Journal of Environment and Earth Science
ISSN 2224-3216 (Paper) ISSN 2225-0948 (Online)
Vol.4, No.9, 2014

Assessment of Groundwater Quality in Selected Areas in Imo State in South Eastern Nigeria

Anthony Chibuzo, Ekeleme[1*] ,Boniface C. Okoro[1] , Ogedi Hippolitus, Ibearugbulem[2]
Ethelbert Chukwunonye Nwadike[2], Agatha.Chima, Egedigwe[3]
1, Department of Civil Engineering, School of Engineering
Federal University of Technology, P.M.B 1526, Owerri, Imo State, Nigeria
2, Federal Polytechnic, Nekede,P.M.B 1036,Owerri, Imo State, Nigeria
3, Federal University of Ndufu Alike, Ikwo, P.M.B 1010 Abakaliki, Ebonyi State
* E-mail of the corresponding author: chytony4real09@yahoo.com

Abstract

Groundwater quality in Owerri West was assessed**.** Forty-five water samples were collected from wash-Boreholes. The physico-chemical and biological parameters of groundwater samples from Nekede (Ward A), Ihiagwa (Ward B), Eziobodo (Ward C), Obinze (Ward D) and Avu (Ward E) were assessed using Atomic Absorption Spectrophotometer (AAS).The study was aimed to determine how distances to a potential source of contamination affect the quality of groundwater, the major contaminants of groundwater in the selected locations and the sources of the major contaminants when compared to WHO standards. A total of three replicates of fifteen different borehole water samples were collected based on distances from closest potential sources of contamination. The pH, turbidity values and temperature of the borehole samples ranged from 5.6 ± 0.005 to 8.6 ± 0.70, 4.5± 0.26 to 9.3±0.56 NTU and 24.0 ± 0.32 to 27.5 ± 0.45^{0}C respectively. Total Viable Count (TVC) and Biochemical Oxygen Demand (BOD) of the borehole samples ranged from 3.0 ±0.05 to 7.3±0.04 cfu/ml to 1.1±0.05 to 2.0±0.07 mg/L respectively. Concentrations of iron, nitrate and calcium ranged from 0.4±0.006 to 3.8±0.01 mg/L, 5.4±0.16 to 16.2 ±0.25mg/L and16.4 ±0.11 to 33.6±0.49 mg/L respectively. The results showed that most of the boreholes were polluted and strongly recommended that access to water from these boreholes could be improved by proper treatment and good sanitation in the selected locations studied.

Keywords: Groundwater, Water –quality, Concentration, Owerri-West

1.0 Introduction

Groundwater makes up about 20% of the world's fresh water supply, which is about 0.61% of the entire world's water, including oceans and permanent ice. Global groundwater storage is roughly equal to the total amount of fabricator stored in the snow and ice packs, including the north and south poles (Sophocleus, 2002). Aquifer is a keyword in discussing the formation of groundwater. There are two basic ways by which groundwater is formed: First is by direct seepage of rain water into the ground and then seepage from the seas, oceans and water bodies. The depth at which soil pore spaces or fractures and voids in rock become completely saturated with water is called the water table. Thus, groundwater is recharged and eventually flows to the surface naturally; natural discharge often occurs at springs and seeps and can form oases or wetlands. Groundwater can be found almost everywhere. The water table may be deep or shallow and may rise or fall depending on many factors. The speed of which ground water flows depends on the size of the spaces in the soil or rocks and how well the spaces are connected. The area where water fills these spaces is called the saturated zone (Schmoll *et al.,* 2006). Groundwater is always found when a bore hole well is drilled, although in some places these may be a very low rate of flow to the well. The size of a well is important in classifying a saturated rock as an aquifer. All water wells pump groundwater but they do not all pump from aquifers. In general, there are three main categories of aquifers: unconfined, confined and perched aquifers (Berardinucci and Ronneseth, 2002).

2.0 Materials and Methods

2.1 Description of Study Area.

Owerri is a rapidly growing urban centre. It became the capital of Imo State in 1976. The Imo state capital has three Local Government Areas - Owerri Municipal, Owerri North and Owerri West. The study area is Owerri West L.G.A in Imo State is in the South Eastern part of Nigeria. It is bounded by latitudes 5^{o}34 and 5 ^{o}34' N and longitude 6 ^{o}52' and 7^{o}05'E.

2.2 Sample Collection

Three replicates of 15 different borehole water samples were collected from five locations in Owerri West. The locations from which the samples were taken are given in Table 1.0. Distance from the borehole to a potential source of contamination which includes landfills, septic tank (sewers) and pit toilet (latrines) was measured with a standard meter rule and recorded. The distance is also included in Table 1.0. For convenience, the water samples from the 45 different boreholes were labeled W_1 – $W_{15.}$ The water samples were collected in the early morning hours when freshly pumped from the ground in compliance with the Nigerian Standard for Drinking

Water Quality (NSDQW) best practices for Water Quality Analysis in October, 2011. Prior to collection as part of quality control measures all the bottles used for the sample collection were washed and rinsed with distilled water. The bottles were rinsed three times with the sample water at the point of collection before the final water sampling was done. The bottles were held at the bottom while filling, to avoid contamination of water from the hands or fingers (Oparaocha*, et al.,* 2011). All the sample containers were kept in ice boxes and brought to the laboratory for analysis.

2.3 Test for Physicochemical and Biological Parameters

The samples collected from the various boreholes were analyzed for the following biological parameters; Biochemical Oxygen Demand (BOD), Total Viable Count (TVC) and coliform test. The membrane filter (MF) technique was used for the analysis. The chemical parameters were: Hardness, Sulphate (SO_4^{2-}), Nitrate (NO_3^-), Calcium (Ca^{2+}), Zinc (Zn), Manganese (Mn), Lead (Pb), Iron (Fe), Magnesium (Mg) and pH according to the procedures described by The samples were examined physically to determine the taste, odour and temperature. Other physical parameters examined included the concentration of suspended and dissolved solids, which gave the total dissolved solids of the various samples APHA (2005).

2.4 Data analysis

Descriptive statistics (means and standard deviations) were used to interpret the raw data on the physicochemical and biological parameters using SPSS Version 17.0 software.

3.0 Results and Discussion

3.1 Biological Parameters of Groundwater Samples

The mean result samples (W_3, W_7 and W_{15}) of the fifteen samples analyzed, representing 20% of the sampling showed the presence of coliform bacteria in the groundwater samples of W_3, W_7 and W_{15} as shown in Table 1.1. The sources of coliform pollution observed in groundwater samples W_7 and W_{15} are likely from pit latrines. The presence of faecal coliform in the borehole wells with pit latrines as close source of pollution is indicative of the contribution of pit latrines to easier seepage of contamination to the groundwater system. Sample W_3 also showed a positive coliform test and this could be attributed to it being the only sample whose source of contamination is a septic tank closely located to the borehole well. For the borehole well which is located at a hostel in Nekede and has a high population density, this population exerts pressure on the use of the toilet facility that could lead to seepage from the septic tank to the groundwater. This observation is in line with other recent studies which have reported on the coliform contamination of groundwater in different parts of Nigeria, especially in Owerri metropolis (Adekunle *et al.,* 2007; Olabisi *et al.,* 2008; Adekunle and Eniola, 2008; Ejechi and Ejechi, 2007 and Nwachukwu *et al.*, 2010). Comely (1987) also reported that poor casing of wells leads to coliform contamination. Urinary tract infections, meningitis, diarrhea (one of the main causes of morbidity and mortality among children), acute renal failure and hemolytic anaemia have all been reported as health implications of water contamination by coliforms (NSDQW, 2007). The presence of coliform in water could also be an indication of feacal contamination and has been associated with waterborne epidemic (Mackenzie *et al*., 1995). Water source used for drinking or cleaning purposes should not contain any organism of fecal origin (Akeredolu, 1991).However, the sample W_1 whose source of contamination would have been from the septic tank with a close distance of 3 meters is not polluted. Although the close distance of the septic tank to the borehole well source did not have an explanation for the non-contamination, but it could be due to the clayey nature of the soil. Nonetheless, all the other samples gave lower values of total coliform count when compared to the WHO standard of 10 cfu/100 ml (WHO, 2004).

Table 1.1 shows the various Total Viable Count (TVC) for all the samples. All the values of TVC are lower than maximum permitted levels of 10 cfu/ml as given by (NSDQW, 2007; WHO, 2004) for portable drinking water. Values such as 7.3, 6.0 and 6.0 cfu/ml as recorded for $W_{1,}$ W_{11} and W_{15} should however be of concern to users. Nwachukwu *et al* (2010) reported that people often overlook both the immediate and future consequences of gradual exposure to contaminated domestic water sources and thereby lead to undesirable health effects.

Njemanze *et al*, (1999) also reported high rate of diarrhea in Owerri and the Imo River basin region. This could be as a result of lack of portable water. On the other hand, the Biochemical Oxygen Demand for the various samples is within the permitted 2.0 mg/L as stipulated by W.H.O for drinking water.

3.2 Chemical parameters of groundwater samples

All the analyzed samples except W_{11} have pH values above the Nigerian Standard for Drinking Water Quality (NSDWQ) and World Health Organization (WHO) standard (see Table 4.2). The groundwater of Owerri West region could be said to be acidic with pH value of 6.21 which could indicate toxic pollution (Akinbile and Yussof,2011). Ibe *et al* (2003); Longe *et al* (1987); Longe and Kehinde (2005); Longe and Enekwachi (2007); Yusuf, (2007) reported the acidic nature of groundwater in certain areas of Owerri West.

All the samples (W_1 – W_{15}) tested showed high iron (Fe^{2+}) contamination with values higher than the 0.3 mg/L maximum permitted value given by Nigeria Standard for Drinking Water Quality and that of the World Health Organization. It imparts a bitter astringent test to water and a brownish color to laundered clothing and plumbing fixtures thereby affecting the general usability of water (WHO, 2004). However, it is important to note that no health-based guideline value is proposed for iron (WHO, 2011).

Nine out of fifteen groundwater samples analyzed showed lead (Pb) contamination with values ranging between 0.02 mg/L and 0.06 mg/L which is above the 0.01 mg/L standard permitted by NSDQW and WHO for potable drinking water. Lead contamination has been reported to have adverse health implication. Nigerian Standard for Drinking Water Quality (2007) reports that cancer, vitamin D metabolism interference, impairment of proper infant mental development, toxicity to the central and peripheral nervous systems are all health risks due to contamination of water by lead. Foster *et al* (2002) report associated lead contamination source as also possible from septic tanks or pit latrines.

The samples (W_1-W_{15}) analyzed for Magnesium showed high values with values ranging from 2.1 mg/L to 13.6 mg/L which is far above the Nigerian Standard for Drinking Water Quality (0.2 mg/L). Although no health impacts have been associated by scholars to magnesium contamination of drinking water, yet it is necessary to meet the required standards. This affects consumer acceptability of the water as reported by NSDQW (2007). It is important to note that salts of magnesium ion also aid in temporary hardness of water.

Zinc values ranged from 0.4mg/L – 2.2mg/L which is within the permissible level of zinc (3.0 mg/L) by the NSDQW. However, sample W_5 with zinc value of 2.2 mg/L which is slightly above the WHO (2.0 mg/L) standard is but still within the 3.0 mg/L Nigerian Standard for Drinking Water Quality. Zinc imparts undesirable astringent taste. No health-based guideline value has been proposed for zinc in drinking-water (WHO,2011).

Manganese sample results ranges from 0.01 to 0.02mg/L. Most of the sample results showed no detectable amount of manganese according to the WHO and NSDQW standards. At levels exceeding 0.1 mg/l, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. The presence of manganese in drinking-water, like that of iron, may lead to the accumulation of deposits in the distribution system (WHO, 2011).

The values for hardness of all the samples ranged from 22.4 mg/L and 44.3 mg/L. Value for hardness ($CaCO_3$) in all the samples were below the WHO and NSDQW permissible levels of 150 mg/L. Sulphate values for all the samples (W_1-W_{15}) analyzed ranged from 22.6- 64.3 mg/L. These values observed fall below the WHO and NSDQW stipulated levels. High levels of sulphate lead to dehydration and diarrhea especially in children (NSDQW, 2007). The presence of sulphate in drinking-water can cause noticeable taste and very high levels might cause a laxative effect in unaccustomed consumers (WHO, 2011).

Nitrate (NO_3^-) level in five samples (W_3, W_7, W_{13}, W_{14} & W_{15}) were found to be more than the stipulated value (10 mg/L) by WHO, but still within the National Water Drinking Water Quality Standard of 50 mg/L. The samples with pit latrine as source of contamination gave higher nitrate values. Natural level of nitrate in groundwater is increased by municipal and industrial wastewater including leachate from sewage sludge disposal (Foster *et al.,* 2002) and sanitary landfills. High nitrate concentrations have detrimental effects on infants less than 3.6 months of age. Nitrate toxicity comes from the body's natural breakdown of nitrate to nitrite. This leads to "blue baby disease" which threatens the oxygen carrying capacity of the blood around the body (Chapman, 1996; Alsabahi *et al.,* 2009). Nitrate is an essential ingredient of plant nutrition. It is, however regarded as an indicator of pollution in public water supply (Offodile, 2002).

Phosphate (PO_4) levels in all the samples ranged from 13.6 to 46.4 mg/L. These values exceed the WHO standard stipulated value tolerance level and this could be linked to seepage of sewage waste into the groundwater system. Longe and Balogun (2010) associated high PO_4 levels in groundwater as due to landfill operations. The highest levels of phosphate are recorded in samples W_{14} and W_{15} with values 33.8 mg/L and 46.4 mg/L respectively. These high levels recorded could be that the samples were located close to pit latrines which are sources of pollution from sewage systems. Punmia and Jain (1998) reported that traces of PO_4^- even at 0.1 mg/L in water could have deleterious effect on water quality and such traces could increase the growing of troublesome algae in the water, and therefore, agricultural activities around these study areas could possibly lead to the high values of phosphate recorded. Phosphates are not toxic to people or animals unless they are present in very high levels (Ijeh and Onu, 2013).

The pH of the borehole wells ranged from 5.6-8.6. It was reported that though 7.0 is the neutral, up to 9.2 may be tolerated, provided microbiological monitoring indicated no deterioration in bacteriological quality (WHO, 2004). Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. No health-based guideline value has been proposed for pH (WHO, 2011).

3.3 Physical Parameters of Groundwater Samples

The use of "not clear" as indicated in the colour of groundwater samples could be an indication of pollution and leachate infiltration into the borehole wells (Mohammed *et al*., 2009; Ogedengbe and Akinbile, 2004). Drinking-water should ideally have no visible colour. No health-based guideline value is proposed for colour in drinking-water (WHO, 2011). The temperature values for the samples (W_1-W_{15}) analyzed ranged from 26.5^0C to 27.5^0C (see Table 4.3). High water temperature enhances the growth of microorganisms and may increase problems related to taste, odour and colour (WHO, 2011). These values were found outside the range of the WHO standard of 5^0C for domestic water and could be attributed to the presence of foreign bodies in the water (Akinbile and Yusoff, 2011).

Turbidity in water is caused by suspended particles or colloidal matter that obstructs light transmission through the water (WHO, 2011). It may be caused by inorganic or organic matter or a combination of the two. The turbidity readings of the samples were above the WHO and NSDWQ standards (Table1.2). High turbidity values observed could be an indication that the wells may be unlined, hence the high values (Sagadoyin, 1991). High values observed in the sample readings may be because turbidity is acting as an indicator of possible sources of microbial contamination (WHO, 2011).

The Total Dissolved Solids (TDS) provide a rough indication of the overall suitability of water. The palatability of water with a total dissolved solids (TDS) level of less than about 500 mg/L is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/l. The total dissolved solids (TDS) of the samples ranged from 22.8 to 112.3 mg L^{-1}.

4.0 Conclusion and Recommendations

The assessment of groundwater quality in selected areas evaluated using standard analytical methods for testing physico-chemical and biological parameters was moderately high. These locations which have been reported by Ibe *et. al*. (2003) to comprise unsaturated zones is composed of sand and gravel with high effective hydraulic conductivity and low absorption properties are known to facilitate the migration of contaminants down to the shallow water table between 19 and 20 meters deep (Ibe *et. al*.,2003). The land-use activities in these locations which include poorly constructed pit latrines, septic tanks, landfills and open dump sites all aid in the vulnerability of the region to groundwater pollution.

Wastes from sewage system, leakages from petrol stations, open dump waste disposal units and even agricultural activities are common in these areas, moderate to high vulnerability in and around selected locations in Owerri West L.G.A. The adverse health implications of the contaminations are well studied and documented and range from mild health discomfort to even death. Also the presence of these contaminants affects water quality in these regions. The rate of contamination, especially by heavy metals, phosphate, nitrates and coliforms (*E.coli*) are of great concern and these land-use activities affect the vulnerability of these regions to groundwater contamination. Therefore, such contaminants should be properly looked into and measures taken to forestall further endangering of the groundwater resources. The phosphate, iron and magnesium levels in the samples (W_1-W_{15}) analyzed were higher than the stipulated WHO and NSDQW were recorded in all.

Mild nitrate and zinc contamination were observed in some of the samples showing higher levels than stipulated tolerable level, especially for nitrate but all still within the National standard water quality level. The groundwater in selected locations showed low pH values below W.H.O and NSDQW stipulated range, indicating that the groundwater within the region is acidic. Major contamination sources include pit latrine, Groundwater is a vital natural resource for reliable and economic provision of portable water supply in both urban and rural areas. It plays a fundamental role in human well-being as well as that of some aquatic and terrestrial ecosystems. Government through the various water resource management bodies should create massive public awareness programmes on the television and other mass media agencies to educate the populace of the health implications of groundwater pollution. There is need for proper treatment of water in the selected locations with more emphasis focused on nitrate, magnesium contained in the water. Policies should be formulated by the appropriate bodies to outline standards for the construction of sewages systems within the region and task-force agencies should be established to enforce compliance to these policies with fines and penalties issued to non-compliance. The practice of pit latrines should be abolished, followed by the construction of cheap but efficient ecological sanitary system in rural areas where these practices still find use. Monitoring and evaluation of the policies formulated and how they fare, and well as evaluation of the efficiency toward groundwater protection should be practiced. General upgrade of the waste disposal units and overall land use activities to modern best practices is highly recommended to guarantee the integrity of the groundwater quality in the areas and with all hands on the desk is natural resources of immense importance (groundwater) would be protected. The direction of ground water flow in these communities when known can aid in mapping out the land area that recharges their public water supply wells, streams, rivers, lakes, or estuaries and thereby take steps to ensure that land use activities in the recharge area will not pose a threat to the quality of the ground water and the resources dependent on it. Since contaminants generally move in the direction of ground water flow, communities can also predict how contaminants might move through the local ground water system.

References

Adekunle, I.M., Adetunji, M.T., Gbadebo, A.M. and Banjoko, O.B. (2007). Assessment of groundwater quality in a typical rural settlement in Southwest Nigeria. International Journal of Environmental Research and Public Health 4(4): 307-318.

Adekunle, A.S. and Eniola, I.T.K. (2008). Impact of Industrial effluents on quality of Asa River within an

Industrial Estate in Ilorin, Nigeria. New York Science Journal 1(1): 17-21.

Akeredolu, F.A. (1991). Setting water Quality Standards for Nigeria. *In:* Proceedings of Proceedings of First National Conference On Water Quality Monitoring and Status in Nigeria, Kaduna. Pp. 216-224.

Akinbile C.O. and Yusoff, M.S. (2011). Environmental impact of leachate pollution on groundwater supplies in Akure, Nigeria. International Journal of Environmental Science and Development 2(1): 81-86.

Alsabahi, E., Abdubrahim, S., Zuhairi, W.Y., Al-Nozailyi, F. and Alshaebi,F. (2009). The characteristics of leachate and groundwater pollution at municipal solid waste landfill of IBB city, Yemen, American Journal of Environmental Sciences 5(3): 256-266.

APHA. (2005). Standard Methods for the Examination of Water and Waste Water, 21st ed. American Public Health Association, Washington, DC. Pp 1-252.

Berardinucci, J. and Ronneseth,K. (2002). Guide to using BC aquifer classification maps for the protection and Management of groundwater. Washington DC, USA. Pp 61.

Chapman, D. (1996) Water Quality Assessments - A Guide to Use of Biota, Sediments and Water in Environmental Monitoring 2nd Ed. UNESCO/WHO/UNEP, Chapman and Hall, London Pp 651.

Comely, H.A. (1987). Cyanosis in infants caused by nitrates in well water. Journal of American Medical Association. 257: 2788-2792.

Ejechi, E.O. and Ejechi,B.O. (2007). Groundwater quality in urban development. In Water Resources (ed. by H .R. Okereke) Nigeria Association of Hydrology. 1(4); 70-73.

Foster, S., Hirata, R., Gomes, D., D'Elia, M. and Paris, M. (2002a). Groundwater quality Protection: a guide for water utilities, municipal authorities and environment agencies. World Bank Publication, Washington DC, USA. Pp 1-116.

Foster, S., Gardino, H., Kemper, K., Turnhof, A., Marcella, N. and Dumars, C. (2002b). Groundwater Quality Protection defining strategy and setting Priorities. Sustainable groundwater management, concepts and Tools. Briefing note series: Notes.The World Bank global water partnership Association program (2002- 2006) Pp 3-38.

Ibe, K.M., Nwankwo, G.I. and Onyeukwu, S.O. (2003). Groundwater pollution vulnerability and groundwater protections strategy for the Owerri area, Southeastern Nigeria. Water Resources system. Water availability and Global change (Proceedings of Symposium) 280: 184 – 193.

Ijeh, B.I. and Onu,N.N. (2013).Assessment of pollution levels of groundwater in parts of Imo River Basin, South Eastern Nigeria. International Journal of Water Resources and Environmental Engineering 5(4):194 - 202.

Longe, E.O., Malomo, S. and Olorunniwo, M.A. (1987). Hydrogeology of Lagos metropolis. J. Afr. Earth Sci. 6(3):163-174.

Longe, E.O. and Kehinde, M.O. (2005). Investigation of potential groundwater impacts at an unlined waste disposal site in Agege, Lagos, Nigeria. Proceeding of 3rd International Conference, Faculty of Engineering University of Lagos, Lagos, Nigeria. Pp 21-29.

Longe, E.O. and Enekwachi, L.O. (2007). Investigation on potential groundwater impact and influence of local hydrogeology on natural attenuation of leachate at a municipal landfill. Int. J. Environ. Sci. Tech. 4(1): 133 – 140.

Longe, E.O. and Balogun, M.R. (2010). Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. Research Journal of Applied Sciences, Engineering and Technology 2(1): 39-44.

Mackenzie, W. R., Schell, W. L., Blair, K. A. and Addiss, D. G. (1995). Massive outbreak of waterborne cryptosporidium infection in Milwaukee, Wisconsin: recurrence of illness and risk of secondary transmission. Clinical Infectious Diseases 1: 57-62.

Mohamed,A.F., Yaacob,W.Z.W.,Taha,M.R. and Samsudin, A.R. (2009). Groundwater and Soil Vulnerability in the Langat Basin Malaysia. European Journal of Scientific Research. 27(4):628-635.

Njamanze, P.C., Anozie, J.O., Iheanacho, J.O., Russel,M.J. and Uwaeziozi, A.B. (1999). Application of risk analysis and geographic information system Technologies to the prevention of diarrhea disease in Nigeria. A.M.J. Trop. Med. Hyg. 61(3)

Nwachukwu, M.A., Feng, H. and Alinmor, K.S. (2010). Assessment of heavy metal pollution in soil and their implication within and around mechanic village. Int. J. Environs. Sci. Technology 7(2): 347-358.

NSDQW, (2007). Nigerian Standard for Drinking Water Quality, Nigerian Industrial Standard (NIS) 554. Standard Organization of Nigeria. Pp. 30-45.

Offodile, M.E. (2002). Ground Water Study and Development in Nigeria, Mecon Geology and Eng. Services Ltd., 2nd Ed. Pp. 303-332

Ogedengbe, K. and Akinbile, C.O. (2004). Impact of Industrial Pollutants on Quality of Ground and Surface waters at Oluyole Industrial Estate, Ibadan, Nigeria, Nigerian Journal of Technological Development, 4 (2): 139-144.

Oparaocha, E.T., Iroegbu, O.C. and Obi, R.K. (2011). Assessment of quality of drinking water sources in the Federal University of Technology, Owerri, Imo state, Nigeria. Journal of Applied Biosciences. 32: 1964 – 1976.

Punmia, B.C. and Jain, A. K. (1998).Wastewater Engineering. Laxmi Publications (P) Ltd, New Delhi. Pp 155.
Sangodoyin, A.Y. (1991).Ground Water and Surface Water Pollution by Open Refuse dump in Ibadan, Nigeria, Discovery and Innovations. Vol. 3(1): 24 - 31.
Schmoll,O., Howard, G., Chilton,J. and Chorus,I. (2006). Protecting Groundwater for Health: Managing the Quality of Drinking-water sources.IWA Publishing, London, UK : Pp 199–242.
Sophocleus, M.A (2002). Interactions between groundwater and surface water: the state of the science. Hydrogeology Journal. 10(1): 52 –67.
WHO (2004). Guidelines for drinking water quality: 3rd edn. Vol. 1 recommendation, Geneva. Pp 515.
WHO (2011).Guidelines for drinking water quality. Acceptability aspects: taste, odor and appearance. 4th Ed. 1: 219-230.
Yusuf, K. A. (2007). Evaluation of groundwater quality characteristics in Lagos-City. Journal of Applied Sciences 7(13): 1780-1784.

Table 1.0: Selected location areas within Owerri West L.G.A and their distances from sources of contamination

Ward	Area	Sample	Depth to static water level (m)	Distance from closest potential Sources of contamination (meters)	Closest contamination source
A	Nekede	W_1	47	3.0	Septic tank
		W_2		12.6	Septic tank
		W_3		14.9	Septic tank
B	Eziobodo	W_4	46	11.0	Septic tank
		W_5		30.2	Landfill
		W_6		20.5	Open site
C	Ihiagwa	W_7	47	26.4	Pit latrine
		W_8		13.6	Septic tank
		W_9		13.9	Septic tank
D	Obinze	W_{10}	46	48.6	Septic tank
		W_{11}		13.3	Septic
		W_{12}		60.4	Septic tank
E	Avu	W_{13}	46	50.4	Septic tank
		W_{14}		61.3	Pit latrine
		W_{15}		13.4	Pit latrine

Table 1.1: Biological Parameters of Samples

Sample	TVC (Cfu/mL)	BOD(mg/L)	Coliform test(Cfu /100mL)
WHO Standard	10	2.0	10
NSDQW Standard	10	2.0	10
W_1	7.3±0.04	1.3±0.02	Nil
W_2	3.0±0.05	1.4±0.08	Nil
W_3	5.0±0.03	1.4±0.02	8.3
W_4	4.7±0.04	1.2±0.02	Nil
W_5	3.3±0.04	1.6±0.00	Nil
W_6	5.3±0.04	1.6±0.03	Nil
W_7	5.0±0.03	1.5±0.01	8.6
W_8	3.7±0.07	1.4±0.06	Nil
W_9	4.7±0.03	1.3±0.02	Nil
W_{10}	4.3±0.08	1.1±0.05	Nil
W_{11}	6.0±0.04	1.2±0.04	Nil
W_{12}	5.3±0.05	1.6±0.04	Nil
W_{13}	3.3±0.06	1.4±0.06	Nil
W_{14}	4.7±0.013	2.0±0.07	Nil
W_{15}	6.0±0.03	1.8±0.04	8.2

Table 1.2: Physical Parameters of Groundwater Samples

Sample Unit	pH	Hardness (mg/L)	Odour	Temperature (^{O}C)	Turbidity (NTU)	TDS (mg/L)	DS (mg/L)	SS (mg/L)
WHO	6.5-8.5	150	-	$5^{0}C$	50	500	NS	NS
NSDQW	6.5-8.5	150	Unobjectionable	Ambient	5	500	NS	NS
W$_1$	6.4±0.04	38.3 ± 0.05	Mild	27.5± 0.45	8.5 ± 0.18	24.2 ± 0.33	24.2 ± 0.40	NIL
W$_2$	6.2±0.005	36.2 ± 0.06	Mild	26.5± 0.38	6.6 ± 0.17	22.8 ± 0.12	22.6 ± 0.32	0.2 ± 0.01
W$_3$	5.9±0.05	22.4 ± 0.05	Mild	26.0± 0.31	9.3 ± 0.56	26.4 ± 0.34	26.4 ± 0.28	NIL
W$_4$	6.1±0.03	31.0 ± 0.30	Mild	27.0± 0.42	5.8 ± 0.51	18.7 ± 0.07	14.30 ± 0.18	4.4 ± 0.28
W$_5$	5.8±0.03	38.0 ± 0.08	Mild	25.5± 0.32	6.8 ± 0.32	112.3 ± 3.43	96.30 ± 0.23	16.0 ± 0.58
W$_6$	6.3±0.06	36.0 ± 0.11	Mild	25.5± 0.32	4.6 ± 0.41	86.4 ± 0.54	77.1 ± 0.33	11.3 ± 0.44
W$_7$	5.6±0.005	29.1± 0.05	Mild	26.5± 0.36	5.3 ± 0.28	62.4± 0.86	62.4 ± 0.25	NIL
W$_8$	6.0±0.03	33.1± 0.18	Mild	26.5± 0.34	6.5 ± 0.45	48.0± 0.57	48.0 ± 0.22	NIL
W$_9$	6.1±0.003	36.8 ± 0.91	Mild	27.5± 0.43	5.6 ± 0.33	28.6± 0.83	28.6 ± 0.38	NIL
W$_{10}$	6.1±0.04	44.3 ± 0.03	Mild	26.5± 0.33	4.9 ± 0.32	33.4± 0.42	33.4 ± 0.34	NIL
W$_{11}$	8.6±0.70	36.2 ± 0.03	Mild	24.0± 0.32	6.4 ± 0.25	41.0 ± 0.65	41.0 ± 0.77	NIL
W$_{12}$	6.3±0.05	36.4 ±1.75	Mild	24.5± 0.28	4.5 ± 0.26	32.6 ± 0.70	32.0 ± 0.34	NIL
W$_{13}$	6.1±0.09	31.0 ± 0.06	Mild	26.7± 0.32	5.3 ± 0.34	38.4 ± 0.32	38.4 ± 0.48	NIL
W$_{14}$	5.9±0.09	28.0 ± 0.05	Mild	25.8± 0.29	5.2 ± 0.28	66.2 ± 0.41	66.2 ± 0.86	NIL
W$_{15}$	5.8±0.04	26.4 ± 0.03	Mild	26.9± 0.40	8.2 ± 0.31	103.4 ± 2.58	103.4 ± 1.52	NIL

NS – Not specified

NC- Not clear

Table 1.3 Chemical Parameters of Groundwater Samples

	←				mg/L				→
Samples	SO$_2$	PO$_4^{3-}$	NO$^{-}_3$	Ca	Zn	Pb	Fe	Mg	Mn
WHO	250	5.0	50	NS	2.0	0.01	0.3	0.2	0.05
NSDQW	100	5.0	50	NS	3.0	0.01	0.3	0.2	0.2
W$_1$	26.8±0.05	18.6±0.28	NIL	26.2±0.16	0.8±0.03	NIL	3.6±0.012	2.1±0.06	NIL
W$_2$	22.6±0.32	20.4±0.26	NIL	22.6±0.15	1.2±0.02	NIL	1.2±0.008	13.6±0.18	NIL
W$_3$	31.4±0.15	16.8±0.05	12.4±0.40	18.4±0.16	1.6±0.03	0.02±0.00	0.4±0.006	4.0±0.05	NIL
W$_4$	33.0±0.06	23.0±0.40	NIL	24.9±0.18	0.4±0.08	NIL	0.8±0.008	6.1±0.03	0.01±0.005
W$_5$	36.2±0.03	13.6±0.20	5.4±0.16	31.3±0.08	2.2±0.00	0.01±0.003	2.2±0.02	6.7±0.02	NIL
W$_6$	30.8±0.08	24.1±0.04	NIL	30.8±0.23	1.8±0.00	NIL	2.0±0.07	6.0±0.10	NIL
W$_7$	26.9±8.28	18.4±0.08	16.2±0.08	16.4±0.11	0.6±0.00	0.04±0.005	1.6±0.01	12.7±0.20	NIL
W$_8$	36.2±0.05	21.2±0.34	7.10±0.45	22.1±0.42	0.8±0.09	0.04±0.005	1.4±0.008	11.3±0.08	NIL
W$_9$	31.4±0.08	16.6±0.22	NIL	26.1±0.17	1.2±0.78	0.02±0.005	1.0±0.06	10.7±0.13	NIL
W$_{10}$	33.8±0.40	31.4±0.40	6.3±0.12	33.6±0.49	2.0±0.07	NIL	0.6±0.00	10.7±0.05	0.01±0.003
W$_{11}$	56.2±0.05	28.6±0.60	NIL	28.9±0.30	1.3±0.00	0.04±0.005	3.8±0.01	7.3±0.04	NIL
W$_{12}$	39.4±0.08	22.0±0.27	5.8±0.29	31.3±0.29	0.6±0.01	0.06±0.005	3.6±0.20	5.1±0.04	NIL
W$_{13}$	46.3±0.12	18.3±0.22	13.0±0.31	20.8±0.10	1.3±0.02	0.02±0.003	3.6±0.008	10.2±0.21	0.02±0.003
W$_{14}$	40.4±0.03	33.8±0.46	11.6±0.23	19.4±0.22	0.8±0.04	NIL	2.9±0.005	8.6±0.11	0.01±0.003
W$_{15}$	64.3±0.10	46.4±0.02	16.2±0.25	20.8±0.28	0.8±0.02	0.04±0.006	3.4±0.01	5.6±0.01	NIL