GROUNDWATER QUALITY ASSESSMENT USING WATER QUALITY INDEX IN SOME PARTS OF ODEDA, SOUTH-WESTERN NIGERIA

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ABSTRACT

Groundwater quality samples were collected from boreholes and hand-dug wells located in some parts of the study area and were assessed for some physico-chemical parameters including pH, Electrical Conductivity, Total Dissolved Solids, total hardness, chloride, sulphate, nitrate, calcium hardness, magnesium hardness, potassium, iron and alkalinity. The results showed that most of the water quality parameters fell below the WHO maximum permissible limits with a few exceptions in about three locations. The quality indices were determined for each location and the values were found to be 20.86 – 57.40 indicating that about 75% of representative samples of the locations were good while about 15% was classified as poor. This can be attributed to high concentration of nitrates, EC, sulphates and total hardness in a few sample locations. The general low water quality index may have resulted from better sanitary conditions and improved living standards as well as the fact that the study was conducted at the peak of the rainy season. This type of assessment could be used as a powerful tool for making decisions and implementing water related policies as it documents water quality results that is easily understood by stake holders.

Keywords: water quality index, Odeda, groundwater.

1.0 INTRODUCTION

Water is a renewable natural resource and its availability is very vital for human existence. In general, water quality is equally important as the quantity, therefore, water quality is considered as an important factor used to assess environmental changes linked to social and economic development. Majority of the population in the developing countries do not have access to potable water and therefore resort to groundwater sources like shallow wells and boreholes which are unsafe for drinking and domestic purposes because of the high risk of contamination. Many African countries including Nigeria are unable to provide safe drinking water to half of their population. Population growth as well as rapid urbanization has put a lot of pressure on natural resources such as water supply in many parts of Odeda such as Camp, Isolu, Alabata, Osiele, etc. Unfortunately, service delivery such as municipal water supply and adequate sanitation has continued to lag behind in keeping pace with population demand which is ever increasing. For this reason, many inhabitants have to rely on alternative sources of water supply especially from groundwater sources for domestic and agricultural uses. However, groundwater in the area is under threat of contamination/pollution due to the utilization of on-site sanitation systems, dominated by pit latrines and septic tank-soak away systems and agricultural pollution originating mainly from irrigation water and runoff water after rains, carrying fertilizers, pesticides, herbicides, and faecal matter. Majority of the residents use pit latrines and yet shallow wells are located in close proximity (less than 10 meters to these wells), thus creating a serious risk of cross contamination of groundwater resources (Ashun, 2014). The contamination of water supplies not only affect water quality but also impact greatly on public health and socio-economic well-being of communities, It is therefore imperative that the groundwater quality status of a community be determined in order to generate a database for planning future water resource development. The formulation and use of indices has been recommended by water supply and sanitation agencies. Water quality index (WQI) is defined as a rating reflecting the composite influence of different water quality parameters (Ramakrishnaiah *et al.*, 2009).The data of quantitative analysis and world health organization (WHO) standards are used to evaluate water quality indices. WQI is a dimensionless number that combines multiple water-quality factors into a single number by normalizing values to subjective rating curves (Miller *et al*., 1986). A WQI summarizes large amounts of water quality data into simple terms (e.g., excellent, good, poor, etc.) for reporting to stakeholders (Hülya, 2009). This type of assessment is therefore a powerful tool for making decisions and implementing water related policies as it documents water quality results that are easily understood by stake holders.

20 MATERIALS AND METHODS

2.1 Geographical Settings

Odeda local Government is one of the twenty Local Governments in Ogun State of Nigeria. Its headquarters is located at Odeda along the Abeokuta – Ibadan road which is about 20 kilometers from the State capital, Abeokuta. Odeda Local Government covers an estimated land area of about 1,492 km2 which represents 1.65% of the total land area of Ogun State. It is composed of semi-urban centers and several small and scattered settlements with a population of 109,449 people .The area spans Northward from Obantoko to Bakatari and Eleso near Ibadan, Ogunmakin in Obafemi-Owode Local Government. It shares boundaries with Abeokuta South, Abeokuta North and Obafemi-Owode Local Government Areas in Ogun State, then Oyo State with Ibarapa and Iddo Local Government Areas in the North and East respectively as shown in fig.1 (Omoare *et al.*, 2015).

2.2 Climate

Odeda has a tropical climate with distinct dry and wet seasons characterized by the prevalence of the moist south westerly monsoon winds that results in heavy rainfall spread between March and October. Average temperature is about 32°C and humidity can be as high as 95%.

2.3 Socio–Economic Activities

The inhabitants are predominantly the Egbas who have their homesteads and farms in the area but mostly reside in Abeokuta. The people of Odeda LGA are predominantly farmers who engage in small scale farming. The major food crops of the area include cassava, yam, cocoyam, plantain, maize and vegetables, while cocoa is the major cash crop. The people of the area also engage in quarry business, trading, craft and artisan works. (Bamgbose *et al.*, 2013).

2.4 Hydrogeology

It is founded on a major part of the Pre-Cambrian basement complex rocks which are largely igneous rocks noted for low porosity. Increased weathering has resulted in the creation of cracks and fissures in the rock formation thereby making it easy for rainwater to seep through and increasing the amount of groundwater existing beneath. This has resulted in the increase in the number of boreholes and shallow wells existing in Odeda region occasioned by persistent incidents of water scarcity (Amori *et al.*, 2013).

2.5 Water Quality Index (WQI) Computation

For developing WQI for Odeda, the physico-chemical analyses of 20 water samples were randomly collected from different sites within the study area. Each ground water was analyzed for 12 parameters including pH, Electrical Conductivity, Total Dissolved Solids, Total Hardness, chloride, sulphate, nitrate, calcium hardness, magnesium hardness, potassium, iron and alkalinity using standard procedures recommended by APHA (1998). In order to compute WQI, three steps were followed according to the method adopted by (Balogun *et al*, 2015). In the first step, each of the 12 parameters were assigned a weight (w_i) according to its relative importance in the overall quality of water for drinking purposes as shown in table 1. The maximum weight of 5 was assigned to the parameter nitrate because of its importance in water quality assessment. Magnesium which is given the minimum weight of 2 as magnesium by itself may not be harmful.

In the second step, the relative weight (W_i) is computed from the following equation:

$$W_i = w_i \div Sw_i$$

Where, Wi is the relative weight, wi is the weight of each parameter. Calculated relative weight (W_i) values of each parameter are presented in Table 1.

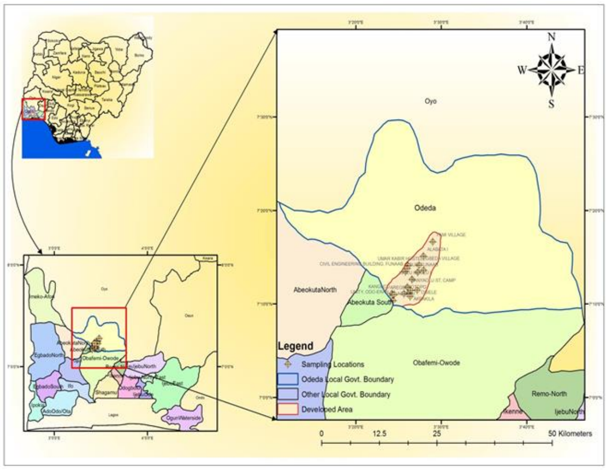

Fig.1 Map of Odeda Local Government showing sample locations. (Inset: map of Nigeria showing Ogun state and Map of Ogun state showing Odeda Local Government area).

Table 1. Standards, Weights and Unit weights for Groundwater Quality Parameters

PARAMETERS	WHO STANDARDS	Weight (w_i)	Relative Weight (W_i)
Ph	6.5-9.2	4	0.102564103
EC	1500	4	0.102564103
TDS	1000	4	0.102564103
HARDNESS	500	2	0.051282051
CALCIUM	200	2	0.051282051
MAGNESIUM	150	2	0.051282051
CHLORIDES	250	3	0.076923077
ALKALINITY	500	3	0.076923077
NITRATES	50	5	0.128205128
SULFATE	250	4	0.102564103
IRON	0.3	4	0.102564103
POTASSIUM	200	2	0.051282051
		39	1

Source: Ramakrishnaiah*et al.*, (2009); Lateef, (2011)

In the third step, a quality rating scale (q_i) is assigned for each parameter by dividing the concentration in each water sample by its respective standard limit value according to the guidelines laid down by WHO and the result is multiplied by 100. The equation for q_i is shown below:

$$q_i = (C_i \div S_i) \times 100 \quad (1)$$

where q_i is the quality rating, C_i is the concentration of each chemical parameter in each water sample in mg/l, and S_i is WHO drinking water standard limit for each chemical parameter in mg/l according to WHO (2004).

For computing the WQI, the Sub-Index (SI) is first determined for each chemical parameter, which is then used to determine the WQI as per the following equations:

$$SI_i = W_i \times q_i \quad (2)$$

$$WQI = \sum SI_i \quad (3)$$

SI_i is the sub-index of i^{th} parameter; q_i is the rating based on concentration of i^{th} parameter and n is the number of parameters. The computed WQI values ranges therefore, can be categorized into five types "excellent", "good", "poor", "very poor" and "unsuitable for drinking" as shown in Table 2 (Balogun *et al*, 2012).

Table 2. Water Quality Classification based on WQI Values

WQI Value	Water Quality
< 25	Excellent
26 – 50	Good
51– 75	Poor
76 – 100	Very Poor
> 100	Unfit for Drinking

2.6 Mapping Spatial Distribution of Groundwater Quality

Geographic information system (GIS) is a tool used to store, organize, manipulate, analyze, retrieve, display, and output geographically referenced information. The Inverse Distance Weighted (IDW) is used as interpolation method to create the spatial distribution map of groundwater quality, which infers the grid value for each cell by calculating the average of sample points. The calculated value depends on measured values of phenomenon in wells and the distance between wells and the calculated grid cell (Buchanan *et al*, 2009). The expected value is a weighted average of the neighboring groundwater wells in Inverse Distance Weighted method. Weights are calculated by taking the inverse of the distance from an observation's location to the location of the point being estimated (Guan *et al*,1999).

3.0 RESULTS AND DISCUSSION

According to WHO (2004), the standard permissible values of pH ranges between 6.5 - 9.2. From the results obtained from the in-situ readings taken from the selected sites as shown in Table 3, only samples S17 and S18 fell within the limits while the other samples collected from the case study showed acidic attributes with the minimum value of 5.3 recorded at S1 while the maximum value of 6.71 was recorded at the S17. The mean pH concentration was 6.0 and this indicates slight acidity of water within the study location. This average value is quite lower than the mean result of pH obtained for groundwater quality in rural land use according to Balogun *et al* (2012) This could be as a result of the time of sample collection which took place at the peak of the rainy season and could have resulted in the dissolution and percolation of acidic substances into the groundwater. Also according to Langmuir (1997) the pH of natural waters is often found slightly acidic (5.0-7.5) which are derived from the decay and subsequent leaching of plant materials. Another probable reason could be as a result of fertilizer application within the vicinity especially S17 which is a hostel located within the federal university of agriculture, Abeokuta and in close proximity to hectares of farmland. Acidic water, however, can be conditioned with lime to give the product water with increased pH (McGuire, 2007). This should be done to water in the study location to increase its pH before it is consumed (Ashun, 2014).

Table 3 Physico-chemical analyses and Descriptive statistics of Groundwater Quality in Odeda

SAMPLE LOCATION	PH	EC	TDS	ALKALINITY	TH	Ca^{2+}	Mg^{2+}	Cl^{-}	No^{3-}	$So_4 2-$	Fe^{3+}	K^{+}
1	5.3	230	140	90	110	96	14	32	47.62	122.5	0.21	2
2	6.36	130	65	110	174	99	75	56	44.22	122.5	0.03	1.5
3	5.6	89	46	190	58	44	14	32	6.8	11.3	0.13	2
4	5.88	215	108	101	64	52	12	36	13.61	98.4	0.24	2
5	5.56	507	256	120	144	86	58	74	62.36	62.9	0.13	11
6	6.1	136	68	200	76	64	12	64	NS	108	0.12	2.5
7	5.68	201	100	90	76	42	14	48	13.61	50	0.04	2.5
8	6.5	138	68	270	96	72	24	22	23.81	83.87	0.08	1.5
9	6	255	127	350	112	66	46	46	90.7	130.65	0.2	19
10	5.82	403	201	170	156	74	82	60	21.54	45.16	0.06	1
11	5.73	365	184	180	170	74	96	76	3.4	91.94	0.11	7.5
12	6.28	549	292	180	352	130	222	98	4.56	174.19	0.08	20
13	5.62	578	290	80	352	268	84	42	22.68	41.93	0.06	1
14	6.16	548	275	220	220	134	86	198	18.14	114.52	0.06	2
15	6.14	410	204	170	170	100	70	104	3.4	159.68	0.01	1
16	5.93	216	108	150	80	76	4	80	21.54	91.94	0.03	1
17	6.71	645	208	200	120	74	46	148	54.42	87.1	0.14	3
18	6.53	647	181	90	70	34	34	98	24.94	122.58	0.14	2
19	6.23	655	114	92	102	68	36	80	7.94	103.23	0.07	0.5
20	5.82	362	91	110	48	22	26	46	38.55	241.9	0.14	5

The maximum TDS value was 292 ppm obtained from sample S12 which is a protected hand dug well while the minimum of 46 was recorded in S3. All the samples collected fell below the maximum permissible limit of 500ppm as recommended by WHO (2004). The mean TDS for the study area is 156.3ppm which is far below the maximum permissible limit as recommended by WHO (2004). However when compared to mean TDS value obtained for groundwater quality for rural land use according to Balogun *et al* (2012), it would be observed that the former is far higher than the latter. Most of the hand dug wells and boreholes are well protected and therefore probably accounted for the low level of dissolved substances and apparent clarity of most of the water samples collected.

From the results obtained, the minimum EC value obtained was 89µS/cm from S3 while the maximum value of 655 µS/cm was recorded at S18 in FUNAAB. This site is located close to a site for commercial activities. However, the mean EC concentration of 363.95 µS/cm was recorded for the study area this is far higher than values obtained in Lagos according to Balogun *et al* (2012). It shows that all the samples collected and analyzed fell below the maximum permissible limit as recommended by WHO (2004). The occurrence of relatively high electrical conductivity values in some parts of the Catchment might be attributed to addition of some salts through the prevailing agricultural activities present within Odeda.

Minimum total hardness value of 48mg/l was recorded at S20, a borehole site located beside the civil engineering building in FUNAAB. The maximum value recorded was at both S12 (a protected hand dug well) and S13 (a borehole) with values 352mg/l, however, all the samples were below the permissible limit of 500mg/l (WHO,2004). It could be inferred that these sample results ranged from moderately soft for S20 to very hard as in the case of S12 and S13. The mean total hardness concentration for the study area was 137.50mg/l and this value is far below the mean TH concentration obtained for Ilorin which occupies a basement complex formation according to Olatunji *et al* (2015). Most of these areas are densely populated and it is probable that many of these locations resort to treatment of wells using Alum, etc. It could also be inferred that disposal of untreated sewage or improperly treated sewage may not impact negatively on the groundwater source due to the protective status of the groundwater sources. The rainy season may have also played a role in the values obtained at the sample locations by dissolving substances such as carbonates, bicarbonates and chlorides of calcium and magnesium.

Maximum value of 268mg/l was recorded at S13 (Osiele borehole scheme) while minimum value of 22mg/l was recorded at S20. The maximum permissible limit as recommended by WHO (2004) is 200mg/l thus indicating that only S13 exceeded the limit. Majority of the remaining samples showed values are of low concentration and the mean calcium hardness concentration for the study area is 83.75mg/l and is higher than the mean value obtained in a groundwater quality analyses for rural land use in Lagos (Balogun et al, 2012). S13 is a community borehole scheme and is located close to a market place. Commercial activities take place around this vicinity coupled with other domestic activities including washing, cooking and bathing. This may have caused the relatively high calcium concentration in that sample location.

The minimum Magnesium concentration of 4mg/l was recorded at S16 while the maximum value of the maximum concentration was recorded at S12. This site, S12 is the only location that exceeded the WHO maximum permissible limit of 150mg/l. The high concentration could be as a result of the fact that the sample location is within a residential area where the residents fetch water for cooking, washing and other domestic chores. It could also stem from sewage sources.

The mean magnesium concentration for the study area is 52.75mg/l which is far below the permissible limit for WHO but higher than the value obtained for the groundwater quality for rural land use in Lagos according to Balogun *et al* (2015).

The maximum concentration of alkalinity was recorded at S15 with 440mg/l while minimum value of 80mg/l was recorded at both S1 and S7. S1 is a protected hand dug well that is constructed outside a residential building while S7 is an unprotected hand dug well located at a block making factory. However, S15 is located within a residential area. The mean alkalinity concentration of the study area is 158.15mg/l and all the results obtained show that the alkalinity concentrations are all below the permissible limit for WHO. It is probable that the weathering of rocks and decaying of organic matter may have accounted for the relatively high concentration at S15.

The maximum chloride concentration is 198mg/l at S14 while minimum value of 22mg/l was recorded at S8.The mean chloride concentration for the study area is 72mg/l thus indicating that all the samples collected within the study area were below the WHO (2004) permissible limit of 250mg/l. This mean value when compared to results obtained for groundwater quality for rural land use in Lagos according to Balogun *et al* (2012) shows that the former is higher than the latter. It also indicates that possible sources of pollution such as organic wastes may not be impacting negatively as to cause problems such as diarrhea, gastrointestinal infections and unpleasant taste.

Samples S5, S9 and S17 all exceeded the maximum limit of nitrates as recommended by WHO (2014). The maximum value of 90.7mg/l was recorded at S9 while the minimum value of 3.4mg/l was recorded at S15 which is a borehole. S9 is located in a rural area beside a household and farmland. It is possible that contamination from a septic tank, sewage or agricultural runoff may have caused a leaching action into the groundwater. S15 is a borehole that is well constructed and located in an environment that is clean. The mean nitrate concentration for the study area recorded was 27.57mg/l which below the WHO permissible limit. These values are lower when compared to results obtained from Abeokuta groundwater sources (Adekunle *et al,* 2013). However, values above 10mg/l may not be safe for pregnant and nursing mothers for fear of “blue-baby syndrome”.

The maximum sulphate concentration of 241.9mg/l was recorded at S20 while a minimum of 11.3 mg/l was recorded at S3. The average sulphate concentration for the study area is 103.21mg/l thus indicating that it is below the WHO recommended limit. However, these values obtained are far higher than values obtained from GW sources in Lagos (Balogun *et al*, 2012).

The minimum iron concentration within the study area was recorded as 0.01mg/l while the maximum value obtained was 0.24mg/l. The mean iron concentration obtained was 0.10mg/l thus indicating that the values all fell below the maximum permissible limit as recommended by WHO(2004). The values obtained are higher in concentration when compared to a similar study carried out on iron concentration by Adekunle *et al* (2013).

The minimum concentration of potassium recorded was 0.50mg/l while maximum concentration recorded was 20mg/l thus indicating that all values fell far below the maximum permissible limit as recommended by WHO (2004). The mean potassium concentration of 4.4mg/l was recorded for the study location thus indicating the absence of any negative effects within the study area. This mean value when compared to the analyses of groundwater quality in Ilorin by Olatunji *et al* (2015) indicates that the former has values far below that of the latter.

Analyses of Water Quality Index

Water Quality Index is calculated to determine the suitability of water mainly for drinking purpose. The results of the water quality parameters as displayed in Table 4 showed that most of the samples collected fell below the limits set by WHO (2004). The WQI values ranged from 20.82 at S3 to 57.40 at S9. Most of the samples collected can be classified as good with high percentage of 75% falling into this category while 15% can be classified as poor, 10% can be classified as excellent. The general low WQI values could be attributed to relatively low values of most of the parameters that were measured. However, The reason for the relatively high WQI values for S9, S12 and S17 could be attributed to high concentration of nitrates in both S9 and S17 and relatively high concentration of EC, sulphate, Total hardness and Magnesium in S12.

It is probable that the low water quality index values may have resulted from better sanitary and improved living conditions within the study areas where sampling was carried out. The study was carried out during the peak of the 2015 rainy season and this may also have resulted in the dilution of dissolved salts thereby reducing their concentration when analyzed. Table 3 shows the Sample Locations and Water Quality Index Results while Table 4 shows the Categorization of Water Quality Index for the study area.

Conclusion

The compilation of different parameters into a single number provides an important tool for decision making especially in communicating information on water quality to the public and to policy makers. It can be concluded that based on the WQI method applied in this study, most of the groundwater sources located within the study area can be classified as good for drinking and other domestic purposes. The sources of pollution within the study location may stem from domestic, agricultural and natural sources. The pollution effects could be better controlled when there is proper legislation on water supply and sanitation as well as having a proactive monitoring activity on water supply and sanitation, all these should involve the relevant stakeholders including the communities, policy and decision makers through effective interactive for a including public enlightenment campaigns, education on water supply and hygiene in primary and secondary schools at Local Government Levels.

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Table 4 Sample Locations and Water Quality Index Results

SAMPLE	SAMPLE LOCATION	NORTHING	EASTING	GW SOURCE	WQI	CONDITION
1	KANGUDU	07° 11' 10"	003 20' 32"	PW	33.71	GOOD
2	UNITY, ODO-ERAN	07° 11' 20"	003 24' 18"	PW	38.7	GOOD
3	AREGBE	07° 11' 06"	003 24´ 14"	PW	20.82	EXCELLENT
4	AGBETU	07° 10´ 23"	003 24' 22"	PW	31.15	GOOD
5	ISOLU I	07° 12´ 38"	003° 26´ 35"	PW	47.16	GOOD
6	ISOLU II	07° 12´ 56"	003° 26´41"	UPW	25.62	GOOD
7	HARMONY STATE, ISOLU	07° 13´ 25"	003° 27´ 14"	UPW	22.11	EXCELLENT
8	ALABATA I	07° 14´ 09"	003° 27´ 24"	PW	30.36	GOOD
9	EGBEDA VILLAGE	07° 15´ 08"	003° 20´ 32"	PW	57.4	POOR
10	FAMI VILLAGE	07° 16' 40"	003° 29´ 0"	UPW	33.52	GOOD
11	AKPAKILA	07° 11´ 11"	003° 26´ 18"	PW	33.56	GOOD
12	OSIELE	07° 11´ 30"	003° 27´ 11"	PW	50.1	POOR
13	OSIELE BOREHOLE SCHEME	07° 11´ 28"	003° 26´ 25"	PB	41.13	GOOD
14	KOTOPO	07° 11´ 06"	003° 25.391´	PW	44.9	GOOD
15	DARASIMI HOSTEL, CAMP	07° 11´ 06"	003° 26´ 11"	PB	33.93	GOOD
16	SANYAOLU ST, CAMP	07° 11´ 42"	003° 26´ 13"	PW	28.01	GOOD
17	UMAR KABIR HOSTEL	07° 13´ 59"	003° 26´ 00"	PB	50.2	POOR
18	FUNAAB GATE	07° 13´ 38"	003° 27´ 56"	PB	38.85	GOOD
19	SUB, FUNAAB	07° 13´ 42"	003° 25´ 58"	PB	30.89	GOOD
20	CIVIL ENGINEERING BUILDING, FUNAAB	07° 13´ 49"	003° 26´ 00"	PB	41.02	GOOD

Table 5 Categorization of Water Quality Index for the study area

Water Quality Index	Description	sample locations	Total number	Percentage
<25	**Excellent**	**S3, S7**	**2**	**10**
26 – 50	**Good**	**S1, S2, S4, S5, S6 S8, S10, S11, S13 S14, S15, S16, S18 S19, S20**	**15**	**75**
50 – 75	**Poor**	**S9, S12, S17**	**3**	**15**
75 – 100	**Very Poor**	**…………**	**……………**	**…………..**
>100	**Unfit for drinking**	**…………**	**……………**	**…………..**

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