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Groundwater Quality Dependence on the Spatial Proximity of Geo-located Dumpsites in Samaru-Nigeria

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ABSTRACT

The coordinates of 10 solid waste dumpsites in proximity to the boreholes and wells in the Samaru community of Kaduna state, Nigeria were acquired with a GPS-enabled smartphone. In addition, 10 groundwater samples in relation to the dumpsites were collected for the testing of 11 physical and chemical parameters of water quality based on the World Health Organisation (WHO) standard limits. The results of the spatial proximity analyses carried out revealed that the requirement for locating dumpsites was not met as specified by the Environmental Protection Agency (EPA) regarding the minimum safe distance from groundwater sources. The results of the study revealed also that a majority (about 90%) of the groundwater samples met the conditions for good drinking water even with their closeness to the dumpsites. However, only Calcium, Dissolved Oxygen, and Biochemical Oxygen Demand concentrations were significantly affected ($p < 0.05$ at the 95% significance level) by the closeness of the solid waste dumpsites to the boreholes and wells with very strong (R^2 = 86%) and strong (R^2 = 79%) relationships, respectively. Suggestions were nonetheless made for investigations into other factors responsible for groundwater contamination.

1. INTRODUCTION

The inability to manage effectively solid waste disposal (Aibor and Olorunda, 2006; Environmental Protection Agency [EPA], 2016; New York State Department of Environmental Conservation [NYSDEC], 2016) has become an issue of great concern in different parts of the world. This is due to the fact that that wastes adversely affect the quality of our food, health, and environment (European Environment Agency [EEA], 2019). Moreover, solid waste dumpsites pollute the underground water sources thereby decreasing their quality as a result of changes to their physical and chemical characteristics (El-Salam and Abu-Zuid, 2015; Simeon, 2009).

The increased quantity of waste in a vast majority of developing countries is as a result of economic growth, industrialisation and urbanisation which is without its attendant problem of waste disposal (Ferronato and Torretta, 2019). As a matter fact, it was estimated that in 2006 the total amount of municipal solid waste (MSW) generated globally reached 2.02 billion tones, representing a 7% annual increase since 2003 (United Nations Environmental Programme [UNEP], 2007).

Arimah and Adinnu (1995) observed that the perceived environmental costs, health-related hazards, social and economic impacts associated with waste dumpsites are often not confined to the immediate environment but extend up to a few kilometres. This is one of the reasons why several research efforts have been carried out in the recent past to manage solid waste in different parts of the world (Abbas *et al.,* 2018; Akinbile and Yusoff, 2011; Pande *et al.*, 2015; Remy *et al.*, 2017; Somani *et al.,* 2019).

It is therefore against this backdrop that this study assessed the quality of groundwater due to the proximity of solid waste dumpsites in Samaru, Kaduna state-Nigeria with a view to proffering proper waste management practices. This is achieved through the identification of dumpsites in proximity to the groundwater sources in the study area and the testing of the leachate concentration from the groundwater

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samples, as well as the determination of the spatial distribution of dumpsites in proximity to the groundwater sources using geospatial techniques. The locations of the dumpsites, boreholes and wells in the study area are shown in Fig. 1.

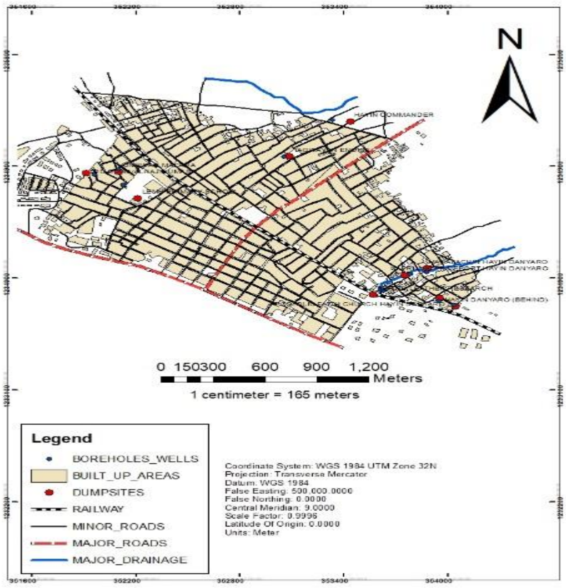

Figure 1. Locations of dumpsites, boreholes, and wells

2. METHOD

2.1. Planning/Reconnaissance

The planning stage involved both the office and field reconnaissance where the choice of relevant data and information (both spatial and attribute data of the dumpsites, boreholes and wells), survey method, and logistics requirements were considered. It also involved the cross-checking of the information obtained as well as determining the number of locations to be surveyed.

2.2. Data Acquisition

The coordinates of the dumpsite, borehole and well locations were acquired using a GPS-enabled smartphone (Tecno WX3 Pro Android Version 7.0) device with an overall average horizontal accuracy to within 13 m (95% of the time) which is consistent with the general accuracy levels observed of recreation-grade GPS receivers in urban environments (Merry and Bettinger, 2019). The attribute information of each dumpsite, borehole and well were obtained on site. Water samples of each of the 10 boreholes and wells in proximity to the dumpsites were also acquired with properly labelled water bottles for testing in the Laboratory.

2.3. Data Processing

The downloaded Google Earth imagery and acquired coordinates (E, N) of the existing dumpsites, boreholes and wells were imported into the ArcGIS 10.3 environment where the reference system (WGS 84, UTM zone 32N) was defined. Thereafter, the digitizing process was carried out with the creation of the dumpsite, borehole, well positions, built-up, roads, railway and drainage layers as shapefiles. The attribute information of the dumpsites, boreholes and wells were added to the attribute table linking the shapefiles in the ArcGIS environment to create the geo-database.

The collected water samples were tested for 11 (Temperature, pH, Electrical Conductivity [EC], Dissolved Oxygen [DO], Chloride, Hardness, Total Dissolved Solids [TDS], Calcium, Nitrate, Turbidity, and Biochemical Oxygen Demand [BOD]) physical and chemical properties according to the WHO (2017) standard for water quality in the Water Resources and Environmental Engineering laboratory in Ahmadu Bello University Samaru, Zaria.

3. RESULTS

3.1. Spatial Proximity of Dumpsites to Boreholes and Wells

Table 1 presents the spatial proximity of the 10 major dumpsites to the boreholes and wells under investigation in this study based on their coordinates.

Table 1. Proximity of dumpsites to boreholes and wells

S/N	Dumpsite Location	Proximity (m)
1	Leather Research	67.85
2	Lemu Primary School	134.86
3	Ungwan Malawa	20.95
4	Alhaji Jumare	50.28
5	Tagwayin Engine	31.69
6	Hayin Commander	103.35
7	Behind Hayin Danyaro	14.64
8	Apostolic Faith Church Hayin Danyaro	25.18
9	Madaki Hayin Danyaro	26.09
10	Napri Water Depot Hayin Danyaro	30.76

The result of Table 1 shows that the closest and farthest dumpsites from groundwater source (borehole or well) are found in the Ungwan Malawa and Lemu Primary School locations at 21 m and 135 m, respectively. Meanwhile, the average distance between a dumpsite and borehole or well is about 51 m. The results indicate that the reuirement set by the EPA (2016) which stipulates that dumpsites should be positioned not less than 160 m from groundwater sources have not been met.

3.2. Results of Physical and Chemical Analyses of Groundwater Samples

Table 2 presents the results of the analyses of pH, temperature [T (°C)], turbidity [Tb (NTU)], and electrical conductivity [EC (ms/cm)]) of water samples obtained from the boreholes and wells in proximity to the dumpsite locations (serial numbers 1 to 10 which directly relate to Table 1) against the WHO (2017) standard limits.

Table 2. Results of pH, temperature, turbidity, and electrical conductivity vs. WHO limits

Dumpsite Location	pH	T (°C)	Tb (NTU)	EC (ms/cm)
1	8.45	24.6	3.04	796
2	8.39	24.8	8.28	860
3	8.25	24.7	6.27	228
4	7.85	23.9	3.51	470
5	8.37	24.3	3.88	770
6	8.43	24.5	1.86	487
7	8.54	24.9	0.77	1593

8	7.74	23.9	1.75	662
9	8.34	24.2	9.13	613
10	7.95	23.9	2.79	377
WHO	6.5-8.5	Nil	1-5	2500

The Fig. 2 displays the concentrations of Dissolved Oxygen (DO), Total Dissolved Solids (TDS), Total Hardness, Nitrate, Biochemical Oxygen Demand (BOD), Chloride, and Calcium, respectively obtained from the groundwater locations.

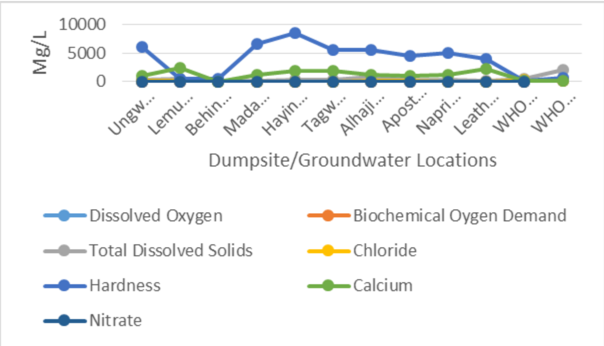

Figure 2. The concentrations of DO, TDS, Hardness, Nitrate, BOD, Chloride, and Calcium at groundwater locations vs. WHO standard

3.3. Relationship between Spatial Proximity of Dumpsites and the Physical and chemical Parameter Concentrations

It is pertinent to investigate whether there is a relationship between the proximity of the dumpsites to the boreholes and wells and whether it has significant effects on the levels of the physical and chemical constituents of the groundwater sources. Therefore, Table 3 presents the results of a multiple regression analysis carried out to verify these assumptions.

Table 3. The relationship and effect of proximity of dumpsites to boreholes and wells

VIF Category	Parameter	R	R Squared	Sig.
I	Electrical Conductivity (ms/cm)	0.93	0.86	0.111
	Chloride (mg/l)			0.236
	Total Hardness (mg/l)			0.109
	Calcium (mg/l)			**0.023**
	Nitrate (mg/l)			0.216
II	pH	0.89	0.79	0.547
	Dissolved Oxygen (mg/l)			**0.009**
	Biochemical Oxygen Demand (mg/l)			**0.018**
	Temperature (^{0}C)			0.950
III	Total Dissolved Solids (mg/l)	0.47	0.22	0.298
				0.295

The multiple regression analysis was based on the Variance Inflation Factor [VIF] (Systat Software Inc., 2014) categories of the variables (physical and chemical parameters) at play. The spatial proximity of the dumpsites to the boreholes and wells formed the dependent variable while the physical and chemical parameters formed the independent variables.

4. DISCUSSION

The results of this study have shown that a majority (about 80%) of the solid waste dumpsites are located too close to the groundwater sources. This is an indication that most of the dumpsites did not meet the requirement set by EPA (2016) regarding the minimum distances required for their location.

A majority (90%) of the groundwater sites revealed pH values within the acceptable limit set by the WHO in 2017 for good water quality.

Only one (10%) of the groundwater sites showed that the concentration TDS was within the limit of good water quality while the levels of DO were unacceptable across all the sites. The results of the Total Hardness revealed that only a couple (20%) of the groundwater sites (Lemu Primary School and Hayin Danyaro) met the requirement set by the WHO. The concentrations of Nitrate and BOD at all the groundwater sites revealed that they were below the limit set by the WHO which is an indication of a condition acceptable for good drinking water. The concentrations of Chloride for a majority (90%) of the groundwater sites showed that they were within the acceptable limit for good water quality as set by the WHO. The results of the concentrations of Calcium revealed that only one groundwater site (Behind Hayin Danyaro) met the requirement set by the WHO.

Meanwhile, the results of the Temperature across the groundwater sites revealed that they were within the limit of being acceptable for good drinking water. However, the results of the Turbidity revealed that 60% of the groundwater sites fell within the permissible limit set by the WHO while 30% of the sites (Lemu Primary School, Behind Hayin Danyaro, Napri Water Depot Hayin Danyaro) exceeded the limit. The remaining 1% (Alhaji Jumare) fell below the limit and may be considered as acceptable. The contents of EC across the groundwater sites revealed that they were acceptable for good water quality.

The results of the study went further to reveal that only the concentrations of Dissolved Oxygen, and Biochemical Oxygen Demand were significantly influenced ($p < 0.05$ at the 95% significance level) by the closeness of the solid waste dumpsites to the boreholes and wells with very strong (R^2 = 86%) and strong (R^2 = 79%) relationships, respectively.

This study is in agreement with Akinbile and Yusoff, (2011) who reported similar findings but differs slightly from (Pande *et al*., 2015; Remy *et al*., 2017) regarding the contamination of the groundwater sources as a result of the proximity of the dumpsites. Moreover, it disagrees with (Abbas *et al*., 2018; Somani *et al*., 2019) based on the fact that the adoption of both controlled and uncontrolled conditions were prejudiced.

5. CONCLUSION

This study was set out to assess the quality of ten (10) major underground water sources (boreholes and wells) in proximity to dumpsite locations in the Samaru community of Kaduna state, Nigeria.

The results revealed that the distances between the dumpsites and boreholes or wells, residential areas, and roads were far less than the minimum stipulated by the EPA regarding safe areas for locating dumpsites. The results also revealed based on the permissible limits set by the WHO that groundwater quality conditions for drinking water were met at some of the water sample sites despite the closeness of these dumpsites to the groundwater sources.

The results of the study showed that the concentrations of only three (3) (Calcium, Dissolved Oxygen, and Biochemical Oxygen Demand) out of the eleven (11) physical and chemical parameters tested were significantly affected by the proximity of the dumpsites to the groundwater sources with very strong and strong relationships, respectively.

In view of the findings of this study, it shows that the proximity of dumpsites to groundwater sources may not be the only reason for groundwater contamination perhaps other factors such as the topography or elevation, soil, slope amongst others may combine to create such a situation and would need to be investigated.

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