PRINT ISSN 1119-8362
ELECTRONIC ISSN 1119-8362

Full-text Available Online at
https://www.ajol.info/index.php/jasem
http://ww.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 23 (1) 05–11 January 2019

Influence of Third Cemetery Location on the Quality of Domestic and Groundwater Resources in Benin City, Nigeria

[1]IDEHEN, O; *[2]EZENWA, IM

[1]Department of Physics, Tayo Akpata University of Education, Ekiadolor Benin, Nigeria,
[2]Department of Zoology and Environmental Biology, University of Nigeria Nsukka, Nsukka Road, Nsukka 410001 Nsukka, Enugu State, Nigeria
**Corresponding author Email: ifeanyi.ezenwa@unn.edu.ng; other Email: idehenosabuohien@gmail.com*

ABSTRACT: The present study investigates impact of burial practices on water quality in Benin City, Nigeria by collecting groundwater samples from boreholes located by the peripheral area of Third Cemetery in Benin City and a reference site approximately 4 km away using standard methods. With the exception of SO_4, $CaCO_3$, Fe and DO, the concentrations of other parameters were higher in water samples obtained from the peripheral area of Third Cemetery than that from the reference site. Principal component analysis (PCA) revealed that pH, Fe, and $CaCO_3$ were differentiating parameters related to reference site, similar condition was attributed to SO_4 and Mg for site 2 and Pb, Mn, Cu, Ni, Zn and DO for sites 1 & 3. Cluster analysis (CA) placed the reference site as outlier to other sites. Higher concentrations of Cl, NO_3, Na, K and BOD_5 in samples obtained by cemetery peripheral when compared to reference site and positive correlations among these parameters are indications of impacts of decomposing activities in cemetery upon water quality in underlying aquifer. Limiting water quality index (WQI) computation to pH, EC, Cl, NO_3, SO_4, Na and BOD_5 showed that quality of groundwater obtained from cemetery peripheral is not good for domestic uses.

DOI: https://dx.doi.org/10.4314/jasem.v23i1.1

Dates: Received: 24 November 2018; Revised: 09January 2019; Accepted 22 January 2019

Keywords: Cemetery, Groundwater, Physicochemical, Multivariate, Water Quality Index

Water, air and land are continuously impacted by anthropogenic activities from birth to death. Several impacts of traditional land uses have been reported with respect to groundwater contamination potential (Ikem *et al*., 2002). Land use for cemeteries; interment in coffin and casket is widely practiced, but its possible impacts have not received significant attention in Nigeria (Onwuanyi *et al*., 2017). In Benin City, major cemeteries are located close to human residential areas. According to DOE (2016), cemetery sites have potential impact on the local environment and the groundwater underlying such sites. Necroleachate resulting from humorous phase of dead body decomposition characterized by the dissolution of cellular elements and the consequent liquefaction of tissue (Neckel *et al*., 2016) is a known source of contaminants such as heavy metals and other toxic substances resulting from the decay of coffin material (Spongberg and Becks, 2000; Jonker and Olivier, 2012). The risk of contamination is influenced by soil nature and infiltration rate, types of burials, and the effect of rainfall on the groundwater level (Üçisik, and Rushbrook, 1998).

Toxic chemicals that may be released into groundwater include substances that were used in embalming as well as varnishes, sealers and preservatives and metal component of ornaments used on wooden coffins (Jonker and Olivier, 2012). Wood preservatives and paints used in coffin construction contain compounds such as copper naphthalene and ammoniac or chromated copper arsenate (Spongberg and Becks, 2000). Paints contain lead, mercury, cadmium, and chromium; arsenic is used as a pigment, wood preservative and anti-fouling ingredient while barium is used as a pigment and a corrosion inhibitor (Huang *et al*., 2010; Jonker and Olivier, 2012). Various reports have established close relationship between land use and groundwater quality (Całkosiński *et al*., 2015; Killgrove, and Montgomery, 2016). Many of them have been devoted to impact of interment of bodies in cemeteries on groundwater quality (Üçisik, and Rushbrook, 1998; DOE, 2016). The objective of this study was to conduct and provide relevant data on the impact of Third Cemetery location on the quality of groundwater resources in Benin City, Nigeria.

MATERIALS AND METHODS

Study Area: This study was conducted in Benin City located in south-south geopolitical zone of Nigeria. Benin City is bounded by latitudes 06° 06’ N, 06° 30’ N and longitudes 005° 30’ E, 005° 45’ E and an area of about 500 square kilometers. The city is located within the rain forest ecological zone with annual mean temperature of 27.5 °C and an annual mean rain fall of about 2095 mm (Ikhile and Oloriode, 2011). Three cemeteries namely First, Second and Third cemeteries are located within this city. The Third cemetery which has existed for over 50 years, is the biggest among the cemeteries in Benin City and covers an area of about 5.167 ha (Ibhadode *et al.*, 2017). Although the burial load of this cemetery could not be obtain (due to inadequate record-keeping regarding the number of people buried), observation made in the course of this study showed about 18 – 42 bodies of varying sizes are buried per week. There is issue where a single grave is used for multiple burials.

Geological sitting of Benin City which is underlain by sedimentary formation is described by Short and Stauble (1967). This formation is assigned to the Oligocene-Pleistocene era in the continent of Africa and to the Oligocene-Pleistocene recent at the sub-oceanic. The formation is made up of top reddish earth which is composed of ferruginized or literalized clay sand, sand capping highly porous fresh water bearing loose pebby sands, and sandstone with local thin clays and shale interbeds which are considered to be of braided stream origin. The sands, sandstones and clays colours vary from reddish brown to pinkish yellow on weathered surfaces to white in the deeper fresh surfaces. Limonitic coatings are responsible for the brown reddish-yellowish colour.

Four boreholes (Fig. 1) (three by the peripheral of the Third cemetery and one as reference) were selected for the sample collection. The reference was positioned approximately 4km away from Third Cemetery in vicinity with no burial record and the groundwater flow direction in similar direction as the boreholes located by the peripheral of the cemetery.

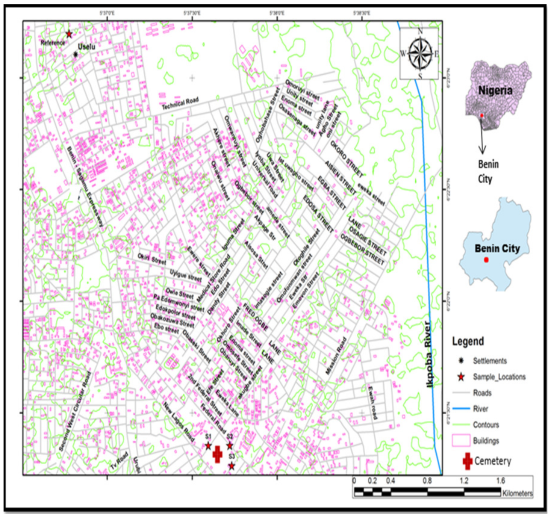

Fig. 1: Map showing sites of sample collection

Field and Laboratory Analyses: At each of the boreholes, the groundwater flow direction was determined. This was done by measuring static water level (SWL) and subtracted the value from the elevation above sea level (ASL) measured by Global Positioning System in meter. The difference obtained which is known as corrected water levels (CWL) in meter were then schemed on a map to determine the flow direction (Otutu, 2010). Groundwater samples were obtained fortnightly for a period of three months (August – October, 2017) from the four boreholes for characterization of the physicochemical parameters of the water. At each of the boreholes, the discharge pipe of the boreholes was swabbed with cotton wool soaked in 70% ethanol and water samples were collected after flushing for 4 to 5 minutes. Sample for determination of other parameters other than in situ parameters, heavy metals component was collected with 1 litre plastic bottles. Sample for heavy metal determination was collected in acid washed polyethylene bottles. All samples collected were labeled properly and stored in iced coolers (0° – 4° C). The samples were immediately taken to the laboratory and analyses were done within 24 hours of sample collection. In situ parameters including electrical conductivity (EC), hydrogen ion concentration (pH) and total dissolved solids (TDS) were determined with the aid of Extech meter probes (Exstik II). In the laboratory, the analysis of other parameters including total suspended solids (TSS), calcium, magnesium, sulphate, nitrate, phosphate, chloride, calcium carbonate ($CaCO_3$), sodium, potassium, lead, copper, chromium, iron, zinc, manganese, cadmium, nickel, mercury, dissolved oxygen (DO), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) were done using standard methods (APHA, 1998; Radajevic and Bashkin, 1999).

Data analysis: Descriptive statistics including measure of central tendency – arithmetic mean and measure of dispersion – standard deviation and coefficient of variations were employed in the summary of the dataset.

Exploratory data analysis was performed by linear display methods (principal component analysis, PCA) and unsupervised pattern recognition techniques (hierarchical cluster analysis, CA) on experimental data. Cluster analysis allows the grouping of obtained samples on the basis of their similarities in chemical composition. Unlike PCA that normally uses only two or three principle components (PCs) for display purposes, cluster analysis uses all the variance or information contained in the original data set (Razmkhah *et al*., 2010).

Determination of water quality index (WQI): The parameters adopted in this study include: pH, EC, TDS, TSS, BOD_5, magnesium, sulphate, nitrate, chloride, $CaCO_3$, sodium, lead, chromium, copper, zinc, iron, manganese, cadmium, nickel and mercury. WQI was computed on a programmed Excel sheet by using the Weighted Arithmetic Index method as described by (Cude, 2001; Ramakrishniah *et al.*, 2009). All mathematical and statistical computations were carried out using Microsoft Office Excel 2010 and PAST version 3.14

RESULTS AND DISCUSSION

Groundwater has for many decades served as a source of drinking water and it is still relevant for same purpose till date (Radajevic, and Bashkin, 1999), despite the impairment of its quality in some locality by different human activities. Thus monitoring of groundwater quality is one of the inevitable practices for ensuring sustainable development. The physical and chemical parameters characterized in this study are among those usually recommended as monitoring guidelines as well as first approach for detecting the groundwater impacts from cemeteries (Tredoux *et al.*, 2004; Environmental Agency, 2004).

The values of static water levels and elevations above sea level were similar at the boreholes located by the periphery of the cemetery. The values of static water levels ranged from 50.47 m at site 3 to 58.53 m at site 2; at site 1, the value was 56.96 m. The elevations above sea level were approximately 108 m at sites 1 & 2 and 99.68 at site 3. The values of static water level and elevation above sea level at the reference site were approximately 46.83 m and 115.00 m respectively. At sites 1, 2 and 3 and reference site, the values of corrected water levels were 51.04 m, 49.47 m, 49.21 m, and 68.17 m respectively. In scheming corrected water levels to the map, the direction of groundwater flow was observed to be from north-west to south-east. Table 1 shows the variations in the physicochemical parameters characterized in the groundwater samples obtained from the various sites.

Table 1: Summary of variations in the physicochemical variables

Variables	Site 1 $\bar{X}$±SD	Site 2 $\bar{X}$±SD	Site 3 $\bar{X}$±SD	Reference $\bar{X}$±SD	CV	NSDQW
pH	4.96±0.97	4.34±0.63	4.05±1.08	6.80±0.72	24.51	7.50
EC	118.00±28.92	112.00±17.22	160.00±21.52	82.00±10.13	67.43	1000.00
TDS	54.00±31.73	53.00±34.39	76.00±42.13	39.30±8.62	67.04	500.00
TSS	0.58±0.01	0.07±00.00	0.66±0.01	0.00±00.00	103.80	0.00
Calcium	3.84±0.89	3.20±0.67	4.48±2.39	2.40±0.94	25.56	NA
Magnesium	1.15±0.29	2.30±0.49	3.84±0.40	3.00±0.41	44.25	0.20
Sulphate	0.17±0.22	0.25±0.57	0.00±0.01	0.43±0.09	83.75	100.00
Nitrate	0.29±0.58	1.37±0.51	1.75±0.68	0.08±0.01	93.23	50.00
Phosphate	0.64±0.33	0.83±0.24	0.33±0.44	0.24±0.08	53.65	NA
Calcium carbonate	30.50±6.49	24.40±3.80	18.60±6.16	50.80±2.17	45.11	150.00
Chloride	44.52±20.36	23.78±17.62	36.40±26.22	18.40±4.32	38.57	250.00
Sodium	37.60±0.55	16.40±0.59	32.00±1.02	2.60±0.85	71.43	200.00
Potassium	48.88±6.05	21.32±11.06	41.60±10.08	3.38±0.22	71.43	NA
Lead	0.01±0.00	0.00±0.00	0.01±0.01	0.00±0.00	115.01	0.01
Chromium	0.01±0.01	0.01±0.00	0.01±0.01	0.01±0.00	0.00	0.05
Copper	0.02±0.01	0.01±0.01	0.03±0.02	0.01±0.00	81.65	1.00
Zinc	0.02±0.01	0.01±0.01	0.02±0.02	0.02±0.01	28.57	3.00
Iron	0.04±0.02	0.02±0.01	0.03±0.02	0.08±0.03	61.88	0.30
Manganese	0.03±0.02	0.01±0.01	0.02±0.03	0.01±0.00	81.65	0.20
Cadmium	0.00±0.00	0.00±0.00	0.00±0.01	0.00±0.00	0.00	0.00
Nickel	0.01±0.01	0.01±0.00	0.02±0.01	0.01±0.00	70.71	0.02
Mercury	0.00±0.00	0.00±0.00	0.00±0.00	0.00±0.00	0.00	0.00
DO	8.80±1.32	6.20±2.61	9.80±2.04	9.20±1.07	18.68	NA
BOD_5	2.60±0.92	1.80±0.75	3.40±1.38	0.60±0.32	56.88	NA
COD	12.46±4.81	10.32±2.94	14.77±4.87	12.10±1.73	14.74	NA

NSDWQ- *Nigerian Standard for Drinking Water Quality (NIS 2007), NA – Not available; All variables except pH and EC were measured in mgl^{-1}; EC was measured in µScm^{-1}.*

The levels of homogeneity of the levels of the variables across the sites including the reference site are represented by the coefficient of variation (CV) while intra-site variations were represented by the standard deviation (SD). TSS and lead had CV values > 100; EC, TDS, sulphate, nitrate, phosphate, sodium, potassium, copper, iron, manganese, nickel and BOD_5 recorded CV values > 50 while pH, calcium, magnesium, alkalinity, chloride, zinc, DO and COD had CV values < 50. The levels of chromium, cadmium and mercury were relatively the same across the sites including the reference site thus no variation was recorded (CV = 0). According to Han *et al.* (2006), CV values of elements dominated by natural sources are relatively low, while Guo *et al.* (2012) expressed that CV values of elements influenced by non-natural sources (biological and anthropogenic) are usually high. The groundwater was slightly acidic at all sites except the reference; electrical conductivity, total dissolved and total suspended solids, nutrients including nitrate and phosphate, the alkali metals, heavy metals (excluding iron values which was high in the reference sites and cadmium and mercury which were not detectable in the water samples) values were low in the water samples obtained from reference site. Generally chloride was the dominant anion across all the sites samples were obtained while the least of the same group were sulphate and nitrate for cemetery peripheral sites and reference site respectively. PCA revealed the nature of variation in the physicochemical parameters across the various sites in which samples were obtained (Figures 2 and 3). pH, Fe, and $CaCO_3$ were the differentiating parameters related to the reference site when compared to other sites; SO_4 and Mg were most influential in site 2 while Pb, Mn, Cu, Ni, Zn and DO were influencing parameters related to sites 1 and 3. Variations of other parameters were not localized to any particular site. Three principle components (PCs) 1, 2 and 3 obtained from the dataset attributed the variations to individual PCs. PCs 1 & 2 which recorded eigenvalues > 1 accounted for 90.61% of the variations. PC 1 associated high variations to pH, TSS, SO_4 and Pb; PC 2 associated high variation to pH, NO_3 and Pb while PC 3 associated high variation to TSS and SO_4. Fig. 4 shows the dendrogram for CA based on the concentrations of all the parameters analyzed in the water. The cophenetic correlation of the CA = 0.772, three well differentiated clusters were obtained and according to the combinations of the clusters, the reference site maintained unique characteristics. The Euclidean distance analysis revealed that the physicochemical characteristics at reference site and site 3 were most dissimilar as the values of 135.71, 85.82 and 176.22 were obtained between the reference site and sites 1, 2 and 3 respectively.

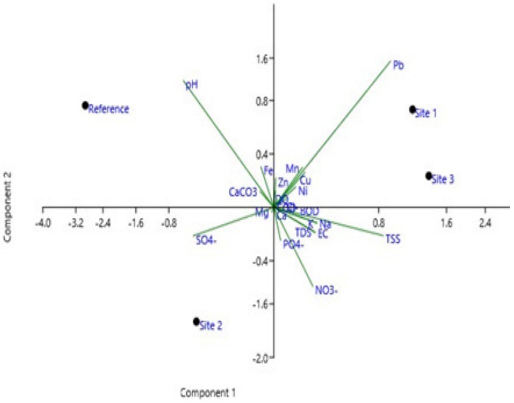

Fig 2: Plot of PCA loadings on parameters characterized in groundwater samples obtained from the various site

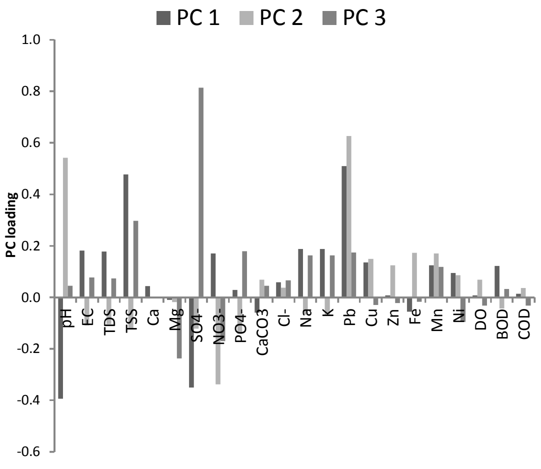

Fig 3: PCA loading across principle components (PCs) 1,2 & 3

In line with the descriptive and multivariate analyses adopted in this study, well defined differences were recorded when the groundwater quality at the cemetery peripheral was compared to the reference site. Review of the dataset showed variations in relation to both the anions and cations. Although the same pattern of variation was observed in terms of the alkali metals (K>Na), high magnitude values were recorded in groundwater samples obtained from boreholes located close cemetery vicinity. Considering the alkali earth metal, inverse pattern of variations were obtained in samples from cemetery peripheral (Ca>Mg) and reference site (Ca<Mg). The pH of the samples from cemetery peripheral general implied an acidic condition; this contradicted the condition obtained from the reference site which was slightly below the neutral pH (by value 0.2). The pH values were also different from the values ranging from 6.0 – 7.0 obtained by Fineza *et al.* (2014) in environment with similar activity in Southeast Brazil. Considering these differences, the pH condition recorded in the samples from cemetery vicinity may primarily be a function of surrounding rock types. The likely implications of low pH values should be of concern, many metals including (heavy metals) stay dissolved in low pH (Winter *et al.*, 1998) hence the availabilities which for some heavy metals (Pb, Hg, Cr, Mn, Cd, Cu, Ni) are deleterious to human health is enhance (Bakare-Odunola, 2005). Cr has been identified as carcinogenic agents, Cd & Mn as nephrotoxic agents, Hg as nephrotoxic and neutrotoxic, and Pb as neutrotoxic and enzyme inhibitor (NIS, 2007; Ernest 2010). Generally the levels of all parameters with defined standard according to Nigerian Standard for Drinking Water Quality (NSDWQ) complied favourably across the sites.

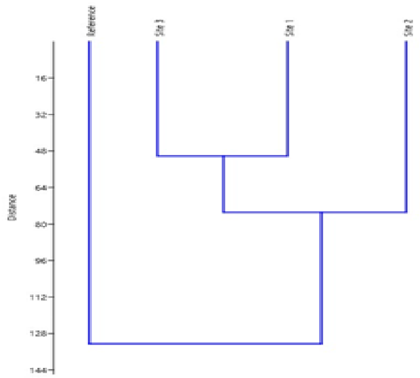

Fig. 4: Dendogram for cluster analysis based on the concentrations of all the parameters. The dissimilarity is defined by Euclidean distance and combination of cluster is based on Ward method

The result of PCA analysis revealed interactions among the characterized parameters were as showed by the ordination plot of PCA loadings. In line with the ordination plot and cluster analyses, defined variations were obtained in relation to the sites and parameters responsible for the variations. pH, TSS,

SO_4, NO_3 and Pb were the principal parameters behind the variations. The pH together with Fe and $CaCO_3$ which were the principle parameter differentiating the reference site from other sites, maintained inverse relationships with NO_3, PO_4, TSS, TDS, EC, Na and BOD_5. Basically NO_3, PO_4, TSS, TDS, EC, Na and BOD_5 influenced the pH of groundwater samples obtained from the cemetery vicinity as increase in them made the water more acidic. Inclusion of solids implied that TSS and TDS seemed primarily to be composed of matters laden with sodium, nitrogen, phosphorous and trace of organic compounds; NO_3 likewise PO_4 can be seen as ahydrides which in hydrated form lows the pH of a medium. The case of high pH recorded in the samples obtained from the reference site is buttressed by relatively high $CaCO_3$ obtained in the same samples; this will enhance neutralization of acidic condition resulting from other compounds (Ntwampe *et al.*, 2015). TDS and EC expressed high concentrations in groundwater samples obtained from cemetery peripheral and these two parameters in high level shows pollution. The positive correlations observed between EC and NO_3, PO_4, TSS, Na & BOD_5 showed their positive effect towards the ionic content in water samples.

Although Pb was the most inferential parameter in sites 1 and 3, other heavy metals including Zn, Cu, Ni and Mn were also important in these sites. The cluster of these heavy metals implies that their input to the groundwater system is of similar source. Site 2 maintained a unique chemical characteristic and SO_4 and Mg were the distinguishing parameters. This distinctness in relation to the parameter characteristics was further buttressed by the result of the cluster analysis as the Euclidean similarity and distance indices in pairwise comparison accorded the least value to sites 1 and 3. These two sites recorded the highest levels in gross variation of characterized parameters when compared to the reference site. The grouping of the sites as captured by dendogram implies that sites 1 and 3 share the same aquifer which may be partitioned from site 2.

The common parameters influenced by decomposing activities in cemeteries include pH, BOD_5, ammoniacal nitrogen, DO, EC, TOC, COD, Cl, NO_3, SO_4, P, Na, K, Ca and Fe (Sawyer *et al.*, 2003; Tredoux *et al.*, 2004). With the exception of pH, DO, SO_4 and Fe the other parameters including Cl, NO_3, Na, and K were generally high in the groundwater samples obtained from sites at cemetery vicinity. To buttress these index parameters, the first and second components of the PCA ordination plot grouped Cl, NO_3, SO_4 , Na, K, Ca, EC, COD together with BOD_5 in un-antagonistic pattern (this implies common source of input). Furthermore, Tredoux *et al.*, (2004) suggested the inclusion of Mn, Cd, Cr, Cu, Ni, Pb and Zn at high risk sites; these heavy metals especially Pb, Mn, Cu, Ni and Zn were the most influencing parameters related to sites 1 & 3. These changes together with other variations discussed above can be seen as clear indications of the impact of the decomposing activities in the cemetery upon the quality of the water in aquifer underlying the area.

Water quality index (WQI) is a means to recapitulate large amounts of water quality data into simple terms (e.g., excellent, good, poor etc.) for reporting to management and the public in a consistent manner (Ashwani and Anish, 2009). The weighted arithmetic index method used in this study evaluates the overall quality of water using an established standard and further predicts if water quality poses a potential threat to various uses, such as habitat for aquatic life, irrigation water for agriculture and livestock, recreation and aesthetics, and drinking water supplies. In formulation of water quality index, the relative importance of various parameters depends on intended use of water (Chandaluri *et al.*, 2010) and in this study, the intended use covers variety of domestic purposes (drinking, cooking, laundering etc). The WQI varied significantly ($p<0.05$) while considering the parameters used in the computation (Fig. 5). The values obtained for sites 1, 2, 3 and reference site while including all the parameters in the computation are 7.28, 4.98, 13.40 and 4.32 respectively. However, when the computation of WQI was restricted to pH, EC, BOD_5, Cl, NO_3, SO_4, and Na which mostly are influenced by on-site activities, the values obtained were 268.12, 251.08, 357.01 and 55.72 for sites 1, 2, 3 and reference respectively. These high values were most influenced by BOD_5 levels.

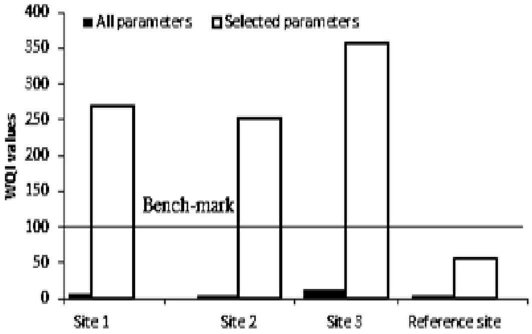

Fig 5. WQI spatial variations in relation to the parameters used in the computation.

A bench mark of 100 considered in this study was adopted from Ramakrishniah *et al.* (2009) (this is a point beyond which the water is termed poor putting into consideration its intended use). In line with Ramakrishniah *et al.* (2009), the WQI values across all the sites were < 50 while considering the contribution of all parameter; this implies that the water qualities were of excellent description. Further elaboration while adopting quality rating showed that slight variations observed in the WQI across the sites were primarily factored by Ni, Pb and Mg.

Considering the following parameters BOD_5, Cl, NO_3, SO_4, Na and K, the computed WQI values scaled above the score of 100 for all sites except reference site. In this sense, the actual effect of the decomposing activities in Third cemetery was in the initial computation masked by the inclusion of all the parameters characterized for this study. This buttressed the claim by Cude (2001) that with too many parameters, small individual changes are not detectable in the aggregated WQI value. The high values of WQI obtained from these sites were primarily factored by BOD_5 loads. In general, defined variations in the water quality were observed when the parameters characterized in the groundwater samples were compared between the reference site and sites at cemetery vicinity.

Conclusion: Human experience has taught that people shall continue dying and they shall continue being buried, however, we could reduce the number of people whose death could be linked to consumption of polluted groundwater by paying attention to obvious risk to residents who live close to cemeteries. Based on the data obtained in this study, we conclude that there are very clear variations between various indices of the groundwater around the cemetery at Benin City, Nigeria and the reference site.

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