. The samples were preserved at 4ºC and thereafter taken to the laboratory for analysis. Table 1 presents the coordinates of the borehole water sampling points.

Table 1: Borehole water sampling points

Sample	Location	Latitude	Longitude	Distance from dumpsite
BH1	North of dumpsite	4º53´34.54462´´ N	6º54´45.63054´´ E	77metres
BH2	East of dumpsite	4º53´39.12198´´ N	6º54´47.64258´´ E	77metres
BH3	South of dumpsite	4º53´38.56956´´ N	6º54´48.62074´´ E	86metres
BH4	North of dumpsite	4º53´36.5028´´ N	6º54´43.24331´´ E	96metres
BH5	North of dumpsite	4º53´33.50317´´ N	6º54´43.63045´´ E	140metres
BH6	West of dumpsite	4º53´36.47054´´ N	6º54´51.36926´´ E	160metres
BH7	West of dumpsite	4º53´36.13351´´ N	6º54´52.3197´´ E	190metres

2.5 Analysis of Borehole Water Samples

Seven borehole water samples were collected and analyzed for relevant water quality parameters following the internationally accepted procedures and standard methods of APHA and ASTM. Table 2 presents the monitored water quality parameters. The parameters selected were based on the leachate analysis; the highest leachate constituents were used.

Table 2: Monitored water quality parameters

Parameter	Unit
pH	NS
Turbidity	NTU
Iron	mg/l
Dissolved oxygen (DO)	mg/l
Zinc	mg/l
Alkalinity	mg/l
Ammonia	mg/l

2.6 Calculation of Water Quality Index (WQI)

Seven important parameters were chosen for the calculation of WQI (See Table 2). The WQI was calculated using standards of drinking water quality recommended by the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ). The weighted Arithmetic index method was used for the calculation of WQI. Further, quality rating or sub-index was calculated using Equation (1).

$$q_n = \frac{100[V_n - V_{io}]}{[S_n - V_{io}]} \qquad (1)$$

where q_n is the quality rating for the n^{th} water quality parameter, V_n is the estimated value of the n^{th} parameter at a given water sampling station, S_n is the standard permissible value of the n^{th} parameter, V_{io} is the ideal value of n^{th} parameter in pure water (i.e., 0 for other parameters except for pH and DO having 7.0 and 14.6mg/l, respectively). The unit weight was calculated by a value inversely proportional to the recommended standard value of Sn of the corresponding parameter, using Equation (2).

$$W_n = {}^{k}/_{S_n} \qquad (2)$$

where W_n is the unit weight for the n^{th} parameter, S_n is the standard permissible value for n^{th} parameter and k is the proportionality constant. The overall WQI was calculated using Equation (3):

$$WQI = \frac{\Sigma q_n W_n}{\Sigma W_n} \qquad (3)$$

2.7 Model Development

A multiple linear regression model was used to develop a mathematical equation describing the impact of pH, turbidity and iron on the quality of groundwater (using WQI). The general form of the multiple regression is represented by Equation (4)

$$y = a_0 + a_1x_1 + a_2x_2 + a_3x_3 \qquad (4)$$

Equation (4) was used to derive normal equations (Equation (5)) to estimate the values of a_0, a_1, a_2 and a_3.

$$\left.\begin{aligned} a_0n + a_1\Sigma x_1 + a_2\Sigma x_2 + a_3\Sigma x_3 &= \Sigma y \\ a_0\Sigma x_1 + a_1\Sigma x_1^2 + a_2\Sigma x_2x_1 + a_3\Sigma x_3x_2 &= \Sigma yx_1 \\ a_0\Sigma x_2 + a_1\Sigma x_1x_2 + a_2\Sigma x_2^2 + a_3\Sigma x_3x_2 &= \Sigma yx_2 \\ a_0\Sigma x_3 + a_1\Sigma x_1x_3 + a_2\Sigma x_2x_3 + a_3\Sigma x_3^2 &= \Sigma yx_3 \end{aligned}\right\} \qquad (5)$$

where y is the estimated dependent variable (WQI) and x_1, x_2 and x_3 are the independent variables (pH, turbidity and iron respectively).

2.8 Statistical Analysis

Water quality measurements from the borehole samples monitored around the dumpsite were compared statistically using one-way multivariate analysis of variance (ANOVA) to check for any significant difference between them.

3. RESULTS AND DISCUSSION

3.1 Dumpsite Waste Characterization

Table 3 presents the results of the physical characterization of dumpsite waste. The dumpsite is composed mainly of plastics, with the fraction of leather as the least in the total composition. This high percentage of plastic (40%) poses a real threat to the environment, especially to groundwater, as toxic chemicals can leach out of them and seep into groundwater. Human exposure to these toxic chemicals can also be linked to cancers, birth defects, impaired immunity, endocrine disruption and other ailments.

Table 3: Physical characterization of solid waste

Waste Component	Mass (kg)	Percentage (%)
Food waste	14	14
Tin/can	5	5
Rubber	4	4
Plastic	40	40
Textile	4	4
Yard waste	10	10
Paper	11	11
Ash/dirt	2	2
Leather	0.5	0.5
Glass	5	5
Wood	4.5	4.5
Total	**100**	**100**

3.2 Dumpsite Leachate Analysis

The results of the analysis carried out on the leachate sample of the dumpsite is presented in Table 4. The temperature, pH, iron, TSS, DO, zinc, BOD_5, alkalinity, ammonia, total hardness, and total coliform are not within WHO and NSDWQ permissible limits. The 29.5^{o}C temperature value of the dumpsite leachate depicts resemblance to normal lithospheric temperature, and important in the metabolic activities of microbes that enhance degradation of waste. The pH of 9.7 indicates that the leachate is basic (alkaline). The significance of this pH value is that it can inhibit all biological processes that may be necessary for the natural treatment of the dumpsite waste thereby resulting in incomplete natural treatment and consequent pollution of the surrounding environment. The high pH also indicates that the dumpsite is an old one (Futta *et al*., 1997) and may have witnessed washing away by rainfall or percolated over time into the soil. The high level of iron (9.08mg/l) and zinc (4.29mg/l) in the leachate indicates that iron and zinc scraps may have been disposed of in the dumpsite. The slightly higher level of TSS (3.68mg/l) may not be an issue as filtration by soil will get rid of it before leachate percolates to groundwater. The lower value of DO (3.9mg/l) and the higher values of BOD_5 (7.2mg/l) and total coliform (1.87×10^{2}Cfu/ml) indicate that the dumpsite contains decomposing waste and active microorganisms capable of polluting the groundwater. The high alkalinity (674.3mg/l) of the leachate could be attributed to the agedness of the dumpsite and is correlated with the high pH value. The high value of ammonia (3.07mg/l) obtained provides evidence of its release from decomposition of nitrogenous substances in the waste. Ammonia is highly toxic and lethal to most fish species even at low concentrations. The high value of total hardness (235.8mg/l) of the leachate is an indication of the presence of elements of hardness such as calcium, magnesium, carbonate, etc., and could be transferred to groundwater.

Table 4: Physicochemical properties of leachate sample

Parameters	Values	WHO	NSDWQ
Temperature (^{o}C)	29.5	25	25
pH	9.7	6.5 – 8.5	6.5 – 8.5
E.C (µS/cm)	621.67	1000	1000
Turbidity (NTU)	0.345	5	5
Iron (mg/l)	9.08001	0.3	0.3
TDS (mg/l)	373.5	500	500

TSS (mg/l)	3.68	3	NS
DO (mg/l)	3.9	5.7	NS
Zinc (mg/l)	4.28947	3	3
BOD_5 (mg/l)	7.2	5.9	NS
Alkalinity (mg/l)	674.3	200	200
Ammonia (mg/l)	3.07	0.5	NS
Calcium (mg/l)	13.20514	200	NS
Total hardness (mg/l)	235.8	150	150
Chloride (mg/l)	149.98	250	250
Nitrate (mg/l)	4.23	10	10
Total coliform (Cfu/ml)	1.87×10^2	NS	10

3.3 Borehole Water Analysis

The analysis carried out on the borehole water samples revealed that most of the water quality parameters monitored were within the permissible limits set by WHO and NSDWQ. Figure 2 shows the pH values for all the boreholes analysed compared with WHO and NSWDQ standards. The pH values of the boreholes ranged from 6.38 to 9.39 with borehole 6 having the least pH value and borehole 3 having the highest value, both outside the WHO and NSDWQ permissible range of 6.5 to 8.5, and slightly acidic and alkaline, respectively. It is likely that borehole 3 was affected by the high alkalinity of the leachate, suggesting that leachate flow may have occurred towards south, but borehole 6 was definitely not affected by the alkaline leachate, perhaps by an unknown acidic source. Acidic water can lead to corrosion of metal pipes and plumping system, while alkaline water shows disinfection in water. High pH for drinking water is undesirable since it could impart a bitter taste to the water, and depresses the effectiveness of disinfection by chlorination, thereby requiring the use of additional chlorine or longer contact times.

Turbidity values for the seven boreholes ranged from 0.008 to 0.018NTU. All values are below WHO set permissible value of 5 mg/l as shown in Figure 3. DO values for all the boreholes ranged from 5.1 to 7.4mg/l as shown in Figure 4. The higher the value of DO, the better the water quality, while any value lower than the permissible limit (5.7mg/l) would indicate that the water is unsuitable for drinking. Boreholes 1, 2 and 7 did not meet the set permissible limit of 5.7mg/l, while the rest met the permissible limit. The observed trend does not show that the dumpsite affected the DO of the boreholes.

Figure 5 shows the alkalinity values for all the borehole water samples analysed and the set standards by WHO and NSDWQ. Values for alkalinity ranged from 50.14 to 153.18mg/l, with borehole 7 having the lowest value and borehole 2 having the highest, and all below the WHO and NSDWQ standard of 200mg/l. Considering that the alkalinity of the leachate (674.3mg/l) is about 3.37 times higher than the standard and that the alkalinity of all boreholes are below the standard with the farthest borehole having the least value, it could be inferred that the leachate had negligible impact on the alkalinity of the neighbouring boreholes.

The measured values for ammonia ranged from 0.014 to 0.056mg/l as shown in Figure 6. The values are considerably below the WHO and NSDWQ set limit of 0.5mg/l. The high ammonia value of the leachate (3.07mg/l) does not seem to impact the boreholes as the ammonia values of the boreholes do not follow any implicating pattern.

Figure 7 shows the concentrations of zinc for all the boreholes sampled ranging from 0.48123 to 3.0018mg/l with boreholes 1 and 4 having the lowest and highest concentrations, respectively. All boreholes except borehole 4 have zinc concentrations lower than the permissible limit of 3mg/l set by WHO and NSDWQ. Considering that boreholes 1 to 3 closer to the dumpsite (than borehole 4) had zinc concentrations below the permissible limit, it could be deduced that the slightly higher concentration of zinc at borehole 4 may not come from the dumpsite but likely from another source.

Figure 8 shows the concentrations of iron from the sampled boreholes ranging from 0.51701 to 3.29819mg/l and generally higher than the permissible limit of 0.3mg/l for drinking water set by WHO and NSDWQ. It is possible that the high concentration of iron in the leachate (9.08mg/l) may have impacted on the boreholes, especially towards the east direction.

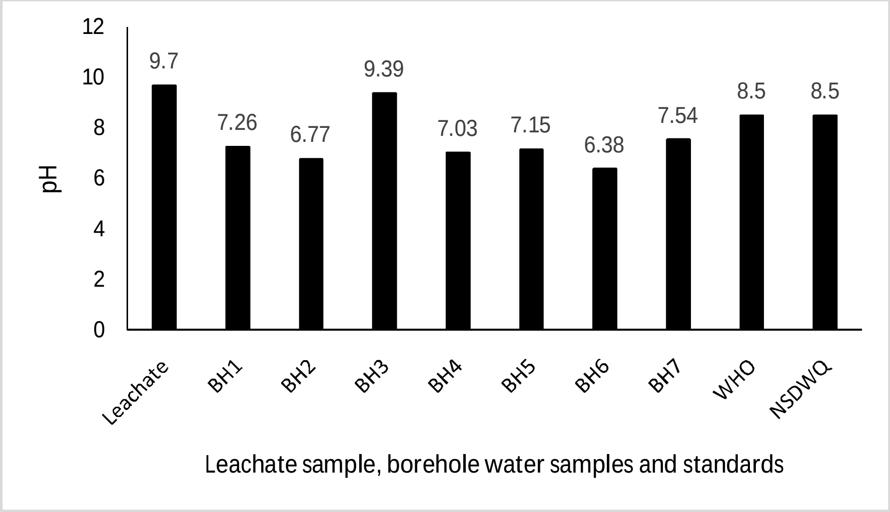

Figure 2: pH levels of dumpsite leachate and borehole water samples and standard for drinking water

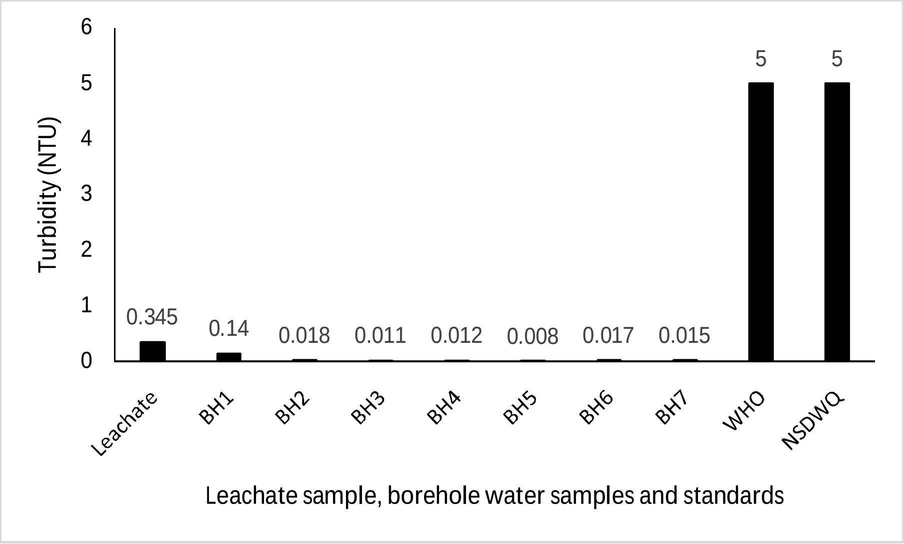

Figure 3: Turbidity levels of dumpsite leachate and borehole water samples and standard for drinking water

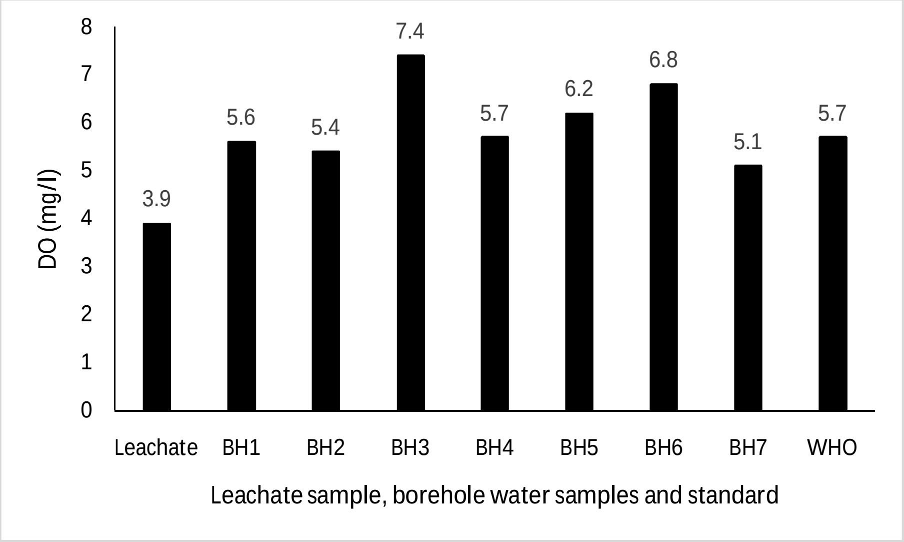

Figure 4: DO levels of dumpsite leachate and borehole water samples and standard for drinking water

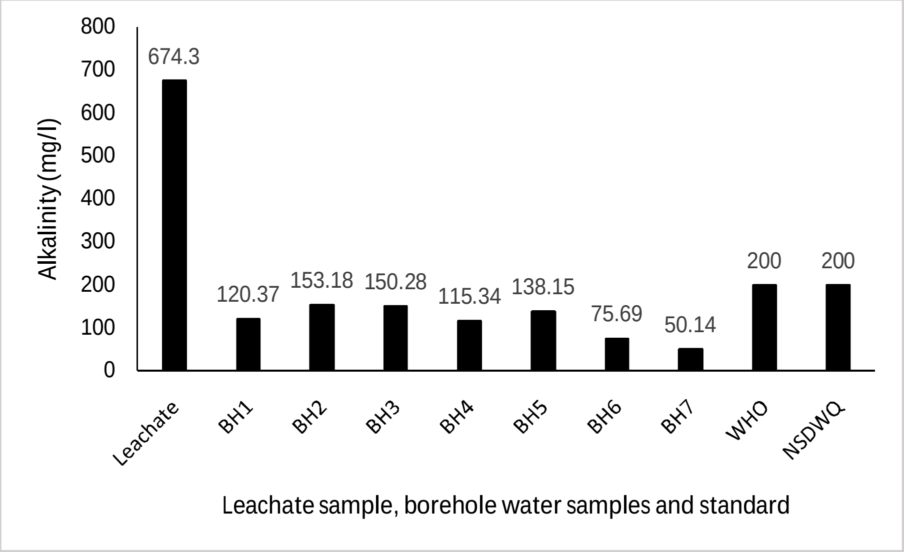

Figure 5: Alkalinity levels of dumpsite leachate and borehole water samples and standard for drinking

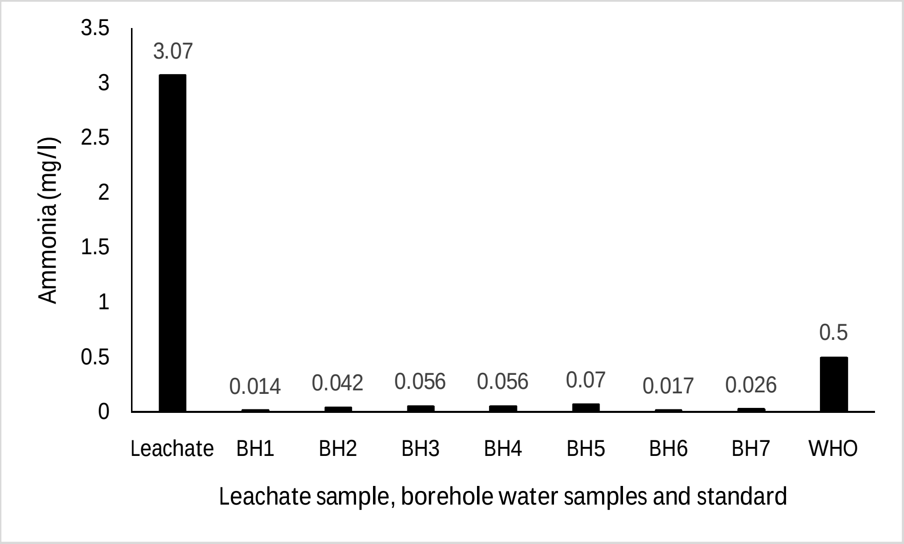

Figure 6: Ammonia concentrations of dumpsite leachate and borehole water samples and standard for drinking

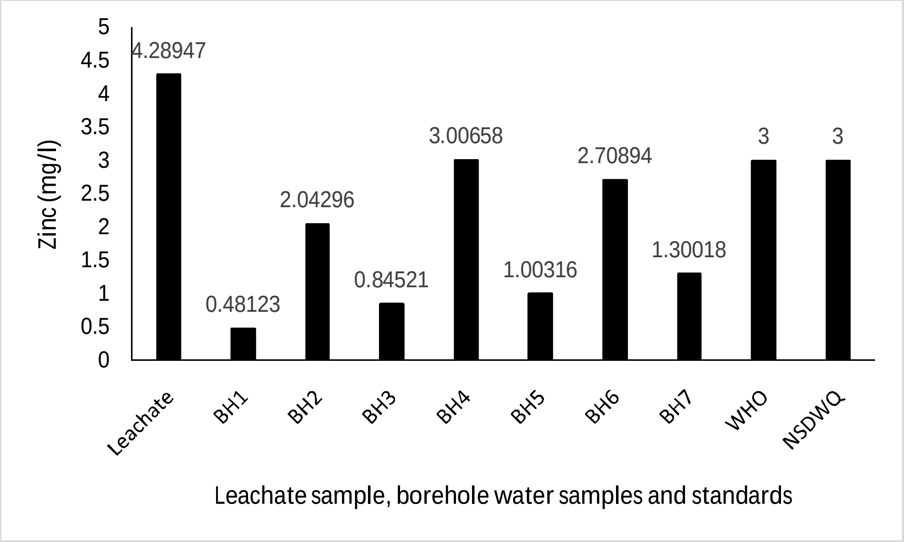

Figure 7: Zinc concentrations of dumpsite leachate and borehole water samples and standard for drinking water

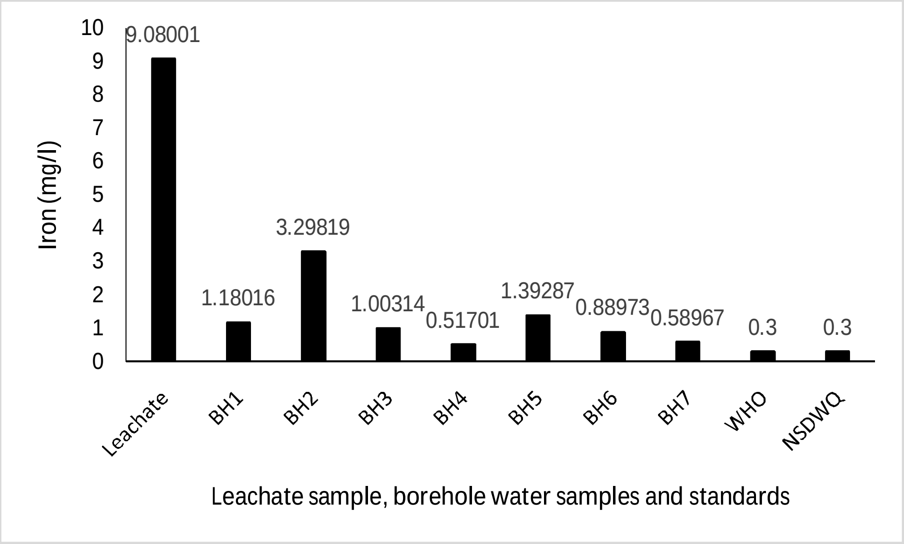

Figure 8: Iron concentrations of dumpsite leachate and borehole water samples and standard for drinking water

3.4 Water Quality Index (WQI)

The estimated WQI values for the seven boreholes are presented in Table 5. The WQI values for all the boreholes show that the quality of the water is unsuitable for drinking. It is likely that the leachate from the dumpsite impacted on the groundwater quality more in the east direction than any other directions (west, north and south), hence the very high WQI in borehole 2 as compared to other boreholes.

Table 5: Water quality index for the seven boreholes

Borehole	WQI	Status
1	217.7497	Unsuitable for drinking
2	603.5833	Unsuitable for drinking
3	196.2364	Unsuitable for drinking
4	105.1749	Unsuitable for drinking
5	260.3335	Unsuitable for drinking
6	168.0941	Unsuitable for drinking
7	114.0905	Unsuitable for drinking

3.5 Statistical Analysis

The data obtained for the monitored boreholes were tested using one-way multivariate ANOVA for similarity in concentrations of water quality parameters. Table 5 shows the values of the multivariate test. The multivariate test tells if there is a significant difference among at least one group across the seven dependent variables (pH, turbidity, DO, alkalinity, iron, zinc and ammonia). It is observed that the Lambda under distance (0.590) is associated to a p-value that is much higher than the significant level (0.05). Therefore, there is no effect of distance on the water quality parameters monitored.

Table 6: Output of multivariate test for concentrations of water quality parameters from the monitored boreholes

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Intercept	Pillai's Trace	.967	29.689^b	1.000	1.000	.116	.967
	Wilks' Lambda	.033	29.689^b	1.000	1.000	.116	.967
	Hotelling's Trace	29.689	29.689^b	1.000	1.000	.116	.967
	Roy's Largest Root	29.689	29.689^b	1.000	1.000	.116	.967
Distance	Pillai's Trace	.861	1.237^b	5.000	1.000	.590	.861
	Wilks' Lambda	.139	1.237^b	5.000	1.000	.590	.861
	Hotelling's Trace	6.186	1.237^b	5.000	1.000	.590	.861
	Roy's Largest Root	6.186	1.237^b	5.000	1.000	.590	.861

a. Design: Intercept + Distance

b. Exact statistic

3.6 Model Development and Validation

Equation (7) shows the model for the prediction of WQI when the pH, turbidity and iron concentrations of borehole water samples around the dumpsite are known.

$$WQI = 9.338 + 0.3pH - 228.232Turbidity + 180.507Iron \qquad (6)$$

Table 6 shows the measured and predicted WQI values which were later plotted against boreholes to check if the predicted WQI will give a good fit to the measured WQI (Figure 9). The observed overlap between the measured and predicted WQI in Figure 9 shows that the developed model has an excellent fit to the measured data.

Table 7: Actual and predicted water quality index

WQI (Actual)	WQI (Predicted)	Residual
217.7497	221.3479	-3.5982
603.5833	602.6072	0.9761
196.2364	190.7182	5.5182
105.1749	102.0321	3.1428
260.3335	261.0799	-0.7464
168.0941	167.9745	0.1196
114.0905	114.6161	-0.5256

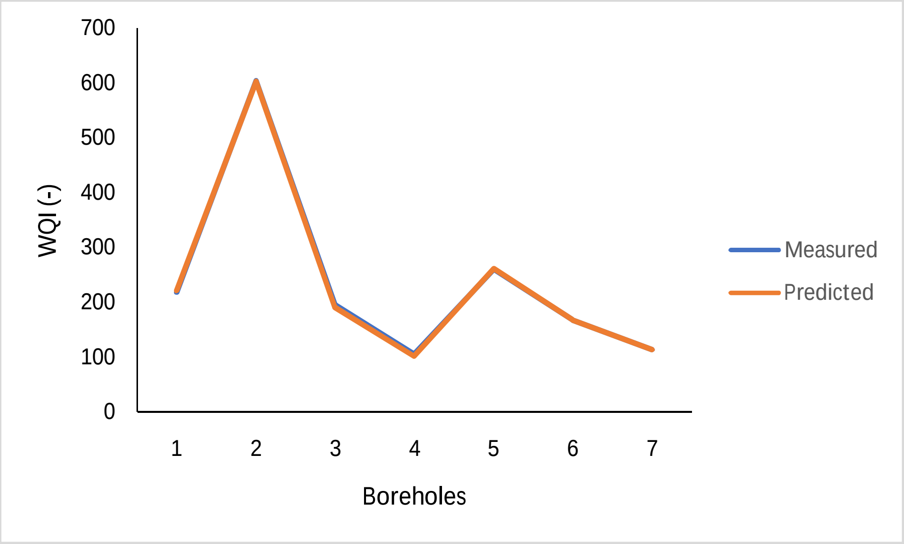

Figure 9: Measured and predicted WQI

4. CONCLUSION

Assessment of the impact of a municipal dumpsite on the quality of nearby boreholes has been conducted. Plastic (40%) dominated the dumpsite waste. The leachate analysis revealed that it has the potential to contaminate the underlying groundwater. Computed water quality index (WQI) for the sampled boreholes gave values ranging from 105.17 to 603.58, indicating that the groundwater around the dumpsite is unsuitable for drinking. The developed multiple linear regression model for WQI has an excellent fit to the measured data. The statistical analysis carried out showed that there is no significant variation in water quality with increasing distance from the dumpsite. Thus, it is concluded that leachate from the municipal dumpsite impacted on the quality of the neighbouring underlying groundwater.

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