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GROUNDWATER QUALITY ASSESSMENT AROUND IGBATORO DUMP YARD USING GEOSPATIAL TECHNOLOGY

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ABSTRACT

This study evaluated the degree of groundwater pollution near the dump yard at Igbatoro, Ondo State. The entire study area was digitized and georeferenced in order to produce pollution maps from results obtained. Forty-five (45) water samples were obtained from fifteen (15) different locations at distances ranging from 50 m to 150 m around the refuge dump. The coordinate of the sample collection points were acquired using handheld GPS. Samples recovered were taken to the laboratory in an air tight plastic container where the physcio-chemical characteristics and other parameters needed for the computation of Water Quality Index (WQI) was calculated. Some parameters evaluated includes but not limited to the followings: dissolve oxygen (DO), total suspended solid (TSS), pH, total dissolved solid (TDS), turbidity, concentration of nitrate and nitrite, chloride, phosphate, total coliform count, and heavy metals including iron, lead, copper, cadmium, and zinc. Results obtained were compared with WHO standards for drinking water and was also used for calculating WQI for the study area. The result showed that WQI in the area ranged from 41.394 – 59.515 (50 m), 58.840 – 66.556 (100 m) and 71.111 – 85.384 (150 m). The water quality range from bad (50 m) to good (150 m) i.e. the quality of the water improved as the distance away from the dump yard increased. Other parameters investigated also had values higher than the permissible limits recommended by WHO. These values were exported into ArcGIS 9.3 software where they were used to produce groundwater quality map of the area. The work therefore recommends that water quality around areas of waste discharge should be monitored and adequate treatment recommended where necessary. This will help prevent epidemics in such locations.

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Keywords: *Geospatial Information Technology, Water Quality Index, Pollution, Treatment*

INTRODUCTION

Increased population, urban expansion, intensification of human daily routine and improvement in the standard of living has a corresponding effect on the volume of solid waste generated. Increase in population is mainly responsible for increase in Municipal Solid Waste (MSW). In most developed and developing countries, land filling is the cheapest and easiest means of disposing solid waste (Jhamnani *et. al.,* 2009).

In Nigeria and many other low-medium income earning nations, virtually all the waste generated are disposed using dumpsite. Availability of land at cheaper rate makes land filling operations most desired in these areas. Even in advanced nations with developed cities where land is scarcely available and the policies of reduction, reuse and diversion from landfill are enforced; large proportion of generated MSW are still land filled (USEPA, 2007).

In Akure as in the case with many cities in Nigeria, there is no accurate record of MSW generated but disposal is usually by indiscriminate dumping into any nearby dumpsite. Apart from incineration, over 80% of MSW generated goes into dumpsites (Longe and Balogun, 2010). However, in most advanced countries like Ireland, Scotland and United Kingdom, there is meaningful reduction in the volume of waste generated because there is much effort in MSW management which is targeted at recycling and reduction of waste to improve the environment (USEPA, 2007, 2008).

Uncontrolled waste disposal into dumpsite poses serious threat in the environment especially land and groundwater. Water is very crucial for existence of plants, animals and man. Every living thing originated from water and depend on it for continuous living. In the last couple of years, there has been increase in demand for fresh portable waterdue to increase in population and industrial growth (Ilaboya *et al.,* 2014). If dumpsites are not properly managed and maintained, it can cause both surface and subsurface water contamination in addition to air pollution and soil degradation (Chavan and Zambare, 2014). The nature of the threat of the contaminants is a function of the composition and quantity of leachate including distance of dumpsite from water source (Zerboc, 2003). Dumpsites have greater tendency of groundwater pollution within the solid waste disposal sites because the leachate from the decay of organic waste at these dumpsites percolates into the local artesian basin. This is serious health implication to groundwater users and their surroundings (Chavan and Zambare, 2014). The danger it portends is so huge that once groundwater is contaminated, it takes a long period of time to remediate or treat (Ilaboya *et al.,* 2014).

Leachates generated by the waste in the uncontrolled landfill sites have become a major environmental trouble in so many cities across the globe. On the contrary, the pollutants are released slowly toward the areas of the system with higher permeability, thereby creating constant level of contamination and maintaining their toxicities. Municipal landfill leachate are highly intense complex effluents which comprises of inorganic compounds, such as calcium, ammonium, potassium, magnesium, sodium, chlorides, sulphates, iron and heavy metals such as lead, zinc, chromium, cadmium, copper and nickel,(Longe and Balogun, 2010).

It is therefore necessary to check the quality of ground water at regular time intervals so as to ascertain the danger of its possible contamination which may cause water-borne diseases to human population. One way to monitor the quality of water is to constantly check the concentration of the associated parameters and cross correlates it against water quality standards. Other methods will involve the use of multivariate statistics to monitor the variability of water quality parameters with time, location and distance and also the water quality index approach that helps to convert the overall quality of water samples into an index that can easily be managed and explained (Ilaboya *et al.,* 2014; Raphael *et al.,* 2007). Hence, the present study involves the analysis of water quality in terms of various parameters of groundwater around the Igbatoro MSW dump yard, in Akure, Nigeria. The aim of the study is to integrate geospatial knowledge into evaluation of groundwater quality in a MSW dump yard with a view to suggesting appropriate measures in protecting groundwater in the region.

STUDY AREA

The project location is along Igbatoro road(Southward of Ondo state capital), Akure South Local Government Area, in Akure, Ondo state, south west Nigeria. Along this same route, is the Ondo State Integrated Wastes recycling and Treatment Project (OSIWRTP), it receives different types of waste from various locations within Akure metropolis. It is the largest dump yard in the state capital which has also impaired negatively on the resident of the vicinity since there is deliberate violation of MSW rules framed by the Ministry of Environment in the state.The dump yard lies between 5^0 14’ 10’’E to 5^0 14’ 30’’E and 7^0 13’ 00’’E to 7^0 13’20’’N of the Greenwich meridian. Within a period of 10years, the population of Akure increased from 2, 312, 535 to 2, 983, 433 while the projected estimate is almost 5,000,000 in 2022. The ratio of rural/urban dwellers stands at 61/39 and rural to urban migration continues to increase with people moving to urban area for white collar jobs and better social amenities. Ondo State is endowed with an abundance of natural resources – bitumen deposits and liquid natural gas, extensive tropical forest reserves and a natural port and river. Akure is the key trading centre for a farming region that grows yams, cassava, maize, bananas, rice, palm oil, okra, and pumpkins; Cocoa is the most important locally commercial crop produced for export and followed by cotton and palm. Solid waste in Akure typically consists of 70.3% from Domestic waste while 18.6%,6.3% and 4.8% are commerce, agriculture and industrial waste respectively (Olarewaju and Ilemobade, 2009). Over 60% of the total annual waste generated are organic and decay material which can percolate down to water table to cause groundwater poisoning.

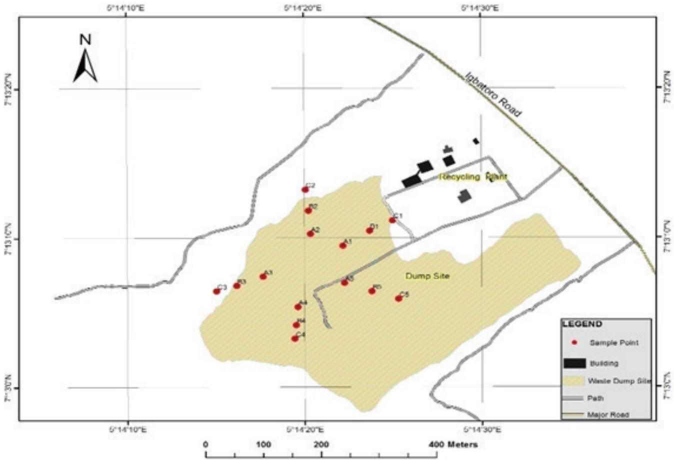

Figure 1: Map of the Study Area Showing Sampling Points

MATERIALS AND METHOD

Water Sample Collection

Fifteen boreholes were selected around the dump yard and were used for these studies. At radial distances of 50 m, 100 m, and 150 m, three samples were collected at five different borehole locations, making a total of forty-five samples (three samples per borehole per radial distance). The sampling was carried out in the peak of the rainy season i.e. June, July and August, 2017. These periods were chosen so as to study the effects of leachate caused by moving water from the dump site on ground water quality. The samples were stored in clean dried plastic containers, incubated at room temperature and analyzed within 12 – 24 hours. The samples were analyzed for various water quality parameters using standard procedures as proposed by standard methods for the examination of water and waste water (2007). The mean value of the water quality test results in each radial distance were represented as where A_1, A_2, A_3, A_4,A_5,B_1, B_2, B_3, B_4,B_5,C_1, C_2, C_3, $C_4$and C_5. The letter A, B and C represent the radial distances of 50 m, 100 m and 150 m respectively.

The water quality index (WQI), for each water sample was developed to evaluate the water quality index trend along the different location based on the measured water quality data sets. Some of the water quality parameters that were investigated include; dissolve oxygen (DO), total suspended solid (TSS), pH, total dissolved solid (TDS), turbidity, concentration of nitrate and nitrite, chloride, phosphate, total coliform count, and heavy metals including iron, lead, copper, cadmium, and zinc.

Determination of Weight age

In calculating WQI, the Weight age of each of the parameters identified is first ascertained. Parameters with higher allowable limit are less toxic because they cannot change ground water quality even when they are in large amount. Therefore, the weight age of tested parameters have an inverse relationship with the allowable limit. Hence

$$W_n = \frac{K}{S_n}$$

W_n = Tested Parameter Unit Weight
S_n = WHO Standard Values
K = Constant of proportionality

$$K = \frac{1}{\sum_{i=1}^{s} \frac{1}{S_n}}$$

Quality Rating Computation

Rating scale was assembled for set of values of each parameter. This rating ranged from 0 – 100 and was shared in intervals of five. The rating q_n= 0 indicates severe pollution (the tested parameter indices surpasses the maximum allowable limit. Conversely, q_n= 100 is an indication that parameter indices available in the water has desirable values. Other ratings (q_n= 40, q_n= 60 and q_n= 80) are within these extremes. These values represent excessive pollution, moderate pollution and slightly less pollution respectively. This is the modified version of the rating scale; it is calculated as follows (Ilaboya *et. al.,* 2014; Rocchini and Swain,2015):

$$q_n = \frac{100(V_n - V_{io})}{(S_n - V_{io})}$$

Where:
q_n = Quality rating or sun index
V_n = Test result for each parameter tested
S_n = Standard value of each parameter
V_{io} = ideal value of selected parameters tested (in pure water V_{io} = 0 for all parameters tested except pH and dissolved oxygen which is 7.0 and 14.6 respectively.
The resulting value is multiplied by a weightage factor which has significance to the water quality. The resulting sums are added to obtain one WQI for the water. It is a mathematical approach for the calculation of a unit number from various test results. The Water Quality Index calculated from the results, is a representation of the level of water quality in any given water body. The steps below were followed in evaluation of WQI in the river

1. The weightage unit (Wn) were determined for all tested parameters and added to get $\sum W_n$

2. The quality rating of all parameters tested were added to get $\sum q_n$

3. The index Wn*qn was calculated for each parameter tested and summed up to obtain $\sum W_n.q_n$

4. Mass balance equation was used to compute WQI for each water sample $\frac{\sum W_n.q_n}{W_n}$

5. Water Quality Index (WQI) = 100-Z was used to represent the level of water quality. The computed WQI and other water parameters that was determined were exported into ArcGIS 9.3 software for the generation of spatial information for the dump yard.

Spatial distribution of the water quality parameters
Spatial distribution is a graphical display that summarizes the data in two or more axes that is used to draw many conclusions. Spatial distribution of water quality parameters is a model representation of the water quality parameters distributed in the study area. The spatial distribution is done here by the Geographical Information system (GIS) software ArcGIS 9.3. The GIS is the sophisticated tool to describe the spatial analysis of the distribution of the water quality on two or more axes.Quality rating computation is used in the spatial analysis of the groundwater. The rating scale isa type of deterministic methodfor multivariate interpolationwith a known scattered set of points.

Table1: (WHO Standard for drinking water)

Factors	WHO Standard
pH	6.5-8.5
Electrical Conductivity (EC)	400
Dissolved Oxygen (DO)	5
Total Dissolved Solid (TDS)	500
Alkalinity	600
Iron (Fe)	0.3
Cadmium (Cd)	0.003
Copper (Cu)	1.0

RESULTS AND DISCUSSION
The results of the physico-chemical characteristics of groundwater samples collectedat the 15 samplings points were used to calculate WQI and are presented in Table 2, 3 and 4 respectively.Eleven (11) physico-chemical parameters which include turbidity, chloride, hardness and the other parameters listed in table 1 were analyzed. Water Quality Index (WQI) was computed using result of parameters listed in table 1.

Table 2: Physico-Chemical Characteristics and WQI of Groundwater samples at A1 – A5(50 m from dump yard)

S/N	Parameter	WHO Limit	Unit	A_1	A_2	A_3	A_4	A_5
1	pH	6.5-8.5	Nil	6.9	6.8	6.7	8.3	8.6
2	EC	400	s/m	284	309	216	189	241
3	DO	5	Mg/L	3.73	4.21	2.77	3.08	3.26
4	TDS	500	Mg/L	274	401	370	438	295
5	Alkalinity	600	Mg/L	361	482	384	447	522
6	Iron (Fe)	0.3	Mg/L	1.38	0.56	0.33	0.1	0.45
7	Cadmium (Cd)	0.003	Mg/L	0.0016	0.0012	0.0017	0.0018	0.0013
8	Copper (Cu)	1.0	Mg/L	0.01	0.3	0.02	0.22	0.47
9	Turbidity	5	NTU	3.50	5.28	4.02	3.06	2.73
10	Chloride	250	Mg/L	155	98	73	84	63
11	Hardness (as in CaCO3)	150	Mg/L	97	66	102	112	85
12	WQI			57.209	41.394	57.072	59.515	44.275

NOTE: pH standard value used was 6.5

Table 3: Physico-Chemical Characteristics and WQI of Groundwater samples at B1 – B5 (100 m from dump yard)

S/N	Parameter	WHO Limit	Unit	B_1	B_2	B_3	B_4	B_5
1	pH	6.5-8.5	Nil	6.7	7.3	6.8	6.6	7.2
2	EC	400	s/m	104	92	87	211	106
3	DO	5	Mg/L	4.3	4.0	3.8	4.2	3.3
4	TDS	500	Mg/L	368	274	178	232	188
5	Alkalinity	600	Mg/L	303	339	290	183	204
6	Iron (Fe)	0.3	Mg/L	0.42	0.2	1.09	0.84	0.11
7	Cadmium (Cd)	0.003	Mg/L	0.0019	0.0011	0.0018	0.0017	0.0014
8	Copper (Cu)	1.0	Mg/L	0.31	0.40	0.1	0.33	0.55
9	Turbidity	5	NTU	2.28	2.85	1.57	2.88	3.04
10	Chloride	250	Mg/L	124	81	64	82	53
11	Hardness (as in CaCO3)	150	Mg/L	84	58	72	50	67
12	WQI	-		64.018	66.556	62.828	58.840	66.372

NOTE: pH standard value used was 6.5

Table 4: Physico-Chemical Characteristics and WQI of Groundwater samples at C_1 – C_5 (150 m from dump yard)

S/N	Parameter	WHO Limit	Unit	C_1	C_2	C_3	C_4	C_5
1	pH	6.5-8.5	Nil	6.7	6.6	6.9	6.8	6.8
2	EC	400	s/m	92	83	71	93	62
3	DO	5	Mg/L	2.1	1.93	1.40	1.5	1.66
4	TDS	500	Mg/L	198	163	112	108	84
5	Alkalinity	600	Mg/L	144	167	182	93	95
6	Iron (Fe)	0.3	Mg/L	0.6	0.94	1.04	0.2	0.4
7	Cadmium (Cd)	0.003	Mg/L	0.0021	0.0025	0.0023	0.0025	0.0024
8	Copper (Cu)	1.0	Mg/L	0.02	0.01	0.02	0.018	0.044
9	Turbidity	5	NTU	1.25	2.01	1.33	1.83	1.44
10	Chloride	250	Mg/L	93	62	51	104	133
11	Hardness (as in CaCO3)	150	Mg/L	57	71	36	40	52
12	WQI	-		71.111	85.384	79.118	82.938	80.315

NOTE: pH standard value used was 6.5

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From the test results, the pH of the water samples analyzed is within permissible limit by WHO, (6.5-8.5) with location A5 as exception which has value of 8.6 indicating the presence of alkaline due to leachate contamination. However, Chavan and Zambare (2014), ascertained that water with pH value ranging from 6.5 to 6.8 is slightly acidic which shows the presence of acidic pollutant. The value of Electrical Conductivity (EC) of the analyzed water samples (indicator of quantity of materials dissolved in water)falls within permissible limit by WHO although there were relatively higher values around point A (189-309). This location being the closest to the dump yards receives organic leachates which pollutes the groundwater. The Dissolved Oxygen values is within WHO permissible limit with only A_2, B_1 and B_2 having very high values. The value of Total Dissolved Solid (TDS) ranged from 84 mg/l to 438 mg/l. As the water sampling distance increases, TDS values decreased correspondingly; this indicates that the groundwater contamination is caused by solid waste from the dump yard and it is also responsible for the increased EC around location A. The values recorded for alkaline, chloride and cadmium were all within the permissible limit of WHO although at location A, the values were relatively higher due to its closeness to the dump yard. Apart from very few locations (A_4, B_2, B_5 and C_4), the value recorded for iron exceeds the allowable limit for iron in drinking water by WHO. Although the human biological system requires some amount of iron for normal metabolic activities, excess of it is carcinogenic (WHO guidelines, 2016). The values of turbidity, chloride and hardness improved as the sampling distance increases from the dump yard. The values were within the allowable limits apart from location A_2 where the turbidity value exceeded the permissible limit. In location A, the values of turbidity, chloride and hardness were relatively higher because of the presence of pollutant (organic fertilizers and leachate) in the groundwater. Higher values of these parameters makes the water unfit for domestic purposes and also with an unpleasant taste. Water Quality Index calculated using the first eight (8) parameters, had values ranging from 41.394 to

57.207 in location A, 58.840 to 66.556 in location B and 71.111 to 85.384 in location C respectively. For full classification of the water quality in the location, National Sanitation Foundation (NSF) was used. The classification criteria used as shown in Table 5, reveals that the water quality in location A can be classified as bad; location B falls under medium (category C) while location C is classified as good.

Table 5: Classification Criteria Standard, based on NSF

NSF-WQI	Descriptor	Category
91-100	Excellent	A
71-90	Good	B
51-70	Medium	C
26-50	Bad	D
0-25	Very Bad	E

The spatial distribution of water quality parameters in the study areas was produced using ArcGIS 9.3; maps generated showed areas of pollution and the distribution of all tested parameters within the area.

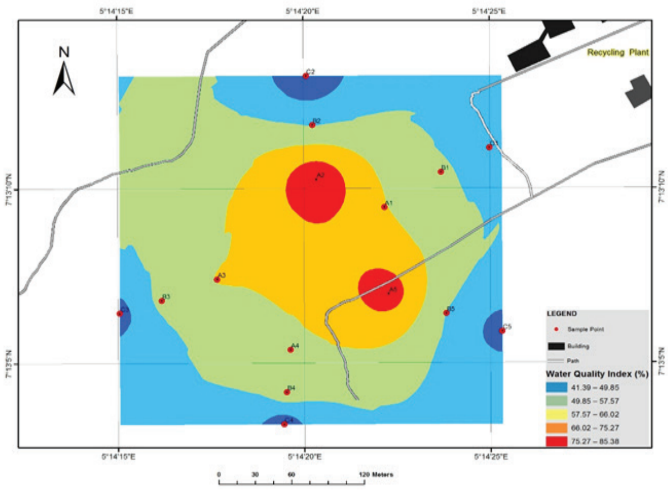

Figure 2: Spatial Distribution of Water Quality Index in the Study Area

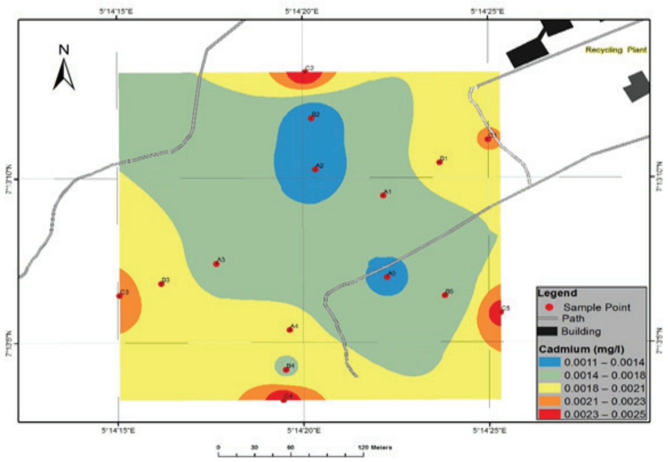

Figure 3: Spatial Distribution of Cadmium in the Study Area

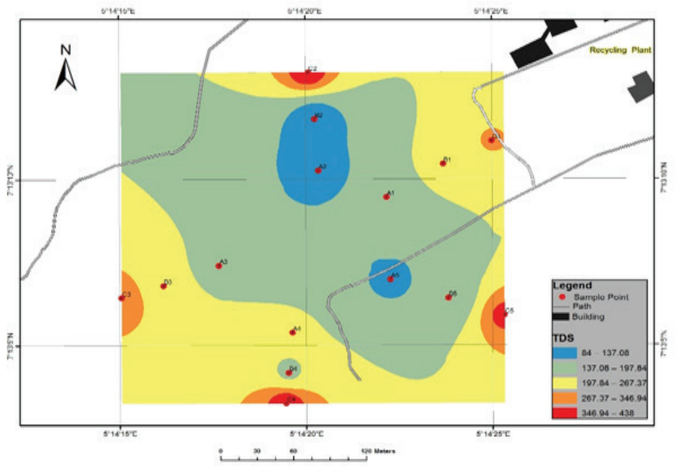

Figure 4: Spatial Distribution of Total Dissolved Solid in the Study Area

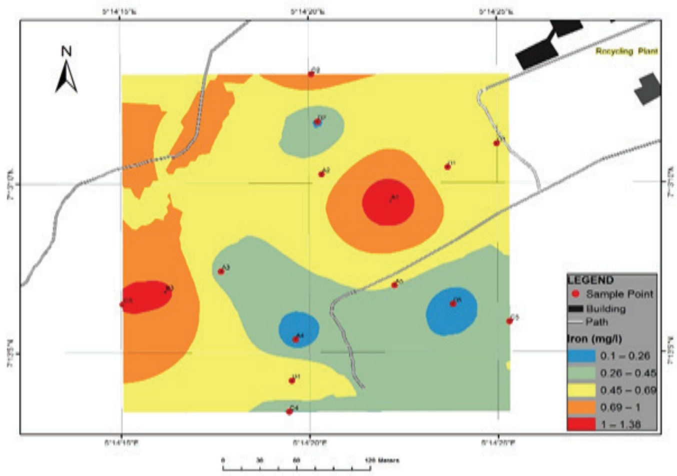

Figure 5: Spatial Distribution of Iron in the Study Area

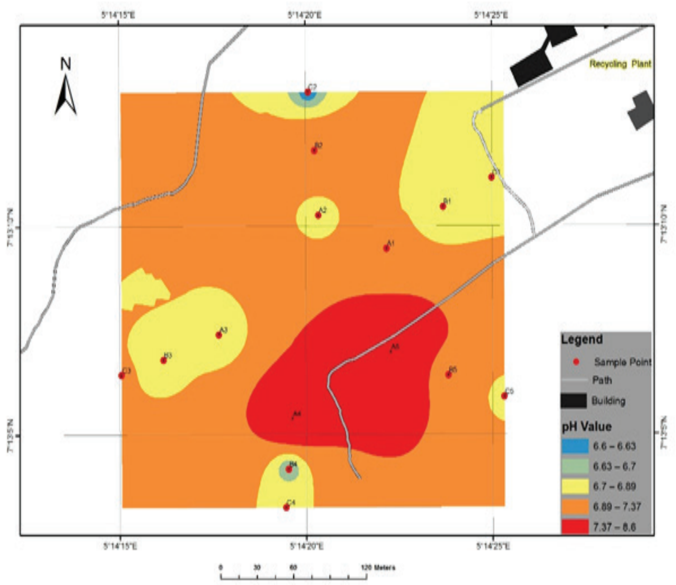

Figure 6: Spatial Distribution of pH in the Study Area

CONCLUSION

This study has established the fact that water quality index and other groundwater parameter around Igbatoro dump site are poor. However, the quality improves as the distance from the dumpsite increased. Water samples collected around location A, had poor water quality, while the samples collected around location C had better water quality index. ArcGIS also proved to be very effective in the spatial distribution of the water quality index as well as other water parameters. It is however recommended that appropriate treatment methods should be designed to help reduce the high iron concentration and also monitor other parameters so as to avoid epidemics.

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