



International Scientific Organization
<http://iscientific.org/>
 Chemistry International
www.bosaljournals.com/chemint/



Vulnerability assessment of groundwater pollution in the vicinity of an active dumpsite (Olusosun), Lagos, Nigeria

Abdulrafiu O. Majolagbe^{1,2,*} Adebola A. Adeyi¹ and Oladele Osibanjo¹

¹Department of Chemistry, University of Ibadan, Ibadan, Nigeria

²Department of Chemistry, Lagos state University, P.M.B. 1087, Apapa, Lagos, Nigeria

*Corresponding author's E. mail: abdulmajss@gmail.com

ARTICLE INFO

Article type:

Research article

Article history:

Received November 2015

Accepted December 2015

October 2016 Issue

Keywords:

Modified DRASTIC model

DRALTC model

Vulnerability

Water quality index

Cluster analysis

ABSTRACT

The deleterious impacts of dumpsite activities and the associated risk on both the environment and human is consequential, hence this study assessed groundwater vulnerability to pollution from dumpsite using a modified DRASTIC model. Six hydrogeological factors: D- Depth to water, R- Net Recharge, A- Aquifer media, L- Distance of well to dumpsite, T- Topography, and C- Clay content were used in the modification (DRALTC) based on peculiarity of the study area. Cluster analysis of groundwater data and Water Quality Index (WQI) were also evaluated. The groundwater vulnerability index was characterized by two zones; forty five percent (45%) moderate and fifty five percent (55%) high zones. The dendrogram showed three clusters of chemical dissimilarities. The WQI showed values between 61.8 and 205, indicating good, poor and very poor class of water. The analysis of the groundwater samples showed nitrate concentration ranging from 7.60 to 35.6 mg/L and from 8.56 to 32.4 mg/L in dry and rainy seasons, respectively. The DRALTC model was validated using nitrate concentration. Though, there appeared relative groundwater protection from contamination, there is still need for measures to mitigate further contamination and associated risk in the moderate vulnerability zones. DRALTC model is proved a good tool in groundwater management.

© 2016 International Scientific Organization: All rights reserved.

Capsule Summary: In this work the groundwater vulnerability to dumpsite pollution revealing index from moderate to high was assessed. The Water Quality Index ranged from 61.8 to 205 delineating good-poor-very poor water type.

Cite This Article As: A. O. Majolagbe, A. A. Adeyi and O. Osibanjo. Vulnerability assessment of groundwater pollution in the vicinity of an active dumpsite (Olusosun), Lagos, Nigeria. Chemistry International 2(4) (2016) 232-241.

INTRODUCTION

Groundwater is a major source of water supply for domestic, agricultural, recreational, and industrial purposes in Lagos, a fast emerging mega city in Africa. Consequently, the adequacy of groundwater resources, both in quality and quantity is essential for socio-economic sustainability in the area. However, the aquifer and groundwater are under

intense threats from both natural and anthropogenic sources such as urbanization, infiltration from dumpsites, intrusion of sea water and effects of various land use configurations (Adesola et al., 2016; Babarinde and Onyiaocha, 2016; Osibanjo and Majolagbe, 2012; Qureshi et al., 2015; Sayed, 2015; Thrumalaivasan et al., 2003; Ukpaka, 2016). The pollutant that infiltrate from dumpsite has once been described as the worst threats to groundwater quality (Bilal et al., 2014; Iqbal and Bhatti, 2014; Iqbal and Khera, 2015;

Iqbal and Nisar, 2015; Iqbal et al., 2014; 2015; 2016; Mor et al., 2005; Singh, 2008; Ukpaka et al., 2015). Olusosun dumpsite is the largest municipal solid waste dumpsite facility in Nigeria and is presently receiving more than 1.2 million tons of wastes annually.

Most of the water wells in Lagos are not too deep (< 35.50 m) probably as a result of the shallow water table of the aquifers in the area and /or the cost implications of digging a very deep well. Thus, groundwater can be easily susceptible to infiltration from dumpsites, septic tanks and other anthropogenic activities. Approximately, one fifth of the world total freshwater situations in the phreatic zone of the sub surface water environment (Saatsaz and Wan, 2011), therefore, the need to protect groundwater resources from contamination.

Vulnerability of groundwater to pollution could be explained as the degree or tendency of groundwater in an area to be contaminated. The knowledge of groundwater vulnerability assessment has improved since it was developed in the United State of America in 1987. It helps to plan and manage groundwater resources. According to Foeazio et al., (2002), vulnerability can be specific contaminant (non intrinsic) or generality of contaminants (intrinsic). So many studies have been reported on various environmental impact of different form of pollution sources on the quality of groundwater in Lagos. Various methods of vulnerability evaluation and assessment have been developed, including overlay index method, hybrid, modeling and simulation as well as statistical methods. Ojuri and Bankole (2013) pointed out that overlay and index method resulted from the intersection of map on a regional basis and the qualitative interpretation of the data by indexing the parameters and assigning appropriate weights. Several procedures (overlay index method) of vulnerability have been reported in this category. These methods include GIS (Geography Information System) based DRASTIC, GOD, AVI, SINTACS, ISIS and EPIK (Saatas and Sulaiman, 2011). DRASTIC, undoubtedly is the most commonly used tool among the class of overlay index method for groundwater planning and decision making (Saatas and Sulaiman, 2011; Rahman 2008). Drastic model is a simple GIS based mapable method, developed by US Environmental Protection Agency (Aller et al., 1987).

The Drastic system is made up of seven hydrogeological parameters which influence the fate and transport of contaminants from the soil surface to aquifer. The drastic parameter with allotted weight and rankings based on importance is summed up together to form a Drastic index. It is a flexible method which helps to systematically evaluate the potential or tendency of groundwater to be vulnerable to pollution. Drastic model can be used in both very wide and small scale. It was initially targeted at non-point source contaminant but studies have reported modification of the model, thereby evaluating groundwater vulnerability due to point source pollution (Lee, 2003). Drastic model is developed on the assumptions that (i) the pollutant is introduced on ground surface, (ii) the

pollutant is further pushed into groundwater by precipitation through gravitational force and (iii) pollutant has mobility in water (Roser 1994). The Drastic model remains a very popular approach in the estimation of groundwater vulnerability among researchers, despite the criticism on the absence of specific method of validation (Ojuri and Bankole, 2013). Nitrate concentration in water (experimental data) was used to validate DRASTIC model (Alwathaf, 2011), pattern of total dissolved solids (TDS) concentration was used by Saatsaz and Wan Nor Azmin (2011), while Ojuri and Bankole (2013) employed correlation coefficients between physicochemical parameters of water and DRASTIC vulnerability indices as a validation tool.

The use of various water quality indices as a tool to assess the quality status of both surface and groundwater in an area has been extensively reported (Almeida et al., 2008; Reza and Singh, 2010; Jena, 2013; Manguyika et al., 2012). Water Quality index (WQI) approach to assess quality status of water was developed by Brown et al. (1970) and various modifications and new evolution (from different countries and regions) have been witnessed since then. This include The US National Sanitation Foundation Water Quality Index (NSFWQI), Canadian Water Quality Index (Canadian Council of Ministers of the Environment (CCME) , Florida Stream Water Quality Index (FWQI), British Columbia Water Quality Index (BCWQI), WQI developed in Bascaran, modified WQI developed in India (Bhargava WQI) and the Oregon Water Quality Index (OWQI) (Rocchini and Swain, 1995; H'ebert, 1996; Prati et al., 1971; Khan et al., 2005; Parmar and Parmar, 2010).

WQI was categorized into four classes based on the type of use namely; public indices, specific consumption indices, designing and planning indices and Statistical indices (Poonam 2013). The first three are collectively referred to as expert opinion (EO). Water Quality Indices play major roles in water quality assessment of a given source as a function of time and other influencing factors (if necessary) by resolving large multi-parameter water analysis data into single digit scores (Poonam, 2013). Multivariate statistical techniques have been extensively used in effective assessment and analysis of various physicochemical parameters of groundwater with respect to space and time (Liu et al., 2006; Palma et al., 2010; Oketola et al., 2013).The Multivariate statistical techniques include Principal component analysis (PCA), cluster analysis (CA), factor analysis (FA), discriminant analysis (DA). Cluster analysis is a powerful statistical tool that helps in grouping similar pairs of correlation in a large symmetric matrix. It can reduce large data set into groups with similar features, systematically compare various chemical constituents. Cluster analysis can present its result in a two-dimensional hierarchical diagram called dendrogram. An observation can be refereed at any point or level of similarity or dissimilarity.

This paper therefore aimed at estimating the potential groundwater intrinsic vulnerability to pollution from Olusosun dumpsite in Lagos, Nigeria, using a modified DRASTIC model (DRALTC) and assessment of groundwater

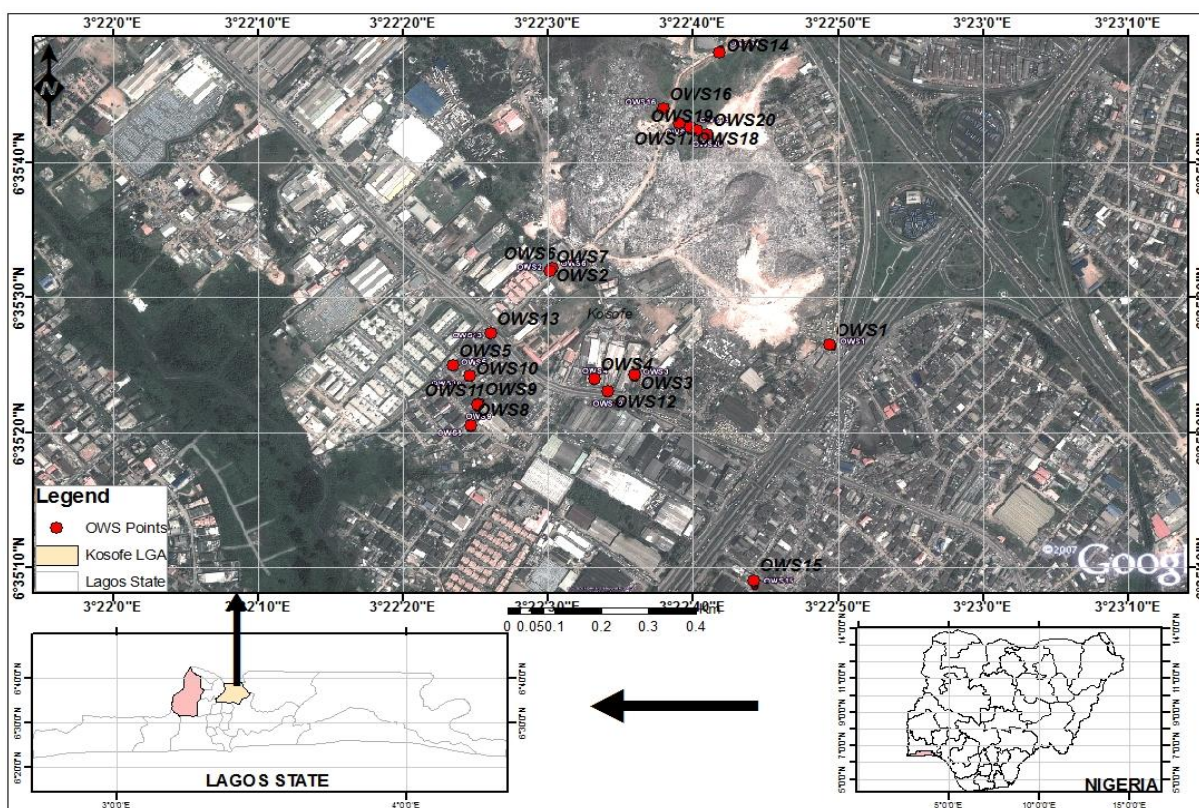


Fig. 1: Sampling locations around Olusosun dumpsite in Kosofe local Government Area

quality around the dumpsite using water quality indices. This will help the policy makers in better understanding of groundwater vulnerability and the adequate measures towards sustainability of the environment.

MATERIAL AND METHODS

Description of study area

Olusosun refuse dumpsite is a government located within the longitude 3°372' East to 3°374' East and latitude 6°588' North to 6°595' North in Ojota, Lagos State. It is the largest dumpsite in Nigeria. It is about 18 meters deep and covers close to 42 hectares of land. Olusosun refuse dump was established in 1988 with a life span of 35 years. The dumpsite is surrounded by Oregon industrial layout, Olusosun residential compound, Shangisha residential areas and commercial neighborhood (Fig.1). It receives an average of 1.2 million tons of wastes annually and is presently serving as a pilot project site for biogas production in Nigeria (Aboyade, 2004).

Sampling and chemical analyses

Forty (40) water samples were collected from twenty different hand dug wells around Olusosun dumpsite

bimonthly, for two consecutive years and analysed for various physicochemical parameters using standard procedures. The pH (pH meter, pHep HANNA HI 98107), electrical conductivity (Mettler Toledo) and temperature (thermometer, 0 - 100 °C) of the water samples were determined in-situ. Alkalinity, acidity, Total hardness, Total suspended solids (TSS), total dissolved solids (TDS), total solids (TS), chloride, sulphate, phosphate and nitrate were determined using American Public Health Association methods (APHA, 2005). Na and K were analysed using flame photometer and other trace metals by Flame Atomic Absorption Spectrophotometer (Buck scientific 210VGP model).

The use of borehole exploitation logs and soil survey reports

Various sources of data were used for this study as captured by Ojuri and Bankole (2013). Data on geology, topography and soil features of Lagos state was obtained from the reconnaissance soil survey of Nigeria (FDALR, 1995) as well as the climatic data (BBC, 2011).

DRASTIC model and estimation of vulnerability index

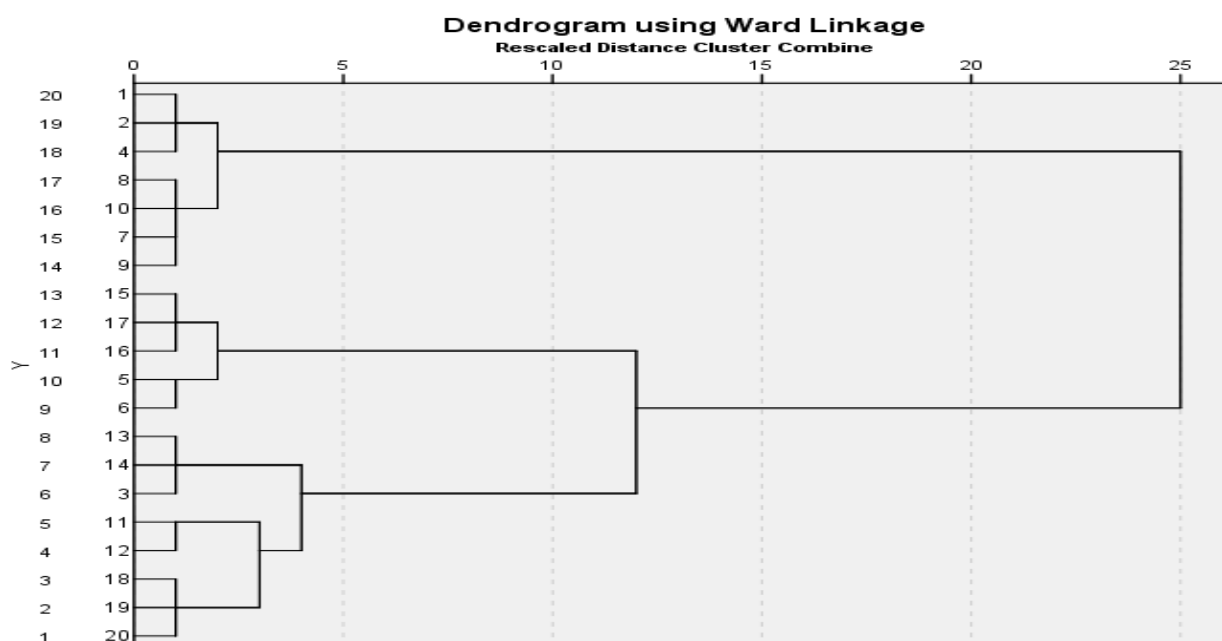


Fig. 2: Dendrogram of 20 wells plotted for groundwater samples around Olusosun dumpsite in Lagos

DRASTIC is a groundwater quality model for evaluating the pollution potential of large areas using the hydrogeologic settings of the region. A hydrogeological setting is defined as a mapable unit with common hydrogeologic characteristics. There are seven hydrogeological parameters or factors that make up the acronym DRASTIC. DRASTIC parameters influence the fate and transport of water from soil surface to aquifer. In this study, modification was made on the DRASTIC model so as to reflect and accommodate some peculiarity of the dumpsite. This result in the formation of six hydrogeologic parameter based model, DRALTC. Each factor was then assigned a weight (w) based on its relative significance in affecting the pollution potential. The weight was further allotted a rating (r) for different ranges of values. The typical ratings range from 1 - 10 and weights are from 1 - 5 as shown in Table 1.0.

The DRALTC vulnerability index was computed through the summation of products of ratings and weights for each factor as shown in Eq. 1:

$$\text{DRALTC Index} = DrDw + RrRw + ArAw + LrLw + TrTw + CrCw \quad (1)$$

Where, Dr = Rating to Depth to water, Dw = Weights assigned to Depth to water, Rr = Ratings for ranges of aquifer recharge, Rw = Weights for ranges the aquifer recharge, Ar = Ratings assigned to aquifer media, Aw = Weights assigned to aquifer media, Lr = Ratings to the distance from well to the dumpsite, Lw = Weights assigned to distance from well to the dumpsite, Tr = Ratings for topography (slope), Tw = Weights for topography, Cr = Ratings for rates clay content, Cw = Weights given to clay content. The vulnerability index of the study area can be classified into four groups : >190, Very High groundwater pollution potential; 160–190, High

groundwater pollution potential; 101–159, moderate groundwater pollution potential; < 100, Low groundwater pollution potential.

Water quality indices

Two international water quality indices were applied in this study so as to have wider interpretations of the field data used. These are Water Quality Index (WQI) and Contamination Index (CI). Water Quality Index (WQI): Three steps are involved in the calculation of WQI as described by Srinivas and Nageswararao (2013). In the first step, each of the parameters was assigned a weight (w_i) according to its relative importance in the overall quality of the water for drinking purpose. A maximum weight of 5 has been assigned to nitrate due to its major importance in water quality assessment. In the second step, the relative weight was calculated using relation shown in Eq. 2.

$$W_i = \frac{w_i}{\sum_{i=1}^n w_i} \quad (2)$$

Where, W_i is the relative weight, w_i is the weight of each parameter and n is the number of parameters. Calculated W_i values of the parameter are given in Table 2. In the third step, a quality rating scale (q_i) for each parameter was assigned by dividing the concentration of each water sample by its respective standard according to the WHO guidelines and the results multiplied by 100 (Eq. 3).

$$q_i = (C_i - C_{io} / S_i - C_{io}) \times 100 \quad (3)$$

Where, C_i is the concentration of each chemical parameter in each water sample in mg/L, C_{io} is the ideal value of the parameter in pure water and S_i is the Indian drinking water

Table 1: Modified DRASTIC (DRALTC) model weight and rating

Factors	Weight	Range	Rating
Depth to water m(D)	5	0 – 5	10
		5 – 15	9
		15 – 30	7
		30 – 50	5
		50 – 75	3
		75 – 100	2
		100+	1
Recharge (Net) (Inches) R	4	0 – 2	1
		2 – 4	3
		4 – 7	6
		7 – 10	8
		10 +	9
Aquifer media (A)	3	Massive Shale 1	2
		Metamorphic	3
		Igneous 2 – 5	4
		Weathered Metamorphic/Igneous	5
		3 – 5	
		Glacial Till 4 – 6	6
		Bedded Sandstone, Limestone and Shale	6
		Sequences 5 – 9	
		Massive Sandstone 4 - 9	8
		Massive Limestone 4 - 9	8
		Sand and Gravel 4 - 9	9
Distance of well to dumpsite (m) (L)	4	Basalt 2 – 10	10
		Karst Limestone 9 - 10	
		0 – 50	10
		50 – 100	9
		100 – 200	7
		200 – 500	5
		500 – 750	3
		750 – 1000	2
Topography (T)	1	1000+	1
		1 -2 %	10
		2 – 6%	9
		6 – 12%	5
Clay content % (C)	4	12 - 18%	1
		0 – 10	10
		10 – 20	9
		20 – 40	8
		40 – 55	5
		55 – 75	3
		75+	1

standard for each chemical parameter in mg/L according to the guidelines of the WHO. For pH, C_{io} is 7 and $q_i = (C_i - 7)/(S_i - 7) \times 100$. For the remaining parameters the ideal value is 0.

Contamination Index (CI): The CI represents the sum of the individual factors of those components that exceed permissible values, as established by the Environmental Protection Agency guidelines (USEPA). It takes into account ion elements and species that exceed permissible limits for human health according to Environmental Protection Agency guidelines. It helps to evaluate the degree of contamination of

groundwater. Contamination Index is mathematically expressed as in Eqs. 4-5.

$$CI = \sum_{i=1}^n Cfi \quad (4)$$

$$Cfi = \frac{C_{Ni}}{CAi} - 1 \quad (5)$$

Where, Cfi = is the contamination factor for the Nth component n = total number of parameters; C_{Ni} = is the analytical value of the Nth component; CAi = is the permissible superior concentration of the Nth component.

Table 2: Relative weight of the chemical parameters

Chemical parameters	WHO standards	Weight	Relative weight (Wi)
pH	6.5 – 8.5	4	0.1818
Total hardness	300	2	0.0909
Ca	75	2	0.0909
Mg	30		0.0909
Cl	250	3	0.1363
Total dissolved solids	500	4	0.1818
Nitrate	10	5	0.2272

Table 3: Water quality classification based on WQI value

WQI	Water quality
< 50	Excellent
50 – 100	Good
100 – 200	Poor
200 – 300	Very poor

To calculate the WQI, the sub index (SI) was first determined for each parameter and then used to determine the WQI using relations shown in Eqs. 6-7.

$$SI_i = W_i \times q_i \quad (6)$$

$$W_i = \sum_{i=1}^n SI_i \quad (7)$$

Where, SI_i is the sub index of the i^{th} parameter. The calculated WQI values are classified into four types as shown in Table 3.

RESULTS AND DISCUSSION

The results of the descriptive statistics of physicochemical parameters of groundwater sample during both dry and rainy season is presented in Table 4 and the computational results of modified DRASTIC (DRALTC) vulnerability index is shown in Table 5. The groundwater vulnerability index of the study area showed an observation depicting moderate to high groundwater vulnerability. The relatively high vulnerability can be attributed to low depth of water despite an average of 63 % clay content of the soil in the study area.

Two distinct groups were delineated; Group A comprising of eleven wells: OWS 2, 3, 8, 9, 10, 11, 12, 13, 14, 15 and 16. The wells revealed indices ranging from high to very high groundwater vulnerability potentials to dumpsite pollution while group B is made up of nine wells: OWS 1, 4, 5, 6, 7, 17, 18, 19 and 20, reflecting wells with moderate groundwater pollution potentials. T.

Cluster analysis

The dendrogram of hierarchical cluster analysis (Fig 2) revealed three main clusters. The clustering of wells indicates

groundwater quality varied in a way to suggest the influence of both natural (geochemical formation of the environment) and anthropogenic sources which include seepage and infiltration of pollutants from the dumpsite.

The dendrogram also reflects variation of water quality with season. Cluster I comprises of wells OWS 1, 2, 4, 8, 10, 7 and 9. The wells are all located on the eastern part of the dumpsite. The wells are scattered upstream of the dumpsite and split into subgroup based on the chemical characteristics of the water from the wells. Wells OWS 1, 2 and 4 (sub group A) have mean values of the anions: PO_4^{3-} , Cl^- and NO_3^- as 0.58, 50.6 and 13.6 mg/L, respectively.

The sub group B has 0.43, 57.1 and 16.9 mg/L for respectively for PO_4^{3-} , Cl^- and NO_3^- . The chloride level in the water may be attributed to contribution from both dumpsite and the nearby canal to the dumpsite. The pH also revealed the contribution of the canal. Sub group A is more acidic (pH = 4.6) than sub group B with pH value of 6.0. Cluster II is made up of wells OWS 5, 6, 15, 16 and 17. The wells are located on the northern part of the dumpsite. The wells splits into two with OWS 5 and 6 comprised of subgroup A and OWS 15, 16 and 17 made up of sub group B.

The inclusion of total dissolved solids distinguished this cluster from others. The TDS mean value for subgroup A was 794 mg/L while subgroup B had 560 mg/L. TSS value was the highest for this cluster. However, this cluster is less acidic than cluster I, possibly as a result of pollutant input from other anthropogenic sources. This cluster shows the moderately polluted region of the study area.

The cluster III comprises of eight wells: OWS 3, 11, 12, 13, 14, 18, 19 and 20. It is the most polluted region of the study area. The wells are scattered on the southern part of the dumpsite. These wells constitute the downstream sampling points around the dumpsite. The cluster III is further splitted into three sub group with different chemical characteristics. Sub group A has OWS 3, 13 and 14; sub group B has OWS 11 and 12 while sub group C consist of wells OWS 18, 19 and 20. The cluster has the highest chloride level, (142 m/L) indicating contamination possibly from dumpsite as well as seepage from septic tanks from residential area. The pH of sub group A is neutral and is within the WHO limits (6.5 –8.5) for drinking water.

Table 4: Seasonal physicochemical characteristics of groundwater around Olusosun dumpsite in Lagos

Variables	Min	Max	Mean	SD	CV%	Min	Max	Mean	SD	CV%	WHO
pH	3.90	7.10	5.26	0.55	1.8	4.1	7.50	6.3	0.8	1.36	6.5-8.5
Temp °C	24.8	27.4	25.5	0.9	17.3	23.9	25.7	25.0	0.5	21.3	
Alkalinity mg/L	23.5	378	144	91	63.2	21.7	375	134	83	64.6	
Acidity mg/L	13.4	154	55.9	37	66.6	11.4	135	122	80	73.5	
TH mg/L	4.34	135	48.8	36	79.2	5.01	127	43.2	41	75.9	500
EC mS/cm	0.32	1.68	0.90	0.6	44.7	0.31	1.71	0.78	0.3	56.2	1.4
TDS mg/L	122	848	411	190	47.8	202	807	395	210	49.0	1000
TSS mg/L	114	549	350	150	42.6	137	583	366	150	41.3	
TS mg/L	323	1420	777	310	37.3	325	1230	762	290	37.8	1000
PO ₄ ³⁻ mg/L	0.066	0.930	0.33	0.3	66.7	0.003	0.819	0.36	0.3	1.3	5
SO ₄ ²⁻ mg/L	9.27	69.9	22.4	17	76.6	6.5	65.0	19.6	22	142	400
NO ₃ ⁻ mg/L	7.60	35.6	13.9	6.4	47.0	8.56	32.4	11.6	5.8	47.9	10
Cl ⁻ mg/L	19.9	142	68.2	34	50.5	20.0	124	75.1	21	59.1	250

Table 5: DRALTC Index for groundwater around Olusosun dumpsite in Lagos

Factor	Depth to water			Recharge net			Distance			Topography			CP			AM			PVI
Weight	5			4			4			1			4			3			
	V	R	N	V	R	N	V	R	N	V	R	N	V	R	N	V	R	N	
OWS1	18.2	7	35	1883	9	36	630	3	12	1-2%	10	10	60%	3	12	8	3	24	129
OWS2	17.7	7	35	1883	9	36	1	10	40	1-2%	10	10	59%	3	12	8	3	24	171
OWS3	8.1	9	45	1883	9	36	95	9	36	1-2%	10	10	65%	3	12	8	3	24	163
OWS4	9.6	9	45	1883	9	36	827	2	8	1-2%	10	10	60%	3	12	8	3	24	127
OWS5	17.6	7	35	1883	9	36	917	2	8	1-2%	10	10	67%	3	12	8	3	24	125
OWS6	11.9	9	45	1883	9	36	761	2	8	1-2%	10	10	67%	3	12	8	3	24	135
OWS7	20.2	7	35	1883	9	36	829	2	8	1-2%	10	10	59%	3	12	8	3	24	125
OWS8	8.9	9	45	1883	9	36	140	7	28	1-2%	10	10	60%	3	12	8	3	24	155
OWS9	12.1	9	45	1883	9	36	530	3	12	1-2%	10	10	61%	3	12	8	3	24	138
OWS10	8.8	9	45	1883	9	36	561	3	12	1-2%	10	10	60%	3	12	8	3	24	138
OWS11	10.8	9	45	1883	9	36	712	3	12	1-2%	10	10	60%	3	12	8	3	24	138
OWS12	10.2	9	45	1883	9	36	739	3	12	1-2%	10	10	64%	3	12	8	3	24	138
OWS13	14.5	9	45	1883	9	36	625	3	12	1-2%	10	10	61%	3	12	8	3	24	138
OWS14	12.9	9	45	1883	9	36	675	3	12	1-2%	10	10	64%	3	12	8	3	24	138
OWS15	10.2	9	45	1883	9	36	621	3	12	1-2%	10	10	59%	3	12	8	3	24	138
OWS16	9.7	9	45	1883	9	36	526	3	12	1-2%	10	10	58%	3	12	8	3	24	138
OWS17	11.6	9	45	1883	9	36	867	2	8	1-2%	10	10	59%	3	12	8	3	24	135
OWS18	12.3	9	45	1883	9	36	871	2	8	1-2%	10	10	58%	3	12	8	3	24	135
OWS19	15.6	7	35	1883	9	36	1321	1	4	1-2%	10	10	62%	3	12	8	3	24	121
OWS20	16.4	7	45	1883	9	36	1127	1	4	1-2%	10	10	58%	3	12	8	3	24	125

V = value, R = rate and Num = N, CP = Clay percentage, AM = Aquifer media

Validation of modified DRASTIC model

There was variation in the concentration of nitrate in groundwater around the dumpsite.. The range of the values are 8.56-32.4 mg/L (rainy season) and 7.6- 35.6 mg/L (dry season) and 85% of the water samples showed values higher

than the WHO permissible limits of 10 mg/L nitrate in drinking water. The N-NO₃⁻ level increased from 33.1 mg/L in 2009 to 35.6 mg/L in 2010 indicating increased cumulative effect of nitrate pollutant from the dumpsite. Nitrate concentration is used in this study to validate the efficiency of the modified DRASTIC model. There is similarity

to some extent between the results of groundwater vulnerability index and the pattern of spatial distribution of N-NO_3^- concentration in the water.

Water quality indices

The quality of groundwater under consideration with respect to drinking purpose can be established based on the WHO guidelines for drinking water (Table 4.0). The calculated WQI classified the water as good - poor - very poor based on the classification shown in Table 3.0. The range of WQI values was 61.8- 205 for groundwater around the dumpsite. The spatial variations classified 10% of the samples collected around Olusosun dumpsite as excellent, 35% as good, 55% as poor and 5% as very poor. Groundwater qualities of some of the wells are critical to human health and would require urgent attention. These wells include OWS 3, OWS 4, OWS 8, OWS 14, OWS 17 and OWS 18 around the dumpsite.

CONCLUSIONS

This study assessed the groundwater vulnerability potential to dumpsite pollution using a modified DRASTIC (DRALTC) model. The vulnerability index varied from moderate to high. The high clay soil around the dumpsite inhibits infiltration of pollutants into the groundwater thereby reducing the impacts of the dumpsite. The Water Quality Index ranged from 61.8 to 205 delineating good-poor-very poor class of water type. About sixty percent of water collected around the dumpsite are unsafe for human consumption without further treatment. The study demonstrated that DRASTIC model is a good tool in environmental management, for it helps in evolving policies necessary for environmental sustainability.

ACKNOWLEDGEMENTS

The authors gratefully acknowledged the effort and contributions of Dr Oluwapelumi O. Ojuri of Federal University of technology, Akure, Nigeria.

REFERENCES

- Aboyade, A., 2004. The potential for climate change mitigation in Nigeria solid waste disposal sector. A case study of Lagos. MSc thesis, Lund University, Sweden. Pp 1- 47.
- Adesola, B., Ogundipe, K., Sangosanya, K.T., Akintola, B.D., Oluwa, A., Hassan, E., 2016. Comparative study on the biosorption of Pb(II), Cd(II) and Zn(II) using Lemon grass (*Cymbopogon citratus*): Kinetics, isotherms and thermodynamics. Chemistry International 2, 89-102.
- Aller, L., Bennett, T., Lehr, J., Petty, R., Hackett, G., 1987. DRASTIC: a standardized system for evaluating groundwater pollution potential using hydrogeologic settings: U.S. environmental protection agency report 600/2- 87/035, Pp. 622.
- Almeida, C., Quintar, S., González, P., Mallea, M., 2008. Assessment of irrigation water quality. A proposal of a quality profile. Environ. Monit. Assess. 142(1-3),149-152. APHA/AWWA/WPCF. 2005. Standard Methods for the Examination of Water and Wastewater. 21st ed. Washington.
- Babarinde, A., Onyiaocha, G.O., 2016. Equilibrium sorption of divalent metal ions onto groundnut (*Arachis hypogaea*) shell: kinetics, isotherm and thermodynamics. Chemistry International 2, 37-46.
- Bilal, N., Ali, S., Iqbal, M., 2014. Application of Advanced Oxidations Processes for the Treatments of Textile Effluents. Asian Journal of Chemistry 26, 1882-1886.
- British Broadcasting Services (BBC), 2011. Weather BBC Weather Lagos Nigeria, BBC, London.
- Brown, R. M., McClelland, N. I., Deininger, R. A., Tozer, R., 1970. A Water Quality Index. Do we dare? Water and Sewage Works 117, 339- 343.
- FD- ALR (Federal Department of Agricultural Land Resources). 1995. "Reconnaissance Soil Survey of Nigeria," FDALR, Lagos, Pp. 281.
- Foster, S.S.D., Hirata, R., Gomes, D., D'Elia, M., Paris, M., 2002. Groundwater quality protection: A guide for water utilities, municipal authorities, and environment agencies. 2th ed. Washington, DC, USA: World Bank.
- H'ebert, S., 1996. Development d'un indice de la quality bacteriologique et aters-chimique de l'eau pour des rivi'eres du Quebec' Report of the Ministi'ere de l. Environnement et dela Faune, Quebec, Q.C, Canada.
- Iqbal, M., 2016. *Vicia faba* bioassay for environmental toxicity monitoring: A review. Chemosphere 144, 785-802.
- Iqbal, M., Bhatti, I.A., 2014. Re-utilization option of industrial wastewater treated by advanced oxidation process. Pakistan Journal of Agriculture Sciences 51, 1141-1147.
- Iqbal, M., Bhatti, I.A., 2015. Gamma radiation/ H_2O_2 treatment of a nonylphenol ethoxylates: Degradation, cytotoxicity, and mutagenicity evaluation. Journal of Hazardous Materials 299, 351-360.
- Iqbal, M., Bhatti, I.A., Zia-ur-Rehman, M., Bhatti, H.N., Shahid, M., 2014. Efficiency of Advanced Oxidation Processes for Detoxification of Industrial Effluents. Asian Journal of Chemistry 26, 4291-4296.
- Iqbal, M., Khera, R.A., 2015. Adsorption of copper and lead in single and binary metal system onto *Fumaria indica* biomass. Chemistry International 1, 157b-163b.
- Iqbal, M., Nisar, J., 2015. Cytotoxicity and mutagenicity evaluation of gamma radiation and hydrogen peroxide

- treated textile effluents using bioassays. *Journal of Environmental Chemical Engineering* 3, 1912-1917.
- Jena, V., Dixit, S., Gupta, S., 2013. Assessment of Water quality index of industrial area surface water samples. *International Journal of ChemTech Research* 5(1), 278-283.
- Khan, A.A., Tobin, A., Paterson, R., Khan, H., Warren, R., 2005. Application of CCME procedure for deriving site-specific water quality guidelines for the CCME Water Quality Index. *Water Quality Research Journal of Canada* 40(4), 448-456.
- Lee, S., 2003. Evaluation of Waste Disposal Site Using DRAS-TIC System in Southern Korea. *Environmental Geology* 44(6), 654-664.
- Liu, C.C., Jean, J.S., Nath, B., Lee, M.K., Hor, L.I., 2009. Geochemical characteristics of the fluids and muds from two southern Taiwan mud volcanoes: Implications for water-sediment interaction and groundwater arsenic enrichment. *Applied Geochemistry* 24, 1793-1802.
- Mangukiyi, R., Bhattacharya, T., Chakraborty, S., 2012. Quality characterization of groundwater using Water Quality Index in Surat city, Gujarat, India. *ISCA International Research Journal of Environmental Sciences* 1(4), 14-23.
- Mor, S., Ravindra, K., Vischher, A.R.P., Dahiya, P., Chandra, P., 2005. Municipal Solid Waste Characterisation and its assessment for potential methane generation at Gazipur Landfill Site, Delhi: A case study. *Science of The Total Environment* 371, 1-10.
- Ojuri, O.O., Bankole, O.T., 2013. Groundwater vulnerability assessment and validation for a fast growing city in Africa: A case study of Lagos, Nigeria. *Journal of Environmental Protection* 4, 454-465.
- Oketola, A. A., Adekolurejo, S. M., Osibanjo, O., 2013. Water Quality Assessment of River Ogun Using Multivariate Statistical Techniques. *Journal of Environmental Protection* 4, 466- 479.
- Osibanjo, O., Majolagbe, A.O., 2012. Physicochemical quality assessment of groundwater based on land use in Lagos city, southwest, Nigeria. *Chemistry International* 2(2), 79-86.
- Palma, P., Alvarenga, P., Palma, V.L., Fernandes, R. M., Soares, A. M., Barbosa, I.R., 2010. Assessment of anthropogenic sources of water pollution using multivariate statistical techniques: A case study of the Alqueva's reservoir, Portugal. *Environmental Monitoring and Assessment* 165, 539-552.
- Parmar, K., Parmar, V., 2010. Evaluation of water quality index for drinking purposes of river Subernarekha in Singhbhum district. *International Journal of Environmental Sciences* 1(1), 77-81.
- Poonam, T., Tanushree, B., Sukalyan, C. 2013. Water quality indices- important tools for water quality assessment: A review. *International Journal of Advances in Chemistry* 1(1), 23-61.
- Prati, L., Pavanello, R., Pesarin, F., 1971. Assessment of surface water quality by a single index of pollution, *Water Research* 5(7), 41-75.
- Qureshi, K., Ahmad, M.Z., Bhatti, I.A., Iqbal, M., Khan, A., 2015. Cytotoxicity reduction of wastewater treated by advanced oxidation process. *Chemistry International* 1, 53-59.
- Rahman, A., 2008. A GIS based DRASTIC model for assessing groundwater vulnerability in shallow aquifer in Aligarh, India. *Applied Geography* 28 (1) 32-53.
- Reza, R., Singh, G., 2010. Assessment of groundwater quality status by using water quality index method in Orissa, India. *World Applied Sciences Journal* 9 (12), 1392-1397.
- Rocchini, R., Swain LG. 1995. The British Columbia Water Quality Index, Water Quality Branch, EP Department, B.C., Ministry of Environment, Land and Park, Victoria, B.C., Canada, 13.
- Rosen, L., 1994. A study of the DRASTIC methodology with emphasis on Swedish condition. *Groundwater* 32(2), 278-285.
- Saatiz, M., Sulaian, W., 2011. GIS DRASTIC model for groundwater vulnerability estimation of Asten-Kouchesfahan plain, Northern Iran. *International Journal of Water* 6(1/2), 1- 14.
- Sayed, M., 2015. Efficient removal of phenol from aqueous solution by the pulsed high-voltage discharge process in the presence of H₂O₂. *Chemistry International* 1, 81-86.
- Singh, U.K., Kumar, M., Chauhan, R., Jha, P.K., Ramanathan, A., Subramanian, V.. 2008. Assessment of the impact of landfill on groundwater quality: a case study of the Pirana site in western India. *Environmental Monitoring and Assessment* 141(1-3), 309-21.
- Srinivas, G. R., Nageswarara, G. 2013. Assessment of groundwater quality using Water Quality Index. *Archives of Environmental Science* 7, 1-5.
- Thirumalaivasan, D., Karmegam, M., Venugopal, K., 2003. AHPDRASTIC: software for specific aquifer vulnerability assessment using DRASTIC model and GIS. *Environmental Modelling and Software* 18, 645-656.
- Ukpaka, C., 2016. Development of model for bioremediation of crude oil using moringa extract. *Chemistry International* 2, 19-28.

- Ukpaka, C., Wami, E., Amadi, S., 2015. Effect of pollution on metal corrosion: A case study of carbon steel metal in acidic media. *Current Science Perspectives* 1, 107-111.
- Yahia, A., Bouabid, M., 2011. Assessment of aquifer vulnerability based on GIS and ARCGIS method: A case study of Sanaa Basin (Yemen). *Journal of Water Resources and Protection* 3(4), 845- 855.

Visit us at: <http://bosaljournals.com/chemint/>
Submissions are accepted at: editorci@bosaljournals.com