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Impact of waste dump on groundwater quality in humid Tropics of Nigeria

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ABSTRACT: *Physical, chemical/heavy metal and bacteriological/biological analyses of water samples from three boreholes (W_1, 120m; W_2, 60m and W_3, 45m) located near a dumpsite at Bishop's Court, Amah-wire were compared with the limits of WHO and NSDWQ. The results from the physio-chemical analysis revealed that temperature was above the set minimum limits of WHO and NSDWQ, while a pH range of $5.01\ to\ 5.85$ indicated that all three wells were acidic. The percentage compliance of W_1, W_2 and W_3, showed that pH for all three wells had a compliance level <100%. Mn, Cu, NO_2, Pb, Cr, Cd, and Fe concentration of all three wells exceeded the limits of WHO and NSDWQ. With the exception of PO_4^{3-}, SO_4^{2-} and NO_3 which were 100% compliant, other chemical parameters were below 100%. Total Coliform Count (TCC) and Total Bacteria Count (TBC) were > 1 in W_2 and W_3, except in W_1, were TCC was 1. DO level of W_3 was lower compared to W_1 and W_2. The Biochemical Oxygen Demand at day 5 (BOD_5) and Chemical Oxygen Demand (COD) for W_3 were higher, indicating that the pollution strength increased towards the dumpsite. Based on these findings, it is observed that solid waste dump has a direct impact on groundwater quality and should be discouraged.*

Keywords: *Dumpsite, physio-chemical, bacteriological, WHO/NSDWQ and groundwater*

I. INTRODUCTION

Water on the earth can be said to be enormous in quantity when it is considered that more than two-thirds of the earth surface is covered by water (Abdulaziz, 2003). It is however, not sufficient merely to have access to water in adequate quantities, the water also needs to be of adequate quality to maintain health and it must be free from harmful biological and chemical contamination. Dauda (1993) noted that as surface water becomes increasingly polluted, people turn to groundwater for alternative supplies. This alternative source however, is becoming unsafe for human consumption due to increasing rate of pollution. The development and efficient management of groundwater resources is of particular concern in Africa especially in humid tropics of Nigeria in which groundwater accounts for 80% of its water supply, as not only are there relative scarcity of water resources and quality degradation, but also face high evaporation rates and high levels of anticipated future demands (Offodile, 2002).

The goal of all countries is to increase economic production as it is generally thought that this will result in a better life for the citizens. In as much as the population of the country is growing, it is likely that the total use of water will increase. The availability of water for use depends to a large extent on the increase in population and their activities. In an attempt to meet man's basic needs he engages in different activities extracting environmental resources and releasing the waste products to the physical environment. With competing demands on limited water resources, awareness of the issues involved in water pollution, has led to a great concern about the environmental effects of uncontrolled waste disposal. Water resources are threatened in three ways by human activities in the watershed. Firstly, the quantity of water available for supply is reduced by activities that decreases the infiltration of water into the ground (e.g., urban pavement) or channel water away quickly before it can infiltrate (e.g., urban and rural drainage). Secondly, the future availability of water supply is threatened by overuse such as excessive demand, inefficient water use, and inappropriate allocation. Thirdly, the quality of water available for water supply is threatened by pollution from both point and non-point sources.

The major problem in the global content is water pollution. It is the leading world-wide cause of deaths and diseases. It accounts for the death of more than 14,000 people daily. More recently, environmental concerns have led water managers to acknowledge the water needs of aquatic/fishing functions and wetland functions, in effect representing other competing users of the water resource. According to Longe and Balogun, (2010), groundwater pollution in Nigeria is mainly due to the process of industrialization and urbanization that has progressively developed over time without regard for environmental consequences. An increase in population as well as increase in industrialization and technological revolution has resulted in the increase in waste generation with the resultant production of wastes which have become increasingly complex to manage and control. The impact of solid wastes in recent times, on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance. These wastes migrates from wastes sites or landfills and releases pollutants that pose a high risk to groundwater resource if not adequately managed (Ikem et al., 2002).

In Nigeria, open dump is almost the verily available option for solid wastes disposal, even in the capital cities. Sanitary landfill, however, is rare and unpopular, except perhaps among few institutions and few affluent people. The practice of landfill system as a method of waste disposal in Nigeria is usually far from standard recommendations (Adewole, 2009). According to Lee and Lee, (2005) instances have shown that landfills have been inadequate in the prevention of groundwater contamination. The immediate identifiable reasons for this in Nigeria are weak or underfinanced and rapid population explosion. Other reasons include the issue of inappropriate guidelines for sitting, designing and operation of new landfills as well as missing recommendations for possible upgrading options of existing open dumps. The available guidelines for landfills are those from high-income countries, and they are based on technological standards and practices suited to the conditions and regulations of the source countries, they often do not take into account the different technical, economical, social and institutional aspects of developing country such as Nigeria. Also, many of the municipal officials think that uncontrolled waste disposal is the cheapest and best possible way of disposal of waste. Thus, for better understanding, it is of paramount importance that the pollutants of water resources of which solid waste is the most critical need be understood. Protection of groundwater is therefore, a major environmental issue since the importance of water quality on human health has attracted a great deal of concern lately and thus, can never be over-emphasized.

II. MATERIALS AND METHODS

Study Area

The study area with Longitude N005°30.693′, Latitude E007°02.886′, and Elevation 417ft as shown in Figures 1, 2a & b, is located within Owerri Municipal Local Government Area Council of Imo State, a case study for Nigerian conditions. The climate of Owerri Municipal and its environs, although comparatively stable is not uniform. Typically, the regions have the characteristic features of the humid tropical wet and dry climate governed primarily by the rainfall. There are two distinct seasons, rainy season which is from March to October and the dry season which begins in November and terminates in April. This region consists of mainly residential buildings, students' hostels and departmental stores. From investigations gathered, it was observed that the dumpsite had been in existence for over ten years and it is the only available option for solid wastes disposal. Observations from the dumpsite revealed that the wastes comprise mainly of nylon, empty food cans, empty aerosol can, and organic wastes, disposed lead accumulators and voltaic cells etc thus, resulted to ill health of some of the occupants. This purely indicated the level of pollution of groundwater by indiscriminate dumping of waste at the referenced area.

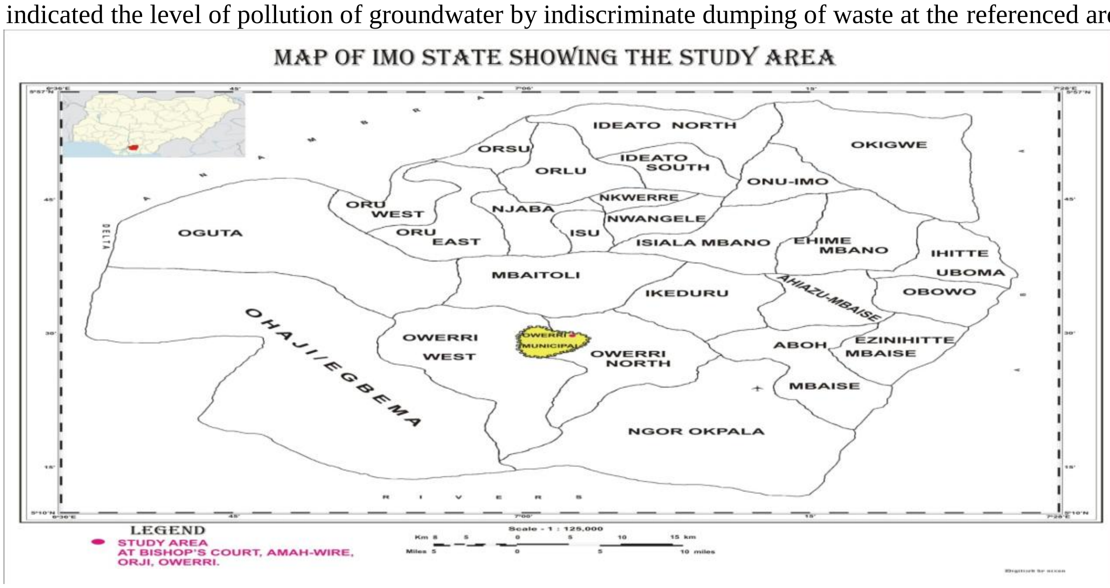


Figure 1: Map of the study area

(a) **(b)**

Figure 2a and b: Dumpsites

Sampling method and data collection

Samples were collected randomly from three different borehole wells at 120m, 60m and 45m respectively from the dump site using clean water bottles. The water samples collected were labeled W_1, W_2 and W_3 respectively. These wells were chosen because the portion of water obtained will give the concentration of constituent of the water as well as show the extent and impact of pollution at the dump site on groundwater within the area. The samples collected were taken to the Imo State Environmental Protection Agency (ISEPA) Laboratory for analysis.

III. MATERIALS

Portable data logging spectrophotometer (DR/2010), Dissolved oxygen (DO) analyzer (JB-607 Portable), Conductivity/TDS meter – DiST3 (HI98303), Electronic weighing chemical balance (ADG 5000), Suntex pH/ Temperature meter (SP-701), Incubator, Autoclave, Conical flask, Beaker, Measuring cylinder (50ml, 250ml), Sample cell bottle (10ml, 25ml), Glass rod/ stirrer, Petri-dish, Spatula, Glass stopper, De-ionized water, Buffer 7 and buffer 4 solution, NitraVer 5 reagent powder pillow, FerrorVer reagent powder pillow, Nutrient Agar (NA), Mac Conkey Agar (MAC), DithiVer metal reagent powder pillow, Buffer powder pillow (citrate type), Sodium periodate powder pillow, PbEX3 Eluate buffer pillow, and CuVer I reagent powder pillow.

IV. METHOD

Experiments on the samples collected were carried out to determine the physio-chemical (i.e. physical and chemical) and biological characteristics of the water. The physical parameters investigated for were Colour, TSS, Turbidity, pH, Temperature and Conductivity. The chemical parameters include Phosphate, Iron, manganese, Copper, Nitrate, Sulphate, Chromium, Cadmium, and Lead while the biological characteristics investigated are TBC, TCC, DO, COD and BOD.

Table: Parameters, their respective wavelengths and program numbers

Parameter	Wavelength (nm)	Program number
Physical parameters, their respective wavelength and program number		
Colour	**455**	**120**
TSS	**810**	**630**
Turbidity	**860**	**750**
pH	**-**	**-**
Temperature	**-**	**-**
Electrical conductivity	**-**	**-**
Chemical/heavy metal parameters, their respective wavelength and program number		
Phosphate	**890**	**490**
Iron	**510**	**265**

Table 1 continues …….

Table 1 continues……………

Manganese	**525**	**295**
Copper	**560**	**135**
Nitrate	**400**	**353**
Nitrite	**585**	**373**
Sulphate	**450**	**680**
Chromium	**540**	**90**
Cadmium	**515**	**90**
Lead	**515**	**90**

Source: Imo State Environmental Protection Agency Laboratory (ISEPA, 2012)

Table 2: Biological/bacteriological parameters, their medium and equipment used

Parameter	Equipment	Medium
Dissolved Oxygen (DO)	DO Analyzer	-
Chemical Oxygen Demand (COD)	-	-
Biochemical Oxygen Demand (BOD_5)	-	-
Total Coliform Count (TCC)	-	Mac Conkey Agar (MA) Nutrient Agar (NA)
Total Bacterial Count (TBC)	-	Mac Conkey Agar (MA) Nutrient Agar (NA)

IV. RESULTS AND DISCUSSION

Results

The results of the laboratory analysis of the water samples (i.e. samples W_1, W_2 and W_3 respectively), gathered from the physical, chemical and biological analysis are given in Table 3. These results were compared with the World Health Organization (WHO) and Nigerian Standard for Drinking Water Quality (NSDWQ).

Table 3: Results of the physical, chemical and biological analysis of raw water samples W_1, W_2 and W_3

Physical Analysis			
Parameters	Sample W_1(120m)	Sample W_2(60m)	SampleW_3(45m)
Physical appearance	Clear	Clear	Clear
Odour	Unobjectionable	Unobjectionable	Unobjectionable
Taste	Unobjectionable	Unobjectionable	Unobjectionable
Colour (pt-Co)	13.0	11.10	11.50
TSS (mg/l)	3	4	4.48
Turbidity (NTU)	4	4.05	4.50
pH	5.85	5.32	5.01
Temperature (℃)	27.4	27.6	28.0
Conductivity (EC) ($\mu s/cm$)	17.00	16.80	17.30
TDS (mg/l)	11.05	12.50	12.78
Chemical/Heavy Metals Analysis (all units are in mg/l)			
Iron (Fe)	0.46	2.40	3.50
Manganese (Mn)	1.1	3.60	3.95
Phosphate	1.78	4.85	5.45
Copper (Cu)	1.50	2.50	2.72
Sulphate (SO_4^{2-})	11	16	19
Chromium (Cr^{6+})	0.58	0.62	0.665
Nitrate (NO_3)	0.60	0.78	0.885
Nitrite (NO_2)	2.0	4.0	4.8
Lead (Pb)	0.045	0.095	0.113
Cadmium (Cd)	0.022	0.136	0.251

Biological/Bacteriological Analysis			
BOD_5 ($BOD_5 = DO_1 - DO_5$) (mg/l)	0.83	1.50	2.4
DO_1 (mg/l) DO_5 (mg/l)	7.2 6.37	6.50 5.0	6.03 3.63
COD($COD = 1.6 \times BOD_5$) (mg/l)	1.33	2.4	3.84
TBC ($Cfu/100ml$)	2	2	3
TCC/E.coli inclusive ($Cfu/100ml$)	1	3	3

Comparison of water samples with WHO and NSDWQ standards

To ascertain the extent of pollution, the results from the laboratory analysis of the water samples were compared with the WHO and NSDWQ standards. Tables 4, 5 and 6 give the respective comparison of the physical, chemical and biological characteristics of the water samples with the WHO and NSDWQ standards.

Table 4: Physical characteristics of water samples as compared with WHO and NSDWQ standards

Sample	Colour (Pt-Co)	TSS (mg/l)	pH	Turb. (NTU)	Temp. (℃)	EC ($\mu s/cm$)	TDS (mg/l)
WHO NSDWQ	15 15	50 50	6.5-8.5 6.5-8.5	5 5	20-30 20-30	1000 1000	250 100
W_1(120m)	13	3	5.85	4.0	27.4	17.00	11.05
W_2(60m)	11.10	4	5.32	4.05	27.6	16.80	12.50
W_3(45m)	11.50	4.48	5.01	4.50	28.0	17.30	12.78
Range	11.10-13	3 - 4.48	5.01-5.85	4.0-4.5	27.4-28.0	16.8-17.3	11.05-12.78
Variance	0	0	<0.65 - 1.49	0	0	0	0

pH is dimensionless

Table 5: Chemical/heavy metals constituents of water samples and their comparison with WHO and NSDWQ standards

Sample	Phos.	Fe	Mn	Cu	NO_3	NO_2	SO_4^{2-}	Cr^{6+}	Cd	Pb
WHO NSDWQ	5 5	0.3 0.3	0.1 0.2	1.0 1.0	40 50	0.91 0.2	250 100	0.05 0.05	0.003 0.003	0.01 0.01
W_1(120m)	1.78	0.46	1.1	1.50	0.60	2.0	11	0.58	0.022	0.045
W_2(60m)	4.85	2.40	3.60	2.50	0.78	4.0	16	0.62	0.136	0.095
W_3(45m)	5.45	3.50	3.95	2.72	0.885	4.8	19	0.665	0.25	0.113
Range	1.78-5.45	0.46-3.5	1.1-3.95	1.5 - 2.72	0.6 - 0.885	2.0 - 4.8	11-19	0.58 - 0.665	0.022-0.25	0.045-0.113
Variance	>0.45	>0.16 - 3.2	>3.4 - 3.85	>0.5 - 1.72	0	>1.09 – 4.6	0	>0.53 - 0.615	>0.019-0.247	>0.035 - 0.103

All dimensions are in mg/l

Table 6: Biological/bacteriological constituents of water samples and their comparison With WHO and NSDWQ standards

Sample	BOD_5	DO	COD	TBC ($Cfu/100ml$)	TCC ($Cfu/100ml$)
WHO NSDWQ	50 50	NS NS	80 80	3 10	0 0
W_1(120m)	0.83	7.2	1.33	2	1
W_2(60m)	1.5	6.5	2.4	2	3
W_3(45m)	2.4	6.03	3.84	3	3
Range	0.83-2.4	6.03-7.2	1.33-3.84	2 – 3	1 – 3
Variance	Within limit	-	Within limit	Slight contamination	+3, indicating the water is contaminated

All dimensions are in mg/l, unless otherwise stated, NS – Not Specified
Source of Tables (4 to 6): WHO (Garg, 2007) and NSDWQ (SON, 2007) standards

Percentage compliance of the water samples

To ascertain the percentage compliance of the laboratory analysis results of the water samples obtained with WHO and NSDWQ, simple percentage technique was adopted. The percentage compliance obtained was then represented using a bar chart. It is worthy to note however that in the calculation of the percentage compliance, the following procedures were adopted:

(i) For parameters with range i.e. pH and temperature etc., having values below the minimum required value,

$$\%\, compliance = \frac{experimental\ value}{minimum\ limit\ value} \times 100 \qquad (1)$$

(ii) For parameters with range having values above the minimum required value,

$$\%\, compliance = \frac{maximum\ limit\ value}{experimental\ value} \times 100 \qquad (2)$$

(iii) For parameters having only maximum allowable limit value, Equation (2) is used.

(iv) Percentage value higher than 100 is considered as 100%.

Estimation of the percentage compliance of the water samples

For Temperature:

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for temperature are the same (i.e. 20 - 30℃);

∴ WHO % compliance = NSDWQ % compliance

But maximum limit value = 30℃

Experimental value for W_1 = 27.4℃,

Experimental value for W_2 = 27.6℃

Experimental value for W_3 = 28℃

∴ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{30}{27.4} \times 100 = 109 \approx 100\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{30}{27.6} \times 100 = 108 \approx 100\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{30}{28} \times 100 = 107 \approx 100\%$$

For pH:

% compliance = $\frac{\text{experimental value}}{\text{minimum limit value}} \times 100$

Since WHO and NSDWQ limits for pH are the same (i.e. 6.5 – 8.5);

∴ WHO % compliance = NSDWQ % compliance

But minimum limit value = 6.5

Experimental value for W_1 = 5.85,

Experimental value for W_2 = 5.32

Experimental value for W_3 = 5.01

∴ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{5.85}{6.5} \times 100 = 90\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{5.32}{6.5} \times 100 = 81.90\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{5.01}{6.5} \times 100 = 77\%$$

Colour :

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for colour are the same (i.e. 15 Pt – Co);
∴ WHO % compliance = NSDWQ % compliance
But maximum limit value = 15 Pt/Co
Experimental value for W_1 = 13.0 Pt/Co,
Experimental value for W_2 = 11.10 Pt/Co
Experimental value for W_3 = 11.50 Pt/Co
∴ WHO% compliance for W_1 = NSDWQ % compliance for W_1

$$= \frac{15}{13.0} \times 100 = 115 \approx 100\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{15}{11.10} \times 100 = 135 \approx 100\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{15}{11.5} \times 100 = 130 \approx 100\%$$

For Electrical Conductivity (EC):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for conductivity are the same (i.e. $1000\mu s/cm$);
∴ WHO % compliance = NSDWQ % compliance
But maximum limit value = $1000\mu s/cm$
Experimental value for W_1 = 17 $\mu s/cm$,
Experimental value for W_2 = $16.80\mu s/cm$
Experimental value for W_3 = $17.30\mu s/cm$
∴ WHO% compliance for W_1 = NSDWQ % compliance for W_1

$$= \frac{1000}{17} \times 100 = 5882 \approx 100\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{1000}{16.80} \times 100 = 5952 \approx 100\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{1000}{17.30} \times 100 = 5780 \approx 100\%$$

For Turbidity:

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for turbidity are the same (i.e. 5NTU);
∴ WHO % compliance = NSDWQ % compliance
But maximum limit value = 5 NTU
Experimental value for W_1 = 4 NTU,
Experimental value for W_2 = 4.05 NTU
Experimental value for W_3 = 4.50 NTU
∴ WHO% compliance for W_1 = NSDWQ % compliance for W_1

$$= \frac{5}{4} \times 100 = 125 \approx 100\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{5}{4.05} \times 100 = 123 \approx 100\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{5}{4.50} \times 100 = 111 \approx 100\%$$

Total Suspended Solid (TSS):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for TSS are the same (i.e. $50mg/l$);

$\therefore$ WHO % compliance = NSDWQ % compliance

But maximum limit value = $50\ mg/l$

Experimental value for W_1 = $3\ mg/l$,

Experimental value for W_2 = $4mg/l$

Experimental value for W_3 = $4.48mg/l$

$\therefore$ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{50}{3} \times 100 = 1666 \approx 100\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{50}{4} \times 100 = 1250 \approx 100\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{50}{4.48} \times 100 = 1116 \approx 100\%$$

Total Dissolved Solid (TDS)

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Note: WHO and NSDWQ limits for TDS are not the same;

$\therefore$ WHO standard for TDS = $250mg/l$, and

NSDWQ standard for TDS = $100mg/l$

WHO Maximum limit value = $250\ mg/l$

NSDWQ Maximum limit value = $100\ mg/l$

Experimental value for W_1 = $11.05\ mg/l$,

Experimental value for W_2 = $12.50mg/l$

Experimental value for W_3 = $12.78mg/l$

Solving for the percentage compliance of W_1

WHO% compliance = $\frac{250}{11.05} \times 100 = 2262 \approx 100\%$

NSDWQ % compliance = $\frac{100}{11.05} \times 100 = 904 \approx 100\%$

Solving for the percentage compliance of W_2

WHO% compliance = $\frac{250}{12.50} \times 100 = 2000 \approx 100\%$

NSDWQ % compliance = $\frac{100}{12.50} \times 100 = 800 \approx 100\%$

Solving for the percentage compliance of W_3

WHO% compliance = $\frac{250}{12.78} \times 100 = 1956 \approx 100\%$

NSDWQ % compliance = $\frac{100}{12.78} \times 100 = 782 \approx 100\%$

For Phosphate:

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for phosphate are the same (i.e. $5mg/l$);

$\therefore$ WHO % compliance = NSDWQ % compliance

But maximum limit value = $5mg/l$

Experimental value for W_1 = $1.78mg/l$

Experimental value for W_2 = $4.85mg/l$

Experimental value for W_3 = $5.45mg/l$

$\therefore$ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{5}{1.78} \times 100 = 281 \approx 100\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{5}{4.85} \times 100 = 103 \approx 100\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{5}{5.45} \times 100 = 91.7\%$$

For Iron (Fe):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for Fe are the same (i.e. $0.3mg/l$);

∴ WHO % compliance = NSDWQ % compliance

But maximum limit value = $0.3mg/l$

Experimental value for W_1 = $0.46mg/l$

Experimental value for W_2 = $2.40mg/l$

Experimental value for W_3 = $3.50mg/l$

∴ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{0.3}{0.46} \times 100 = 65.2\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{0.3}{2.40} \times 100 = 12.5\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{0.3}{3.50} \times 100 = 8.57\%$$

For Copper (Cu):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for Cu are the same (i.e. $1.0mg/l$);

∴ WHO % compliance = NSDWQ % compliance

But maximum limit value = $1.0mg/l$

Experimental value for W_1 = $1.50mg/l$

Experimental value for W_2 = $2.50mg/l$

Experimental value for W_3 = $2.72mg/l$

∴ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{1.0}{1.5} \times 100 = 66.70\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{1.0}{2.50} \times 100 = 40\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{1.0}{2.72} \times 100 = 36.80\%$$

For Chromium (Cr^{6+}):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for Cr^{6+} are the same (i.e. $0.05mg/l$);

∴ WHO % compliance = NSDWQ % compliance

But maximum limit value = $0.05mg/l$

Experimental value for W_1 = $0.58mg/l$

Experimental value for W_2 = $0.62mg/l$

Experimental value for W_3 = $0.665mg/l$

∴ **WHO% compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{0.05}{0.58} \times 100 = 8.60\%$$

WHO% compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{0.05}{0.62} \times 100 = 8.06\%$$

WHO% compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{0.05}{0.665} \times 100 = 7.50\%$$

For Cadmium (Cd):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for Cd are the same (i.e. 0.003mg/l);

$\therefore$ WHO % compliance = NSDWQ % compliance

But maximum limit value = 0.003mg/l

Experimental value for W_1 = *0.022*mg/l

Experimental value for W_2 = *0.136*mg/l

Experimental value for W_3 = *0.251*mg/l

$\therefore$ **WHO % compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{0.003}{0.022} \times 100 = 13.60\%$$

WHO % compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{0.003}{0.136} \times 100 = 2.21\%$$

WHO % compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{0.003}{0.251} \times 100 = 1.20\%$$

For Lead (Pb):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Since WHO and NSDWQ limits for Pb are the same (i.e. 0.01mg/l);

$\therefore$ WHO % compliance = NSDWQ % compliance

But maximum limit value = 0.01mg/l

Experimental value for W_1 = *0.045*mg/l

Experimental value for W_2 = *0.095*mg/l

Experimental value for W_3 = *0.113*mg/l

$\therefore$ **WHO % compliance for W_1 = NSDWQ % compliance for W_1**

$$= \frac{0.01}{0.045} \times 100 = 22.2\%$$

WHO % compliance for W_2 = NSDWQ % compliance for W_2

$$= \frac{0.01}{0.095} \times 100 = 10.5\%$$

WHO % compliance for W_3 = NSDWQ % compliance for W_3

$$= \frac{0.01}{0.113} \times 100 = 8.90\%$$

For Manganese (Mn):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Note: WHO and NSDWQ limits for Mn are not the same;

$\therefore$ WHO standard for Manganese = 0.1mg/l , and

NSDWQ standard for Manganese = 0.2mg/l

WHO Maximum limit value = 0.1 mg/l

NSDWQ Maximum limit value = 0.2 mg/l
Experimental value for W_1 = $1.1\ mg/l$,
Experimental value for W_2 = $3.60\,mg/l$
Experimental value for W_3 = $3.95\,mg/l$

Solving for the percentage compliance of W_1

WHO% compliance = $\frac{0.1}{1.1} \times 100 = 9.10\%$

NSDWQ % compliance = $\frac{0.2}{1.1} \times 100 = 18.2\%$

Solv ing for the percentage compliance of W_2

WHO % compliance = $\frac{0.1}{3.6} \times 100 = 2.78\%$

NSDWQ % compliance = $\frac{0.2}{3.6} \times 100 = 5.56\%$

Solving fo r the percentage compliance of W_3

WHO% compliance = $\frac{0.1}{3.95} \times 100 = 2.53\%$

NSDWQ % compliance = $\frac{0.2}{3.95} \times 100 = 5.06\%$

For Sulphate (SO_4):

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Note: WHO and NSDWQ limits for sulphate are not the same;
$\therefore$ WHO standard for sulphate $= 250\,mg/l$, and
NSDWQ standard for sulphate $= 100\,mg/l$
WHO Maximum limit value = 250mg/l
NSDWQ Maximum limit value = 100mg/l
Experimental value for W_1 = $11\ mg/l$,
Experimental value for W_2 = $16\,mg/l$
Experimental value for W_3 = $19\,mg/l$

Solving for the percentage compliance of W_1

WHO% compliance = $\frac{250}{11} \times 100 = 2272 \approx 100\%$

NSDWQ % compliance = $\frac{100}{11} \times 100 = 909.1 \approx 100\%$

Solving for the percentage compliance of W_2

WHO% compliance = $\frac{250}{16} \times 100 = 1562.50 \approx 100\%$

NSDWQ % compliance = $\frac{100}{16} \times 100 = 625 \approx 100\%$

Solving for the percentage compliance of W_3

WHO% compliance = $\frac{250}{19} \times 100 = 1315.8 \approx 100\%$

NSDWQ % compliance = $\frac{100}{19} \times 100 = 526.3 \approx 100\%$

For Nitrate:

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Note: WHO and NSDWQ limits for Nitrate are not the same;
$\therefore$ WHO standard for Nitrate $= 40\,mg/l$, and
NSDWQ standard for Nitrate $= 50\,mg/l$
WHO Maximum limit value = 40mg/l
NSDWQ Maximum limit value = 50mg/l
Experimental value for W_1 = $0.60\ mg/l$,
Experimental value for W_2 = $0.78\,mg/l$
Experimental value for W_3 = $0.885\,mg/l$

Solving for the percentage compliance o f W_1

WHO% compliance = $\frac{40}{0.60} \times 100 = 6666.67 \approx 100\%$

NSDWQ % compliance = $\frac{50}{0.60} \times 100 = 8333.33 \approx 100\%$

Solving for the percentage compliance of W_2

WHO% compliance = $\frac{40}{0.78} \times 100 = 1528.20 \approx 100\%$

NSDWQ % compliance = $\frac{50}{0.78} \times 100 = 6410.30 \approx 100\%$

Solving for the percentage compliance of W_3

WHO% compliance = $\frac{40}{0.885} \times 100 = 4519.80 \approx 100\%$

NSDWQ % compliance = $\frac{50}{0.885} \times 100 = 5649.72 \approx 100\%$

For Nitrite:

% compliance = $\frac{\text{maximum limit value}}{\text{experimental value}} \times 100$

Note: WHO and NSDWQ limits for Nitrite are not the same;

$\therefore$ WHO standard for Nitrite $= 0.91 mg/l$, and

NSDWQ standard for Nitrite $= 0.20 mg/l$

WHO Maximum limit value = $0.91 mg/l$

NSDWQ Maximum limit value = $0.20 mg/l$

Experimental value for W_1 = $2.0 mg/l$,

Experimental value for W_2 = $4.0 mg/l$

Experimental value for W_3 = $4.8 mg/l$

Solving for the percentage compliance of W_1

WHO% compliance = $\frac{0.91}{2.0} \times 100 = 45.50\%$

NSDWQ % compliance = $\frac{0.2}{2.0} \times 100 = 10\%$

Solving for the percentage compliance of W_2

WHO% compliance = $\frac{0.91}{4.0} \times 100 = 22.75\%$

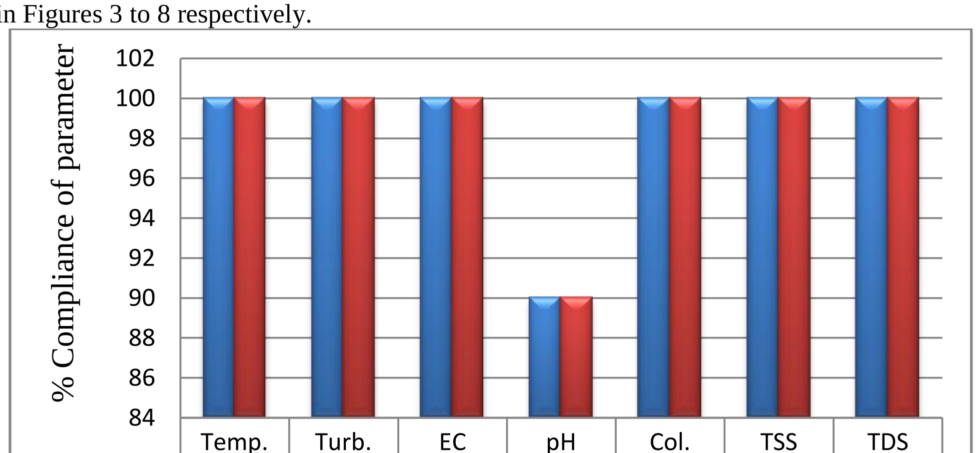
NSDWQ % compliance = $\frac{0.2}{4.0} \times 100 = 5.0\%$

Solving for the percentage compliance of W_3

WHO% compliance = $\frac{0.91}{4.8} \times 100 = 18.96\%$

NSDWQ % compliance = $\frac{0.2}{4.8} \times 100 = 4.17\%$

The different percentage compliances of the different parameters both for WHO and NSDWQ standards are represented in Figures 3 to 8 respectively.



	Temp.	Turb.	EC	pH	Col.	TSS	TDS
WHO	100	100	100	90	100	100	100
NSDWQ	100	100	100	90	100	100	100

Figure 3: Percentage Compliance of Physical Parameters of W_1 with WHO and NSDWQ Standards

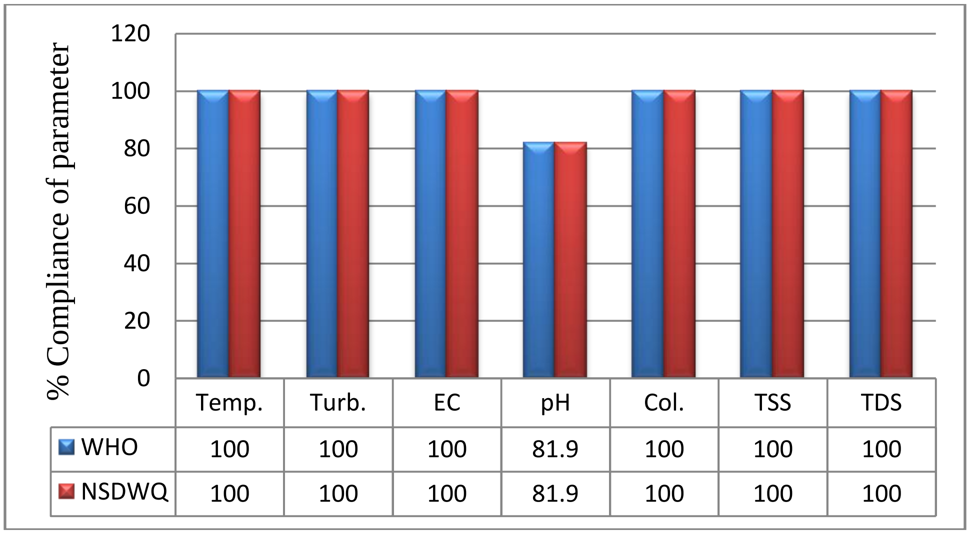


Figure 4: Percentage Compliance of Physical Parameters of W_2 with WHO and NSDWQ Standards

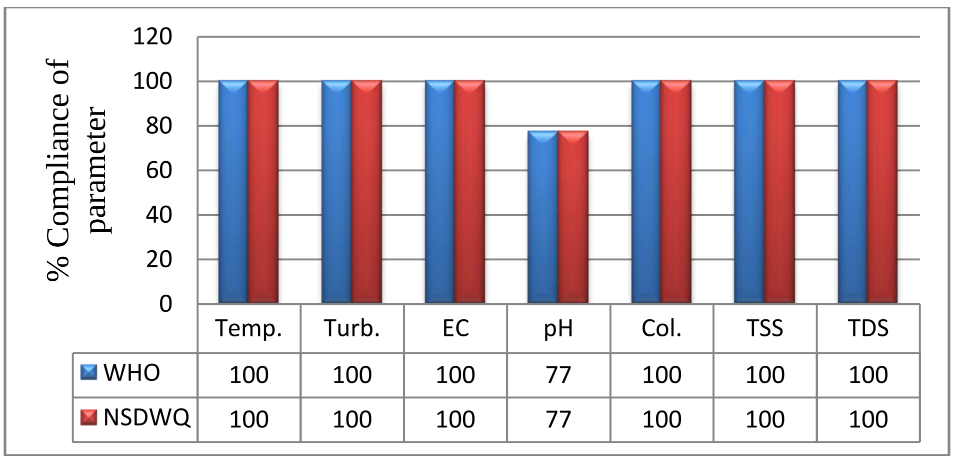


Figure 5: Percentage Compliance of Physical Parameters of W_3 with WHO and NSDWQ Standards

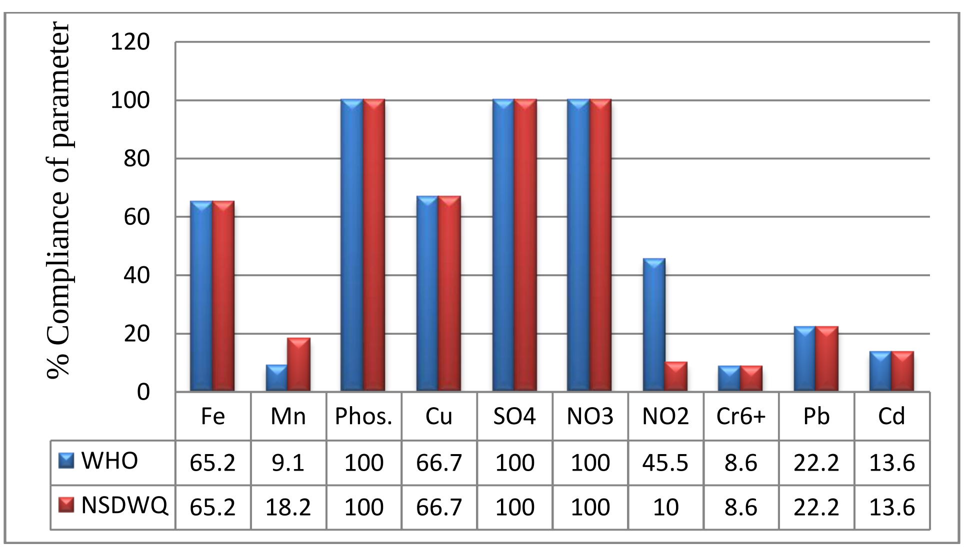
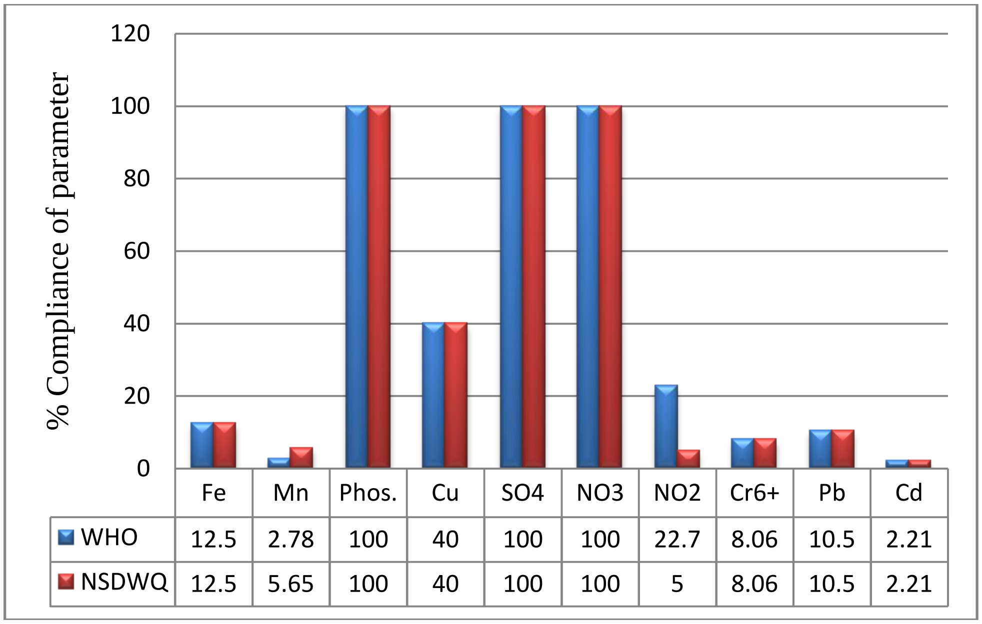
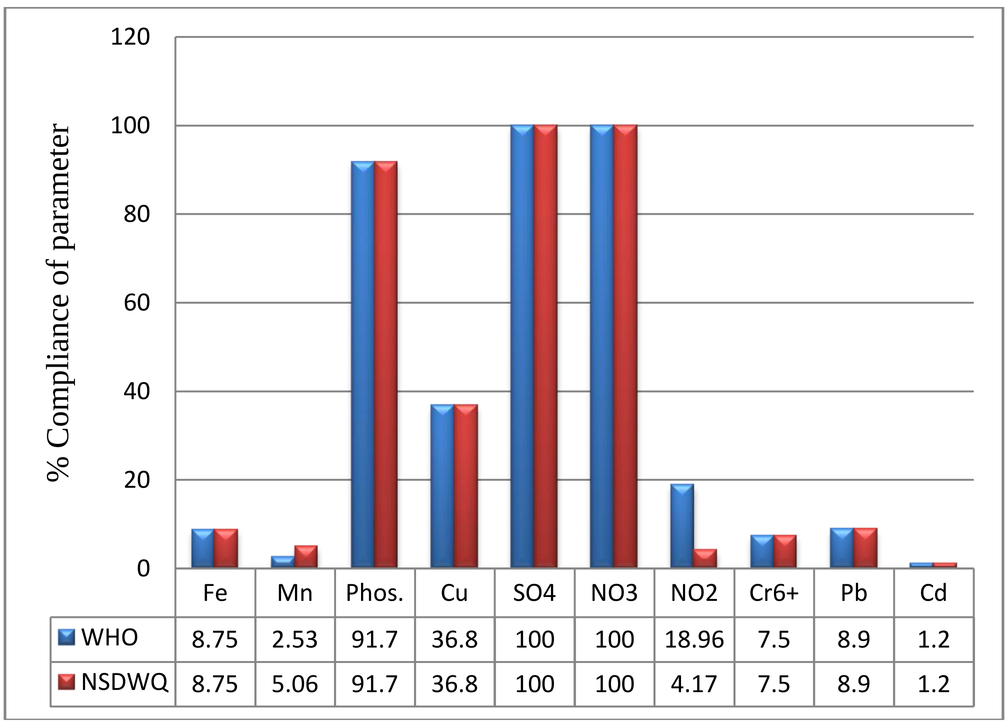


Figure 6: Percentage Compliance of Chemical/heavy metal Parameters of W_1 with WHO and NSDWQ standards



	Fe	Mn	Phos.	Cu	SO4	NO3	NO2	Cr6+	Pb	Cd
WHO	12.5	2.78	100	40	100	100	22.7	8.06	10.5	2.21
NSDWQ	12.5	5.65	100	40	100	100	5	8.06	10.5	2.21

Figure 7: Percentage Compliance of Chemical/heavy metal Parameters of W_2 with WHO and NSDWQ standards



	Fe	Mn	Phos.	Cu	SO4	NO3	NO2	Cr6+	Pb	Cd
WHO	8.75	2.53	91.7	36.8	100	100	18.96	7.5	8.9	1.2
NSDWQ	8.75	5.06	91.7	36.8	100	100	4.17	7.5	8.9	1.2

Figure 8: Percentage Compliance of Chemical/heavy metal Parameters of W_3 with WHO and NSDWQ standards

V. DISCUSSION

The results and comparison of the sample parameters with the World Health Organization (WHO) and the Nigerian Standard for Drinking Water Quality (NSDWQ) were presented in Tables (4 to 6), the percentage compliance represented in Figures (3 to 8), with bar charts were shown in Table 4.5 for easy comparison.

Table 4.5: Comparison of laboratory analysis results with WHO and NSDWQ standards, observations, remarks and recommendations

Parameter	Standards		Laboratory findings			Range	Variance	% compliance						Observation	Remarks	Recommendation
	WHO	NSDWQ	W_1	W_2	W_3			WHO			NSDWQ					
								W_1	W_2	W_3	W_1	W_2	W_3			
A. Physical characteristics																
Colour (Pt-Co)	15	15	13	11.10	11.5	11.1 – 13	0	100	100	100	100	100	100	Within limits	Acceptable	Fit for consumption
TSS (mg/l)	50	50	3	4	4.48	3 – 4.48	0	100	100	100	100	100	100	Within limits	Safe for use	Does not require treatment
pH	6.5 – 8.5	6.5 – 8.5	5.85	5.32	5.01	5.01 – 5.85	<0.65 – 1.49	90	81.9	77	90	81.9	77	Slightly acidic	Lower than the minimum limits of WHO & NSDWQ. Not safe.	Treat before use
Turbidity (NTU)	5	5	4.0	4.05	4.5	4.0 – 4.5	0	100	100	100	100	100	100	Within limits	Acceptable	No treatment
Temp. (°C)	20 – 30	20 – 30	27.4	27.6	28	27.4 – 28.0	0	100	100	100	100	100	100	Within limits	Acceptable	No treatment
EC ($\mu s/cm$)	1000	1000	17	16.8	17.3	16.8 – 17.3	0	100	100	100	100	100	100	Within limits	No health implication	No treatment
TDS (mg/l)	250	100	11.05	12.5	12.78	11.05 – 12.78	0	100	100	100	100	100	100	Within limits	Highly palatable	No treatment
B. Chemical/heavy metal characteristics (All units are in mg/l, unless stated otherwise)																
Phosphate	5	5	1.78	4.85	5.45	1.78 – 5.45	>0.45	100	100	91.7	100	100	91.7	W_3 is above limits, while W_2 & W_1 are within limits	W_2 & W_1 is acceptable for use. W_3 is not safe for use.	Treatment of W_3. W_2 may also be treated as it is little below the set limit
Fe	0.3	0.3	0.46	2.40	3.503	0.46 – 3.5	>0.16 – 3.2	65.2	12.5	8.75	65.2	12.5	8.75	Above the required limit	Not safe for consumption	Treat water
Mn	0.1	0.2	1.1	3.60	3.95	1.1 – 3.95	>3.4 – 3.85	9.1	2.78	2.53	18.2	5.65	5.06	Above the required limit	Not safe for consumption	Treat water

Table 7 continues …………………

Table 7 continues …………………

Source of Table (7): Laboratory analysis (2012); WHO standards (Garg, 2007) and NSDWQ standards (SON, 2007)

NO3 40 50 0.60 0.78 0.885 0.6 – 0.885 0 100 100 100 100 100 100 Within limits Safe for use Require no treatment
NO2 0.91 0.2 2.0 4.0 4.8 2.0 – 4.8>1.09 – 4.6 45.5 22.7 18.9 45.5 5 4.17 Above the required limit Not safe for consumptionTreat water
SO_4^(2-) 250 100 11 16 19 11 - 19 0 100 100 100 100 100 100 Within limits Safe for use Require no treatment
Cr6+ 0.05 0.05 0.58 0.62 0.665 0.58 – 0.665 >0.53 – 0.615 8.6 8.06 7.5 8.6 8.06 7.5 Above the required limit Not safe for consumption Treat water
Cd 0.003 0.003 0.022 0.136 0.25 0.022 – 0.25 >0.019 – 0.247 13.6 2.21 1.2 13.6 2.21 1.2 Above the required limit Not safe for consumption Treat water
Pb 0.01 0.01 0.045 0.095 0.113 0.045 - 0.113 >0.035 – 0.103 22.2 10.5 8.9 22.2 10.5 8.9 Above the required limit Not safe for consumption Treat water
Bacteriological/biological characteristics
BOD5 50 50 0.83 1.5 2.4 0.83 – 2.4 0 - - - - - - Within limit Safe for use Treatment not necessary
DO NS NS 7.2 6.5 6.03 6.03 – 7.2 - - - - - - - DO level reduces towards the dumpsite Moderate level of dissolved oxygenTreatment not necessary
COD
80
80
1.33
2.4
3.84
1.33 – 3.84
0 - - - - - - - Within limit Safe for use No treatment required
TBC
(Cfu/100ml) 3 10 2 2 3 2 – 3 Slight contamination - - - - - - - Slight Contamination of water Not safe for consumptionTreatment required
TCC (Cfu/100ml)0 0 1 3 3 1 – 3 +3 indicating water contamination- - - - - - - Contamination of water by anthropogenic activitiesIndicates presence of harmful bacteria Water should be treated before use

VI. CONCLUSION

The study revealed that the concentration of waste materials in dump sites systematically pollutes soil and groundwater over time. The impact of such pollution as determined from the study implied that the contamination of the groundwater was more dependent on proximity to the dump site. The extent of the pollution is attributed to the influence of topography, type and state of waste disposal systems and more so, the hydrogeology of the area. The contamination of water with high levels of chemical and bacteriological contaminants poses health problems such as typhoid fever, and worm infestation. Coliform and total bacteria count indicated microbial pollution of the groundwater by anthropogenic activities. The presence of Fe, Cd, Mn, Pb and Cr in detectable quantities indicated high toxicity level in the groundwater and therefore posed serious environmental risk to life. It is worthy to note however, that not only the study area had been polluted by the indiscriminate dumping of wastes, but areas within the humid tropics of Nigeria that suffer the impact of groundwater and surface water pollution. To combat this menace, orientation should be given not just to the inhabitants of the region but also to the general public, while government should provide a means of efficient waste disposal system and recycling machines. The government on focus their resources should be channeled towards combating obnoxious odour within the sites. This would not only help protect our ecosystem but also provide jobs for the populace as well as preserving the aesthetic values of our water resources planning and development.

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