Investigation of the Impacts of Solid Waste Disposal Sites on Groundwater in Nasarawa Metropolis, Nigeria

MUHAMMAD SANI ALIYU[1], JIBRIN ABDULLAHI MAIRIGA[2], USMAN HASSAN AHMED[3], SALEH U. BORORI[4], ABUBAKAR HARUNA[5]

[1, 3, 5] *Department of Civil Engineering Technology, Federal Polytechnic Nasarawa, Nigeria*

[2] *Department of Building Technology, Federal Polytechnic Nasarawa, Nigeria*

[4] *Department of Science and Laboratory Technology, Federal Polytechnic Nasarawa, Nigeria*

Abstract- ***Population increase generatesconcerns for waste disposal. Absence of standard sanitary-disposal methods has left many city residents with open dumpsites as their only means of disposing waste, thereby resulting in leachate from the decomposition of these waste materials, which will later pollute underground water. The reserach investigated the effects of solid waste disposal sites on underground water quality through the examination of some physical and chemical properties of water in hand-dug wells around some selected disposal sites in Nasarawa metropolis, Nasarawa State. Three hand-dug wells were sampled at various distances from each dumpsite. The samples were thoroughly tested at the Federal Ministry of water resource, Regional Water Quality Laboratory, Minna, Niger state. The overall quality of the water was determined using the Water Quality Index method. The results showed high degree of non-conformity with W.H.O and NSDWQ standards. The study of chemical properties from the three wells showed that seven (7) parameters (dissolved oxygen, total dissolved solids, total suspended solids, conductivity, chloride, total hardness, manganese) are above W.H.O. limits in some samples. Also the Water Quality Index of the three samples; Unguwar Bai1, Unguwar Bai2 and Student Village which had been calculated to be 1072.2, 1867.1 and 69.85 respectively, were far out of the range of safe drinking water quality (according to Weighted Arithmetic Water Quality Index Rating). The water is therefore not safe for human consumption and there is a serious need to improve its quality. Therefore the need for adequate planning, design and construction vis-a-vis strategic management of waste becomes very crucial.***

Indexed Terms- ***Solid Waste, Disposal Sites, Water Quality Index, Groundwater***

I. INTRODUCTION

The intensity of man's activities has led to increased volume of solid waste worldwide despite the current level of technological advancement and industrialization. Explosive population growth is one other major factor responsible for increased municipal solid waste (MSW). Land filling of municipal solid waste is a common waste management practice and one of the cheapest methods for organized waste management in many parts of the world (El-fadel M. Lekie J.O. 1997). The study therefore focusses on the reckless abundance of solid wastes (evident by the number of open dumpsites) within Nasarawa Metropolis and the impacts of these wastes on neighbouring groundwater sources. A thorough analysis of certain water parameters would assist in revealing the impacts of solid wastes on the groundwater. In most parts of Nasarawa Metropolis refuse are dumped indiscriminately on open grounds, without considering the direct and indirect health threats associated therewith. Just like what obtains here (Nasarawa Metropolis), Landfill operations are most feasible in developing countries as land is vastly available and moderately inexpensive. Even in many developed countries where land is scarce and where policies of reduction, reuse and diversion from landfills are strongly promoted, great percentage of their generated MSW are still land filled. For instance, in 2006, out of the 251 million tons of MSW generated in the United States of America, 138.2 million tons representing 55% was disposed of in landfills (USEPA, 2007). In England, out of the

29.1million tons of municipal solid waste generated between 2003 and 2004, 72% was land filled (DEFRA, 2005). Landfills may however pose serious threat to the quality of the environment if incorrectly secured and improperly operated. The threat to surface and ground waters could be deleterious. The scale of this threat depends on the composition and quantity of leachate and the distance of a landfill from water sources (Somczyska B. Somczyska T. 2004) .This study was undertaken to assess the impact of solid waste disposal sites on groundwater in Nasarawa metropolis, Nasarawa State.

II. MATERIALS AND METHOD

2.1 Description of Study Area

The study areas are in Nasarawa metropolis of Nasarawa state and are located between Coordinates: 8°32′N8°18′E. Nasarawaas a Local Government Area in Nasarawa State, Nigeria. It has an area of 5,704 km² and a population of 189,835 according to the 2006 census.

FIGURE 3.1: Map Sketch of Nigeria Showing the Location of Nasarawa State.

2.2 Groundwater Collection Procedure

Samples for groundwater were taken from points identified as Unguwar Bai 1, Unguwar Bai2 and Student Village. Sample from Unguwar Bai 1 (for contaminated groundwater sample) was a well located about 5m downstream of the dumpsite. The well was suspected to be contaminated with leachate from the dumpsite on account of its spatial and hydrologic characteristics such as proximity to the dumpsite, groundwater flow direction and topography. Unguwar Bai 2 (for contaminated groundwater sample) was a well about 10m downstream of the dumpsite. This well was suspected to be contaminated by leachate from the dumpsite due to its downstream location with respect to hydrologic and spatial influences. Sample from Student Village was a well located about 13m, downstream a dumpsite that had been cleared. All samples were obtained on same day and were collected in previously sterilized containers and stored in iced boxes at 4°C and conveyed to the laboratory for analysis within 5 to 8 hours.

Water samples were measured and analysed for temperature (°c), turbidity (NTU), conductivity, Dissolved Oxygen (DO), Total Dissolved Solids (TDS), total suspended solids (TSS),chloride (Cl), Calcium, Total Hardness, iron (Fe), Copper (Cu), Nitrate, Zinc, manganese (Mn), Chromium (Cr6+), lead (Pb), Silicate, Chemical Oxygen Demand (COD), total coliform (TC), colour; and Taste. Analysis of groundwater for the above listed parameters was done in accordance with standard methods for the analysis of water and wastewater (APHA, 1992).

2.3 Determination of physico-chemical parameters

Physical and chemical parameters were determined in each water sample according to Standard methods as recommended by relevant authorities such as World Health Organization (WHO), United State Environmental Protection Agency (US- EPA).

2.3.1 Determination of Temperature.

The temperature was determined in the sample with an Hg filled glass thermometer. The thermometer was dipped into each sample and observed for movement of the mercury (Hg) thread, reading was taken at point when there no more development. It was ensured that the thermometer was brought to room temperature (30°C) before each reading was taken and held upright to avoid parallax error (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986).

2.3.2 Determination of pH

The pH meter was standardized using buffer solutions of pH 4 and 9, the response of the pH meter

corresponded with the manual temperature of the buffer solution at both instances. Before each sample was measured, the electrode was placed in distilled water. In measuring the pH of sample, the meter was placed inside the sample and the electrode response taken. This was repeated thrice for accuracy for all samples measured (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986).

2.3.3 Determination of Conductivity

A conductivity meter was used .The conductivity cell was calibrated with the standard KCl solution. The sample was brought to room temperature. The conductivity cell was washed with portion of the sample and then filled completely with the sample ensuring there was no air bubble adhered to the electrode and reading taken. The results were expressed as micro Siemens per centimetre (µS/cm) (US – EPA, 1983; APHA – AWWA – WPCF, 1985; Trivedy and Goel, 1986; NWRI, 2001).

2.3.5 Determination of turbidity

- Apparatus: Turbidity Meter
- Procedure: Switch on the Turbidity Meter by pressing the ON/OFF key […RD…] and insert cleaned prepared calibration standards Cal 800NTU and press read. Remove the first one, insert the second one cal200NTU and press read. Remove the second one, insert the third one Cal 100NTU and press read. Fill the sample cell with the sample to the mark and insert it to the sample holder, Press READ/ENTER key, the display blinks […Rd…] and a value will appear, which the turbidity value is. Repeat step for other samples (if any).

2.3.6 Determination of Total Hardness

The EDTA titration method was used in determining the total hardness of the samples. The sample was shaken thoroughly. 25cm^3 of the sample was taken and diluted with 50cm^3 of distilled water and transferred quantitatively into a clean 250cm^3 Erlenmeyer flask. 2cm^3 of buffer solution (NH_4CL – NH_4OH) was added, followed by two drops of Eriochrome Black indicator and the sample titrated with standard EDTA solution that has been standardized using the standard calcium solution. The formation of blue colour indicated the end point, titre value was recorded. (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986; NWRI, 2001)

- Calculation: Hardness (EDTA) as mg $CaCO_3$

$$= \frac{A * B * 100}{\text{ml of sample}}.$$

Where; A = Titre for sample (ml) and; B = mg $CaCO_3$ equivalent to 1.00ml EDTA titrant.

2.3.7 Determination of Total Dissolved Solids

100ml of the sample was quantitatively transferred into an evaporating dish that has been previously weighed and dried in an oven for one hour and cooled in desiccators. The content of the dish was evaporated to dryness on a water-bath to a constant weight. The residue was dried in an oven between 103-105^oC for two hours, cooled in a desiccators and the difference in weight calculated (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986; NWRI, 2001).

$$\text{Calculation TDS (mg/l)} = \frac{\text{mass of suspended solid} * 100}{\text{ml of sample}}$$

2.3.8 Determination of Chemical Oxygen Demand (COD)

20cm^3 of sample was placed in a 500cm^3 refluxing flask. 10cm^3 of standard $K_2Cr_2O_7$ with several glass beads already heated for 1 hour was added and 30cm^3 of sulphuric acid containing 0.4g of Ag_2SO_4 was added slowly and mixed to dissolve Ag_2SO_4. It was then refluxed for 1hour. It was cooled and diluted with 150cm^3 of distilled water, the mixture was titrated against standard ferrous ammonium sulphate (FAS) using 0.15cm^3 ferrion indicator. Reflux of blank containing the reagents was also titrated as above. (Nsi, 2007).

$$\text{Calculation: COD as } O_2/l = \frac{(A-B)*M*8000}{\text{ml of sample}}$$

where; A = ml FAS used for blank,
B = ml FAS used for sample and
M = Molarity of FAS.

2.3.9 Determination of Chloride

Highly coloured samples was treated with $Al(OH)_3$ suspension, allowed to settle and then filtered. 50ml of the sample was placed in 250cm^3 flask. 1.0cm^3 of K_2CrO_4 indicator solution was added and sample titrated with standard $AgNO_3$ (0.14M) to a reddish brown colour. Blank and standard titrations were

carried out. (US-EPA, 1983; APHA-AWWA-WPCF, 1985; Trivedy and Goel, 1986; NWRI, 2001; Nsi, 2007).

III. RESULT ANALYSES AND DISCUSSION

3.1 Physical Parameters

Analysis of the physical properties of sampled groundwater (Table 4.1) shows that temperature ranged between 28.8°C - 28.9°C, indicating the presence of foreign bodies such as active micro-organisms (Akinbile and Yusoff, 2011; Jaji et al., 2007). Algae was also observed growing in and around most of the well sampled. The complete data set is provided in Appendix D and E.

Table 4.1: Results of Physical Parameters Determination.

s/no	Parameters	Unguwar Bai 1	Unguwar Bai 2	Student Village
1	Ph	6.73	7.42	6.15
2	Temperature (°c)	28.90	28.9	28.8
3	Turbidity (NTU)	1.00	0.00	0.00

3.2 Chemical Parameters

The concentrations of chemical parameters, inclusive of heavy metals, of groundwater samples are shown in Tables 4.2 and 4.3 compared with WHO and NSDWQ standards

Table 4.2:concentration of chemical and heavy metal parameters in the tested samples.

s/no	Parameters	Unguwar Bai1	Unguwar Bai 2	Student Village
1	Dissolved oxygen (mg/l)	6.20	6.40	6.92
2	Total dissolved solid (mg/l)	1087	1379	318
3	Total suspended solid(mg/l)	5.00	0.00	6.00
4	Chloride (mg/l)	276.7	299.9	52.0
5	Conductivity (µs/cm)	1632	2060	478
6	Calcium (mg/l)	178.2	60.9	35.0
7	Total hardness (mg/l)	693	563	143
8	Iron (mg/l)	0.34	0.07	0.35
9	Copper (mg/l)	1.03	1.20	0.44
10	Nitrate (mg/l)	3.40	63.0	39.1
11	Zinc (mg/l)	2.33	2.55	0.69
12	Manganese (mg/l)	3.30	5.40	0.21
13	Chromium (mg/l)	0.09	0.13	0.03

14	Lead (mg/l)	0.02	0.05	0.00
15	Silicate (mg/l)	25.0	14.8	16.5
16	COD (mg/l)	0	0	0

Table 4.3: comparison between parameter concentrations, WHO standards and NSDWQ standards.

s/no	Parameters	Unguwar Bai 1	Unguwar Bai 2	Student Village	WHO	NSDWQ
1	Ph	6.73	7.42	6.15	6.5-8.5	6.8-8.5
2	Temperature (^{o}c)	28.90	28.9	28.8	25	NS
3	Turbidity (NTU)	1.00	0.00	0.00	1-5	1-5
4	Dissolved oxygen (mg/l)	6.20	6.40	6.92	2.0	NS
5	Total dissolved solid (mg/l)	1087	1379	318	500	500
6	Total suspended solid(mg/l)	5.00	0.00	6.00	3.0	NS
7	Chloride (mg/l)	276.7	299.9	52.0	250	250
8	Conductivity (µs/cm)	1632	2060	478	1000	1000
9	Calcium (mg/l)	178.2	60.9	35.0	300	NS
10	Total hardness (mg/l)	693	563	143	100	150
11	Iron (mg/l)	0.34	0.07	0.35	0.3	0.3
12	Copper (mg/l)	1.03	1.20	0.44	2.0	1.0
13	Nitrate (mg/l)	3.40	63.0	39.1	10	50
14	Zinc (mg/l)	2.33	2.55	0.69	NS	3.0
15	Manganese (mg/l)	3.30	5.40	0.21	0.05	0.2
16	Chromium (mg/l)	0.09	0.13	0.03	0.05	0.05

3.2 Discussion of Result

The presented results above are analysed using the Weighted Arithmetic Water Quality Index (WQI) as discussed in the previous chapter.

The Weighted Arithmetic Water Quality Index allows for easy computation of the quality of water and its source by using a mathematical formula.

The results from this study clearly demonstrate that the water quality obtained from the sampled wells are unfit for human consumption. This is because the calculated Water Quality Index (for all samples) exceeded the normal range with unguwar bai and 2nd unguwar bai water samples having WQI values of 1072.2 and 1867.1 respectively and student village sample 69.85 (Appendix A,B,C). The summary of the water quality index is presented in table 4.4 according to Weighted Arithmetic Water Quality Rating.

Table 4.4: quality rating of tested water-quality parameters

Water samples	WQI	Remarks
Unguwar bai 1	1072.2	Unsuitable for drinking purposes
Unguwar bai 2	1867.1	Unsuitable for drinking purposes

Student village	69.85	Poor water quality

CONCLUSION

The study suggests (from analysis) indiscernible transformation of decomposed waste into leachate from the base of the landfill to be the point source of groundwater pollution. This obviously could limit groundwater functions for various purposes (such as domestic, industrial and agricultural). Different health related problems could also be attributed to groundwater pollution.

The dumpsites are neither properly managed to contain leachate nor are they operated in a way that keeps out rainwater, which is responsible for the formation and percolation of leachate. As a result, groundwater and soil around these areas are contaminated. Concentrations of electrical conductivity (EC) in Unguwar Bai 1 and Unguwar Bai 2 groundwater samples are as high as 1632 and 2060µs/cm respectively compared to the required limit of 1000µs/cm. Also, concentrations of total dissolved solid (TDS) in Unguwar Bai 1 and Unguwar Bai 2 are equally as high as 1087mg/l and 1379mg/l respectively compared to the maximum limit of 500mg/l. Hence samples from these two wells are profoundly contaminated by dissolved wastes, therefore, they pose serious health threats to the consumers. The research work has revealed that leachate is the main agent for pollution of groundwater sources in the study area (from the high concentration of TDS). As such, the location of the dumpsite close to the groundwater sources and especially, the fact that rainwater is allowed to flow through the waste, are important precursor conditions for the observed pollution. The results from the research also proved that the groundwater sources sampled are unfit for consumption due to their high degree of contamination as deemed from the overall water quality index.

Season have been found to influence the magnitude as well as the occurrence of pollution emanating from the dumpsites. Rainwater flows through the waste in the dumpsite, which is not covered, leaching out pollutants, which later moves away from the dumpsite.

Conclusively, both surface and groundwater may be available in appreciable quantity in Nasarawa metropolis owing to its geographical location, but quality water sources are rare.

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APPENDIX

Appendix A: water quality index table for student village sample.

Parameter	v_i	v_o	s_i	$\frac{1}{si}$	$Q_{i=100(\frac{vi-vo}{si-vo})}$	$W_{i=\frac{k}{si}}$	Q_iW_i
pH	6.15	7	8.5	0.12	-56.67	0.00081	-0.046
Turbidity	0	0	5	0.2	0	0.0014	0
E.C	478	0	1000	0.001	47.8	0.0000069	0.00033
DO	6.92	14.6	5	0.2	80	0.0014	0.112
TDS	318	0	500	0.002	63.6	0.000014	0.00089
TSS	6	0	3	0.33	200	0.0023	0.46
Chloride	52	0	250	0.0004	20.8	0.000028	0.00058
Calcium	35	0	300	0.0033	11.67	0.000023	0.00027
T. hardness	143	0	150	0.0067	95.33	0.000046	0.0044
Iron	0.35	0	0.3	3.33	116.67	0.023	2.68
Copper	0.44	0	2	0.5	22	0.0035	0.077
Nitrate	39.1	0	10	0.1	391	0.00069	0.27
Zinc	0.69	0	1	1	69	0.0069	0.48
Manganese	0.21	0	0.05	20	420	0.138	57.96
Chromium	0.03	0	0.05	20	60	0.138	8.28
Lead	0	0	0.01	100	0	0.69	0
∑total				145.79		1.0061	70.28

$K=\frac{1}{\sum\frac{1}{Si}} = \frac{1}{145.79} = 0.0069$ $WQI=\frac{\sum(QiWi)}{\sum Wi} = \frac{70.28}{1.0061} = 69.85$

Appendix B: water quality index table for unguwar bai sample.

parameter	v_i	v_o	s_i	$\frac{1}{si}$	$Q_{i=100(\frac{vi-vo}{si-vo})}$	$W_{i=\frac{k}{si}}$	Q_iW_i
pH	6.73	7	8.5	0.12	-18	0.00082	-0.015
Turbidity	1	0	5	0.2	20	0.0014	0.028
E.C	1632	0	1000	0.001	163.2	0.0000069	0.00113
DO	6.2	14.6	5	0.2	87.5	0.0014	0.12
TDS	1087	0	500	0.002	217.4	0.000014	0.003
TSS	5	0	3	0.33	166.67	0.0023	0.38
Chloride	276.7	0	250	0.004	110.68	0.000028	0.003
Calcium	178.2	0	300	0.0033	59.4	0.000023	0.0014
T. hardness	693	0	150	0.0067	462	0.000046	0.02
Iron	0.34	0	0.3	3.33	113.33	0.023	2.61
Copper	1.03	0	2	0.5	51.5	0.0035	0.18
Nitrate	3.40	0	10	0.1	34	0.00069	0.02
Zinc	2.33	0	1	1	233	0.0069	1.61
Manganese	3.3	0	0.05	20	6600	0.138	910.8
Chromium	0.09	0	0.05	20	180	0.138	24.84
Lead	0.02	0	0.01	100	200	0.69	138
∑total				145.77		1.006	1078.6

$WQI=\frac{\sum(QiWi)}{\sum Wi} = \frac{1078.6}{1.006} = \underline{1072.2}$

$K=\frac{1}{\sum\frac{1}{Si}} = \frac{1}{145.77} = 0.0069$

Appendix C: water quality index table for 2nd unguwar bai sample.

parameter	v_i	v_o	s_i	$\frac{1}{si}$	$Q_{i=100(\frac{vi-vo}{si-vo})}$	$W_{i=\frac{k}{si}}$	Q_iW_i
pH	7.42	7	8.5	0.12	28	0.00082	0.02
Turbidity	0	0	5	0.2	0	0.0014	0
E.C	2060	0	1000	0.001	206	0.0000069	0.0014
DO	6.40	14.6	5	0.2	85.4	0.0014	0.12
TDS	1379	0	500	0.002	275.8	0.000014	0.0039
TSS	0	0	3	0.33	0	0.0023	0
Chloride	300	0	250	0.004	120	0.000028	0.0034
Calcium	60.9	0	300	0.0033	20.3	0.000023	0.00047
T. hardness	563	0	150	0.0067	375.3	0.000046	0.017
Iron	0.07	0	0.3	3.33	23.3	0.023	0.54
Copper	1.20	0	2	0.5	60	0.0035	0.21
Nitrate	63	0	10	0.1	630	0.00069	4.35
Zinc	2.55	0	1	1	255	0.0069	1.76
Manganese	5.4	0	0.05	20	10800	0.138	1490.4
Chromium	0.13	0	0.05	20	260	0.138	35.88
Lead	0.05	0	0.01	100		0.69	345

					500		
∑total				145.77		1.006	1878.31

$$K=\frac{1}{\sum\frac{1}{Si}} = \frac{1}{145.77} = 0.0069$$

$$WQI=\frac{\sum(QiWi)}{\sum Wi} = \frac{1878.31}{1.006} = \underline{1867.1}$$