Groundwater Quality Assessment near an Open Dump Municipal Solid Waste Disposal Site in Ekiti State, Southwestern Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author EAO wrote the research proposal, designed the study and presented the research proposal before Ekiti State University Tertiary Education Trust Fund Research Committee. Author MSA managed the literature searches and wrote the first draft of the manuscript. Author AB carried out the tests on soil samples and performed the statistical analysis. All authors read and approved the final manuscript.

Original Research Article

ABSTRACT

This study assessed groundwater quality around an open dump municipal solid waste (MSW) disposal site at Ilokun, a village on the outskirts of Ado-Ekiti, Ekiti State, Nigeria. Three geotechnical boreholes and three water boreholes (tube wells) were drilled at intervals of 15m, 30m and 45m away from the disposal site. Soil samples were obtained near the top and at the bottom of the geotechnical boreholes. Tests carried out on these samples included the sieve analysis, specific gravity, bulk density, natural moisture contents, Atterberg limits, linear shrinkage, and hydraulic conductivity tests, and these were used to index and classify the soils at the landfill dumpsite. It was discovered that the soils belonged to the clay and clayey-sand USCS groups (CL and SC mainly). Groundwater samples were taken from the three water boreholes (tube wells), and physical, chemical and microbiological investigations carried out on the water samples and on water obtained

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from an existing hand-dug well in the neighbourhood of the dumpsite. The parameters obtained from the tests on the samples were compared with the Guidelines for Drinking Water Quality of the World Health Organisation (WHO) and the Nigerian Standard for Drinking Water Quality of the Standards Organisation of Nigeria. The water quality parameters determined included: the acidity (pH), temperature, electrical conductivity (EC), colour and odour, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total hardness (TH), and contents of the constituents such as total iron, chloride, sulphate, nitrate, etc. The microbiological characteristics determined are the Total Bacterial Count (Total coliform count), and the presence of Faecal streptococci, Staphylococcus aeurus and Escherichia coli. It was discovered that the groundwater at the dumpsite has been heavily contaminated and unfit for human consumption or usage without appropriate treatment to render them potable and fit for domestic use.

1. INTRODUCTION

Anthropogenic activities within the urban and industrial sectors generate large quantities of wastes worldwide on a daily basis [1]. For many decades, landfills have been the most widely-used disposal method for all these wastes. However, in the developing economies, disposal of wastes through controlled landfills is not prominent due mainly to the non-existence of designed engineered sanitary landfills. For example, construction commenced only in the year 2017 of an engineered sanitary landfill located in Epe, Lagos State, Nigeria, which would make it the first of such in Nigeria, and even in the West Africa sub-region [2,3,4]. The Open Dumping method of waste disposal or dumping in unlined landfills has been the ubiquitous approach to waste management in Nigeria, despite the numerous apparent defects. These defects include: pollution of the air (in terms of toxic gases, volatile gases, foul odours, etc.), soil and groundwater contamination, contamination of run-off and surface water bodies (streams, rivers, and lakes), occupation and wastage of an unnecessarily large area of land, eventual damage to plant and wildlife habitats, health hazards (in terms of breeding of disease carrying germs and viruses), environmental hazard (in terms of breeding of insects, rodents, vermin and scavengers), decrease in the quality of life of nearby residents and the local community, creation of a public nuisance, diversion of land from more productive uses, and depression of the value of surrounding property and land, amongst others.

Development of an open dump waste disposal site usually starts with the unplanned dumping of waste at a vacant site (or open pit or depression in the earth's surface which needs to be filled) which is at a distance away, and adjudged to be sufficiently remote, from the urban development, which in many instances is the waste generator, as an easy and immediate way out of the problem of waste disposal. For example, according to the chairman of the Ekiti State Waste Management Authority at the time, waste taken from various homes in Ado were disposed of around the Ilokun waste dump (being considered in this study) and one other waste dump (Fagbohun waste dump along Ado-Ikere Road), and he considered these sites to be "locations in the capital which are clinically far from human habitation and could therefore not reasonably constitute any form of danger to humans or animals" [5]. Though this may be true at the time, the reality now on the ground at the vicinity of the Ilokun solid waste disposal site is that urban development had brought residential quarters to within 20 metres of the dumpsite, while the offices and transmission tower of a local radio station are located within 150 metres of the dumpsite. Further development in the near future is expected to bring residential quarters closer to the dumpsite, perhaps with the peripheral portions of the dumpsite being "reclaimed" for urban development.

The waste deposited into the dumpsites accumulates over the years and undergoes oxidation, corrosion of metallic components and decomposition of organic matter, resulting in the generation and release of toxic leachate. The leachate contaminates the surface soil and water within the environment and percolates downwards to pollute the groundwater directly beneath and in the vicinity of the open dump or unlined landfill, or where there is significant groundwater flow due to the geomorphology of the area, even extending to significant distances from the location of the open dump or unlined

landfill. The leachate from the waste can thereby significantly impact the soil surface and groundwater resources and affect the potability of the underground water [6].

The toxicity of pure leachate generated from wastes and collected at lined sanitary landfills, as well as the pollution effect of the leachate on groundwater resources when it has been able to percolate through leakages and runoffs from unlined landfills and open dumps to contaminate them, has been demonstrated by many researchers. In their study of two municipal landfills (one having a lining system and the other without) in the Gaza Strip, Alslaibi et al. [7] assessed the degree of groundwater pollution around the two landfills due to percolated leachate from the dumped waste. Their results showed that for most of the water samples obtained, the concentration of most physical and chemical parameters were above acceptable standard levels for potable or irrigation water. They concluded that, evidently, landfills present potential threats to the surrounding environment. Shittu et al. [8] showed that the surface soils within and around the Ilokun dumpsite have a very high degree of contamination with heavy metals such as nickel, manganese, lead, chromium, copper, cadmium and iron. Several other researchers have worked on groundwater quality assessment near municipal solid waste (MSW) disposal sites/landfills in parts of southwestern Nigeria. A few of them are [9,10,11,12,13,14,15,16] and others.

Groundwater, especially in the developing countries, has been a valuable, cheap and widely available source of drinking water, often without any further treatment in many cases. It is therefore of concern that pollution of groundwater from poor waste management practices has constituted a major threat to groundwater as a source of potable water [17,18]. Leakages and runoffs from unlined landfills and open dumps adversely affect the quality of the ground and surface waters by polluting them with salts, nitrates, heavy metals and numerous synthetic organic compounds.

The study aimed to ascertain the level and extent of contamination of the groundwater resources within the vicinity of the Ilokun open dump municipal solid waste disposal site, with a view to ascertaining their suitability for human consumption and usage in view of recent and imminent extension of urban development to the area.

2. MATERIALS AND METHODS

2.1 Study Area

The open dump waste disposal site is near Ilokun village on outskirts of Ado, the capital of Ekiti State, Nigeria, along the northerly Ado-Iworoko road. The disposal site is being used as dumpsite for disposal of solid waste generated within the capital city and its environs by the Ekiti State Waste Management Authority (EKWMA). The Ilokun open dump waste disposal site lies between latitudes 7°41′08.2″N and 7°41′27.6″N and longitudes 5°15′36.0″E and 5°15′52.4″E, and assumes an areal extent amorphous in shape but bounded by a rectangle of dimension 440m by 420 m. The dumpsite has been in active existence for more than 20 years. It harbours various types of waste, some of which are biodegradable and easily decompose, while others which are largely non-biodegradable have been compacted over the years and have undergone long term interaction between the waste materials, the soil and the subsurface geological unit. Wastes deposited into dumpsites undergo oxidation, corrosion of metallic components and decomposition of organic matter, resulting in the generation and release of leachate which can contaminate the soil surface and groundwater resources. Geologically, this area and Ado region in general falls within the crystalline basement complex of Southwestern Nigeria, which extends westwards and is continuous with the Dahomeyan of the Benin-Togo-Ghana region. The deposits in the Nigerian section are basically undifferentiated basement rocks from the Pre-Cambrian to Upper Cambrian geologic age. They consist of mainly migmatitic and granitic gneisses; quartzites; metasedimentary schists and metaigneous rocks; charnokitic, gabbroic and dioritic rocks; and the members of the Older Granite suite mainly granites, granodiorites and syenites [19]. Into this basement complex are high-level discordant intrusions (in form of outcrops) of the Younger Granites of the Cretaceous geologic age. These consist predominantly of granites and other basic and intermediate rocks [20].

Geomorphologically, the characteristic landforms in this area are the extensive dissected pedi-plains above which rise prominent steep-sided residual hills. This morphology gives credence to the notion that soils in the area are products of erosion rather than depositional. The soils formed are mainly ferruginous [21], and in fact, a major recognized lithologic unit widely distributed

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over the area and capping the tops of the pedi-plains is the ferruginous laterite crust. The laterite crust is a thin layer of ironstone, from about 1 to 6 meters thick, deposited within the Quaternary age.

The climate of the study area is fairly uniform, with the temperature being continually high (20-30ºC) throughout the year. The soil temperatures are also very high, with the mean monthly soil temperatures measured being higher than the corresponding mean monthly air temperatures. The mean monthly soil temperatures, measured to a depth of 1.2 metres in the rainy season, vary between 27.2ºC and 32ºC [22]. The rainfall is fairly high with a few dry months (the duration of the rainy season being between 210 and 240 days), and the mean annual rainfall between 150 and 200 cm [23]. The seasonal rainfall results from the influence of the west-southwesterly Monsoon winds from the sea and the hot dry dusty North East trade winds from the Sahara known locally as the harmattan. In brief, the climate is typified by hot, humid tropical conditions.

The vegetation of the area closely follows and is derived from its climatic conditions. The vegetation type is the secondary rain forests consisting of tall trees and dense bush vegetation.

Water functions as an agent in decomposition, oxidation and other chemical reactions. It is also required as a carrier of the products away from the sites of the chemical reactions. The quantity of water flowing through the weathering environment and the rate of leachate removal also affects the rate of formation of leachate. The nature of the rainfall (heavy, concentrated and of short duration) in the humid climatic environment would enhance the formation and the percolation of leachate.

2.2 Sampling Techniques and Sample Preparation

Three numbers each of a geotechnical borehole and a water borehole (tube well) were drilled at spacings of 15 m (G1 and W1), 30 m (G2 and W2), and 45 m (G3 and W3) away from the landfill. Soil samples were obtained from the geotechnical boreholes while water samples were obtained from the water boreholes (tube wells). The geotechnical boreholes were drilled to a depth of 20 m and disturbed soil samples for laboratory testing retrieved at depths of 5 m (G_iS1) and 20 m (G_iS2) from the ground surface,

i being from 1 to 3. Tests were carried out to determine basically the index properties of the soils (i.e. those needed for their classification). Soil classification tests were carried out on disturbed samples and included the particle size distribution, specific gravity, bulk density, natural moisture contents, Atterberg limits, linear shrinkage, and hydraulic conductivity tests, all in accordance with the methods stipulated by the British Standards Institute (BSI, 1990). The soil groups were thereafter determined according to the Unified Soil Classification System (USCS). The water samples obtained from the water boreholes were subjected to laboratory tests consisting of water quality tests such as the physico-chemical characteristics, and the microbiological characteristics. In addition, water from an existing well (EW) in a residential building about 180 m from the landfill was subjected to the same tests for comparison. The physico-chemical parameters of the water determined in the laboratory included the acidity (pH), temperature, electrical conductivity (EC), colour and odour, turbidity, dissolved oxygen (DO), biochemical oxygen demand (BOD), total dissolved solids (TDS), total hardness (TH), and contents of the constituents such as total iron, chloride, sulphate, nitrate, etc. The microbiological characteristics determined are the Total Bacterial Count (Total coliform count), and the presence of Faecal streptococci, Staphylococcus aeurus and Escherichia coli. The retrieval, preservation, treatment and laboratory testing of the water samples were all in accordance with the Standard Methods for Examination of Water and Wastewater (APHA, 1998). Thereafter, the World Health Organization (WHO) Guidelines for Drinking Water Quality [24] and the Nigerian Standard for Drinking Water Quality of the Standards Organisation of Nigeria (SON, 2015) were used to compare water quality results with acceptable or recommended values.

3. RESULTS AND DISCUSSION

The results of the soil tests at the site are presented in Table 1.

The results of the physico-chemical analysis on the water samples are presented in Table 2, while the results of the microbiological tests on the water samples are presented in Table 3.

3.1 Geotechnical Tests

From the results of the tests on the soils at the site, it was found that the upper layer of the

ground is covered by clay, which is underlain by clayey sand. The clay fraction contents of the soils at the upper level are above 50%, which value decreases to around 17% at the lower level. This would hinder free infiltration of leachate formed at the ground surface into the groundwater, indicating pollution at relatively shallow depths from the ground surface. This postulation is supported also by the relatively low values of the hydraulic conductivities.

3.2 Physico-Chemical Analysis

The physico-chemical analysis of the borehole water samples in this study shows that the groundwater is slightly acidic, with pH ranging from 6.40 to 6.55, which fall below the WHO and SON permitted levels. The pH indicates the acidity/alkalinity of a medium. The pH of a water body is very important because it may affect the solubility and toxicity of metals in the aquatic system, which may have adverse effects on human health.

Temperatures of the water samples were slightly lower than the room temperature. High temperature is known to increase the toxicity of some substances such as ammonia, reduce the concentration of dissolved oxygen, increase water acidity and influence the activities of some microorganisms.

The Dissolved Oxygen (DO) values range from 6.41 to 8.45mg/l with the highest value in sample W3 within the dumpsite. All the water samples tested had values above the 5 mg/l WHO threshold. Adequate DO is necessary for good water quality and the lack of oxygen in body tissues creates a defect of red blood cells.

Drinking water with low dissolved oxygen concentration further exacerbates the condition by constricting blood vessels in the lungs.

The Electrical Conductivity (EC) of the groundwater was high, ranging from 647 µS/cm to 278 µS/cm. The highest desirable level of EC is 500 µS/cm. A high value of EC indicates high concentration of anions and cations.

Excellent water should have TDS of less than 300 this means that near the dumpsite the water is not of excellent water quality. The Total Dissolved Solids (TDS) were high in the range of 183 to 413 mg/l. Lower TDS values are more desirable for drinking water.

Hardness is one of the important properties of ground water from utility point of view, particularly for domestic purposes. The Total Hardness (TH) was found in the range of 54 to 81 mg/l. Though this is within the bounds of the maximum allowable limit of 150 mg/l, lower values are more desirable.

3.3 Microbiological Analysis

The Total Coliform Count values of the water samples of from 36 to 41 cfu/ml within and around the landfill are much higher than the maximum permitted values of 10 stipulated by both WHO [24] and SON [25]. This, coupled with the presence of *Faecal streptococci*, *Staphylococcus aeurus* and Escherichia coli indicate a high level of contamination by human excreta. High coliform populations in all the water samples (Table 3) are an indication of the poor quality of the water.

Table 1. Results of tests on soil samples from geotechnical boreholes

Parameter	Unit	G1S1	G1S2	G2S1	G2S2	G3S1	G3S2
% gravel (d > 2.36 mm)	%	0.86	60.3	0.58	58.80	0.40	42.94
% sand (0.075 mm < d < 2.36 mm)	%	44.30	22.28	47.78	26.42	64.60	39.88
% clay (d < 0.075)	%	54.84	17.42	51.64	14.78	35.00	17.18
Natural moisture content	%	13.34	27.64	25.58	18.15	25.17	20.89
Specific gravity		2.55	2.39	2.44	2.51	2.52	2.60
Liquid Limit	%	32.5	38.2	38.0	36.1	24.4	29.2
Plastic Limit	%	12.28	17.35	17.92	15.64	13.59	16.00
Linear Shrinkage	%	10.71	4.29	10.71	7.14	10.71	7.14
Hydraulic conductivity [$\times 10^2$]	cm/s	1.63	1.92	1.40	1.90	1.49	1.64
% passing Sieve No. 4 (d < 4.75 mm)	%	99.86	44.36	99.96	53.08	99.92	59.40
USCS Group Symbol		CL	SC	CL	SC	SM	SC
USCS Group Name		Clay	Clayey sand	Clay	Clayey sand	Silty sand	Clayey sand

Table 2. Results of physicochemical analysis on water samples

Parameter	Unit	W1	W2	W3	EW	Maximum permitted level (WHO, 2011)	Maximum permitted level (SON, 2015)
pH		6.40	6.45	6.55	7.4	6.5-8.5	6.5-8.5
Temperature	ºC	22.5	22	21	22	Ambient	
Conductivity (EC)	µS/cm	647	313	278	187	500	500
Colour	Hu	15	5	5	1	15	15
Odour		Objec-tionable	Objec-tionable	Odour-less	Odour-less	Unobjec-tionable	Unobjec-tionable
Turbidity	NTU	3.0	2.0	2.0	1.0	5.0	5.0
TDS	mg/l	413	188	183	116	600	500
Iron content	mg/l	0.56	0.41	0.39	0.25	0.3	0.3
Chloride content	mg/l	57.88	49.17	38.10	34.42	200	250
Sulphate content	mg/l	12.0	8.0	8.4	6.2	100	100
Nitrate content	mg/l	3.64	3.06	2.04	2.0	50	50
Hardness	mg/l	81.0	54.0	78.0	48.0	150	150
BOD	mg/l	6.44	8.40	9.46	4.82		
DO	mg/l	6.41	7.12	8.45	8.80		

Table 3. Results of microbiological analysis on water samples

Parameter	Unit	W1	W2	W3	EW	Maximum permitted level (WHO, 2011)	Maximum permitted level (SON, 2015)
Total coliform count	cfu/ml	41	37	36	14	10	10
Faecal streptococci	cfu/100 ml	+ve	+ve	-ve	-ve	Nil	Nil
Staphylococcus aureus	cfu/100 ml	+ve	+ve	+ve	+ve	Nil	Nil
Escherichia coli	cfu/100 ml	+ve	+ve	-ve	-ve	Nil	Nil

In all the parameters tested, water from the existing well (EW) in the residential quarters near the dumpsite showed acceptable values within the ranges recommended by WHO [24[and SON [25], or at least better than the values obtained for groundwater within the dumpsite.

4. CONCLUSION AND RECOMMENDATIONS

The results of the physico-chemical and microbiological tests within and very close to the Ilokun dumpsite indicate a very high level of contamination of the groundwater within the area. This portrays a potential high risk to human health.

The open dumping system of waste disposal brings along with it many disadvantages and hazards to human health. Moreover, in view of present trends of high population growth and land usage dynamics, areas possibly thought to be remote from urban access at the moment would come within urban reach only a few years from now. It is therefore recommended that there should be a shift from the open dumping system of waste disposal to the usage of engineered landfills designed according the geology, topography and other criteria as listed by the United Nations Environment Programme [26].

In the meantime, water from wells within such an area that has once be subjected to exposure to contamination should be boiled or given other appropriate treatment to render them potable and fit for domestic use.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Awopetu MS, Awopetu RG, Sample ED, Coker AO, Awokoka OS, Fullen MA, Booth CA, Hammond FN. Municipal solid waste management and the role of waste pickers in Nigeria. International Journal of Education and Research (IJER). 2014; 2(3):89-100.
    Available:http://www.ijern.com/journal/March-2014/26.pdf

2. Nwannekanma B. Visionscape, environ-mentalists tour first engineered sanitary landfill in Nigeria, Guardian Newspapers; 2018.
    Available:https://m.guardian.ng/news/visionscape-environmentalists-tour-first-engineered-sanitary-landfill-in-nigeria/

3. Akuki A. Lagos begins construction of first engineered sanitary landfill In West Africa, Independent Newspapers Ltd; 2017.
    Available:https://www.independent.ng/lagos-begins-construction-of-first-engineered-sanitary-landfill-in-west-africa/

4. Visionscape. Visionscape accelerates works on Epe landfill; 2018.
    Available:https://www.visionscape-sanitation.com/visionscape-accelerates-works-on-epe-landfill/

5. Salawudeen S. Ekiti mounts sanitary campaign. The Nation Newspaper; 2012.
    Available:https://thenationonlineng.net/ekiti-mounts-sanitary-campaign/

6. Bayode S, Adeniyi KE. Integrated geophysical and hydrochemical investiga-tion of pollution associated with the Ilara-mokin dumpsite, South-western Nigeria. American International. J Contemp Research. 2014;4(2):150-161.

7. Alslaibi Tamer M, Mogheir Yunes K, Afifi Samir. Assessment of groundwater quality due to municipal solid waste landfills leachate. Journal of Environmental Science and Technology. 2011;4(4):419-436.

8. Shittu OS, Ayodele OJ, Ilori AOA, Filani AO, Afuye AT. Heavy metal contamination of a dumpsite environment as assessed with pollution indices. International Journal of Agricultural and Biosystems Engineering. World Academy of Science, Engineering and Technology. 2018;12(1):1-7.

9. Adebisi NO, Oluwafemi OS, Songca SP, Haruna I. Flow system, physical properties and heavy metals concentrations of groundwater: A Case study of an area within a municipal landfill site. Inter-national Journal of Water Resources and Environmental Engineering. 2013;5(11): 630-638.

10. Bayode S, Olorunfemi MO, Ojo JS. Assessment of impact of some waste dumpsites on the groundwater quality in parts of akure metropolis, Southwestern Nigeria. The Pacific Journal of Science & Technology. 2012;13(2):528-536.

11. Ige OO, Olaifa AO. Groundwater Pollution assessment around waste disposal sites in parts of Lagos State, Nigeria. ARPN Journal of Earth Sciences. 2013;2(2):54-61.

12. Longe EO, Balogun MR. Groundwater quality assessment near a municipal landfill, Lagos, Nigeria. Research Journal of Applied Sciences, Engineering & Technology. 2010;2(1):39-44.

13. Majolagbe AO, Kasali AA, Ghaniyu LO. Quality Assessment of groundwater in the vicinity of dumpsites in Ifo and Lagos, Southwestern Nigeria. Advances in Applied Science Research. 2011;289-298.

14. Odukoya AM, Abimbola AF. Contamination of Surface and groundwater within and around two dumpsites. International Journal of Environmental Sciences and Technology. 2010;7(2):367-376.

15. Olagunju E, Olabode B, Ogunlana F, Babalola M. Environmental impact assessment of waste dumpsite using integrated geochemical and physico-chemical approach: A case study of Ilokun Waste Dumpsite, Ado-Ekiti, Southern Nigeria. Civil Eng Res J. 2018;4(2): 555631.
DOI: 10.19080/CERJ.2018.04.555631

16. Oyelami AC, Ojo AO, Aladejana JA, Agbede OO. Assessing the effect of a dumpsite on groundwater quality: A case study of Aduramigba estate within Osogbo metropolis. Journal of Environment and Earth Science. 2013;3(1):120-130.

17. Morris BL, Lawrence ARL, Chilton PJC, Adams B, Calow RC, Klinck BA. Groundwater and its susceptibility to degradation: A global assessment of the problem and options for management. Nairobi: United Nations Environment Programme. 2003;126. (Eary warning and assessment report series, 03-3).

18. Narasimhan TN. Groundwater: From mystery to management. Environmental Research Letters. 2009;4(3):035002.
DOI: 10.1088/1748-9326/4/3/035002

19. Rahaman MA. Review of the basement geology of South-Western Nigeria. Ch. 2 in Kogbe CA. (Ed.). Geology of Nigeria. The Elizabethan Publishing Company, Lagos, Nigeria. 1975;39-56.

20. Rahaman MA, Malomo S. Sedimentary and crystalline rocks of Nigeria. Ch. 2 in Ola SA. (Ed.). Tropical Soils of Nigeria in Engineering Practice. Balkema AA, Rotterdam. 1983;17-38.

21. Durotoye Bisi. Geomorphology and quaternary deposits of Nigeria. Ch. 1 in Ola SA. (Ed.). Tropical Soils of Nigeria in Engineering Practice. Balkema AA, Rotterdam. 1983;1-16.

22. Malomo S. Weathering and weathering products of Nigerian rocks: Engineering implications. Ch. 3 in Ola SA. (Ed.). Tropical Soils of Nigeria in Engineering Practice. Balkema AA, Rotterdam. 1983; 39-60.

23. Barbour K. Michael, Oguntoyinbo Julius S, Onyemelukwe JOC, Nwafor James C. Nigeria in Maps. Hodder and Stoughton Educational, London. 1982;148.

24. WHO. Guidelines for drinking water quality. 4th Edition. Geneva: World Health Organization. 2011;1:564.
Available:Www.who.org

25. SON. Nigerian Industrial Standard (NIS-554-2015). Nigerian Standard for Drinking Water Quality, Standards Organisation of Nigeria, Abuja. 2015;28.

26. UNEP. Closing an open dump site and shifting from open dumping to controlled dumped and to sanitary landfilling (training module). United Nations Environment Programme; 2005.

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