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# EFFECT OF DUMPSITE LEACHATE ON GROUNDWATER QUALITY IN MPAPE COMMUNITY, BWARI AREA COUNCIL, ABUJA, NIGERIA

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## ABSTRACT

This work aimed at assessing the extent of groundwater pollution by dumpsite leachate in Mpape community, Abuja, Nigeria. The groundwater samples from five different locations were investigated for various physicochemical and microbiological parameters using standard analytical methods. The results obtained were compared with World Health Organisation (WHO) (2011) permissible limit of those parameters in drinking water. The results indicated that the groundwater in the study area was acidic and hard in nature which did not meet the required standards. However, $Cl^-$, $NO_3^-$ and $SO_4^{2-}$ had values within the WHO limits. The Total bacteria count (TBC) ranged from 1.25 – 1.87 × $10^4$ cfu/ml to 1.25 – 1.71 × $10^4$ cfu/ml while Total coliform (TC) was 7.00 – 8.20 MPN/100 ml and 6.40 – 8.35 MPN/100 ml for wet and dry seasons respectively, but faecal coliform was not detected in Wells A, C, and E; and Wells A, D and E for wet and dry seasons respectively. From the computed Water Quality Index (WQI), the samples under consideration were found unsafe for drinking since all values recorded were >300 and so needs urgent attention and treatment. This suggested that the dumpsite leachate had great impact on the quality of the groundwater under investigation.

**Key words:** Groundwater, Mpape, leachate, seasons, World Health Organisation

## INTRODUCTION

Human beings depend on water for their existence. The quality of groundwater which is the primary source for human consumption, agriculture, and industrial purposes have deteriorated especially in developing countries, such as Nigeria due to population growth, rapid urbanization, and industrialization. Thousand tons of solid wastes are daily generated in the country [1] and 90% of these wastes are disposed illegally and haphazardly (without regards for environmental concerns) at various dumping sites on the surface of urban centres like Mpape community which is capable of causing environmental degradation in its immediate

environment [2]. Charles et al. [3] stated that Nigeria generates about 25 million tonnes of municipal solid wastes (MSW) in a year and forecasted that MSW would increase due to the uncontrolled population growth and fast urbanization.

Many developed nations have been able to address the problem of leachate production in waste dumpsites through sanitary landfill systems, various wastes to wealth agenda and modern waste recycling and reuse technology [4,5]. But the problem is worse especially in developing countries where there is no modern waste disposal system in practice. The waste disposal method of landfill practiced in countries like Nigeria is usually far from recommended standards [6, 7].

Landfills or dumpsites have been identified as one of the major threats of groundwater resources due to the production of leachates and its migration through the soil into the aquifer [8-10]. Other threats to groundwater resources include industrial effluents discharges, residential effluents discharges, agricultural chemicals and fertilizers applied on farms, oil spills and leakages, as well as salt water intrusion and urban surface runoff [11, 12].

In recent times, the effect of leachates on groundwater resources has attracted lots of attention due to its overwhelming environmental importance, and the ever increasing population will continue to rely on groundwater as the main source of water supply [13, 14]. Contamination of groundwater resources from leachates could pose a considerable risk to human health and the natural environment. About two million people die each year, as a result of contaminated water and poor sanitation, of which 90% are children [15].

Various studies on the impact of landfill and dumpsite on groundwater quality have been reported using different approaches. Adeyi & Majolagbe [1] reported the impact of two major active dumpsites (Olusosun and Solus) on groundwater quality in Lagos using the physicochemical assessment and water quality index approaches and discovered minimal contamination of the groundwater. However, the nitrate level in almost all the groundwater collected around the Olusosun dumpsite was worrisome and they recommended concerted efforts to be put in place to address the situation and ensure sustainable environment. A study of the impact of waste disposal on the groundwater resources around a refuse dumpsite at Oke-odo, Iwo, Osun state, Nigeria was carried out by Alagbe et al. [8] using Very Low Frequency Electromagnetic method (VLFEM) and Vertical Electrical Sounding (VES) of the Schlumberger array. The results of the VLF-EM and VES revealed the presence of contaminant plumes which were detected as conductive anomalies mainly of dissolved salts from decayed organic matters. The results of the hydrochemical analyses conducted were compared with the standard guidelines of the World Health Organization to ascertain their

quality and it was shown that the quality of water in the study area fell below standard. John & Brownson [5] conducted a comparative study using WHO standards and Federal Ministry of Environment (FMEnv) on the effects of leachate on groundwater in selected dumpsites in Rivers State, Nigeria by assessing the physical and biochemical characteristics of the groundwater. The results revealed high values of analyzed parameters which exceeded the standards of the WHO and FMEnv and it was concluded that the results were an indication of the groundwater contamination. Besufekad et al. [6] carried out assessment of the effect of solid waste dumpsite on surrounding soil and river water quality in Tepi Town, Southwest Ethiopia by analysing the physicochemical parameters of the surface water, leachate, and soil samples in comparison with the limits prescribed by the Ethiopian Environmental Protection Agency (EEPA) and WHO standards. The results were found to be higher than standard guideline values. The finding suggested that solid waste open dump site adversely affects soil and water quality in the study area and becomes a probable source of risk for human health via the food chain.

As groundwater is the main source of water supply for drinking and irrigation at Mpape, the imperative of regular monitoring of the Wells cannot be over-emphasized to check for various activities that could affect the wellbeing of the source. This work therefore is aimed at assessing the quality of groundwater located around the major active refuse dumpsites in Mpape Community, Abuja, by evaluating the water quality index and physicochemical parameters of the water samples in comparison with the maximum permissible limits by known regulatory bodies such as World Health Organization.

## MATERIALS AND METHODS

### Description of Study Area

Mpape is a large, well-populated district within the Federal Capital Territory Abuja, Nigeria. It is located 9 km North of Abuja and falls under the administration of the Bwari Area Council. Although largely undeveloped, it has lots of potential. Mpape lies on the foothills and on the top of the famous Mpape Rocks that are easily sighted from the neighbouring Maitama District. Geographically, Mpape lies between Latitudes 9.175699° and 9.113010° north of the equator and Longitudes 7.463892° and 7.524349° east of the Greenwich Meridian. It occupies a land area of 44.325 Ha and the largest slum settlement in Abuja and densely populated [16]. With the rural-urban migration reportedly being on the rise in Nigeria, the village has grown into an informal settlement with a population tethering over 1.1 million inhabitants without the commensurate infrastructure. Mpape is almost

predominantly underlain by high grade metamorphism and igneous rocks of precambrian age generally trending. These rocks consist of gneiss, migmatites, granites and schist belt outcrops along the eastern margin of the area. The rocky nature of Mpape makes it suitable for quarry business which is thriving well. The weather in Abuja is always warm and most of the time the sun shines bright. The temperature varies from 26 $^{o}$C to 40 $^{o}$C. Abuja weather is a "Tropical wet and dry climate" which follows two main seasons – a dry season and a wet season. The wet season starts in April and ends in October. During these months the climate is quite humid and the temperature will drop to 26-30 $^{o}$C. It is cold at night with temperatures down to about 20 $^{o}$C [16, 17].

## SAMPLE COLLECTION, HANDLING AND PRESERVATION

A total of fifteen (15) groundwater samples were used for the study. Three (3) samples each were collected from five (5) different Wells in the community around the major active dumpsite from the period of June to August for wet season and October to December for dry season (2021) in order to assess the contamination status of the water. Samples from different locations were taken at 400 m, 1 km, 1.6 km, 2.3 km and 3.5 km from the dumpsite and labelled A, B, C, D, and E respectively. Sampling was done in 1 L well-labelled high-density polyethylene bottles (HDPE) which were prewashed and soaked in 1 M $HNO_3$ for 24 hours and later rinsed with deionised water. The samples were transported to the laboratory in a cooler of ice to ensure rapid cooling and were protected from direct sunlight during transportation to avoid depletion of the contamination due to oxidation. They were further preserved in the refrigerator prior to analyses [18].

## PHYSICOCHEMICAL ANALYSIS

The standard methods adopted in investigating the physicochemical parameters of water samples were in consistence with the American Public Health Association series of Standard Methods of Examination of Water and Effluent [19] and all chemicals used were of AnalaR grade (BDH, England). Each water sample was analyzed for their physicochemical properties.

### Temperature

The temperature of the water samples were determined *in-situ* with a mercury-in-glass thermometer by placing the thermometer vertically into the water sample and allowed to stand till the temperature reading was steady.

**pH and Electrical Conductivity (EC)**

The pH was determined using a pocket digital pH meter (HANNA Inst. Italy) by inserting the probe into the samples and values were read from the LCD screen. Electrical Conductivity was measured at 25 ºC using conductivity meter (Systronics-304). All these were recorded at the site of sample collection [20].

**Total Dissolved Solid (TDS)**

Total dissolved solid was obtained by difference between total solids and total suspended solids (TDS = TS – TSS)----------(1)

**Total Hardness (TH)**

Total hardness in the water samples was determined titrimetrically using the sodium salt of ethylene-diamine-tetra-acetic acid (EDTA) as titrant. 50 ml sample was placed in 125 ml Erlenmeyer flask and the pH of the sample was adjusted to 7-8 with 1 ml of 50% HCl. Exactly 0.2 g solo chrome black-T indicator was added to the sample and a colour change observed. The sample was titrated with 0.01 M EDTA until an end point was reached and the titre value recorded. Hardness as $CaCO_3$ for each sample was calculated using the following:

$$CaCO_3 = \frac{D \times N \times EW \times 1000}{\text{Vol. of sample (mg/l)}} (mg/l) \quad \text{----------(2)}$$

Where, D = volume of EDTA used for titration

N = normality of EDTA

EW = equivalent weight of $CaCO_3$

**Dissolved Oxygen (DO)**

Initial DO content was done using a modified azide method by adding 2 ml of manganese (ll) sulphate ($MnSO_4$) and 2 ml of alkaline iodide azide (OH-I-$NaN_3$) solution, then with 2 ml of conc. $H_2SO_4$ and 300 ml of sample. This was titrated against a standard solution of 0.025Nsodium thiosulphate ($Na_2S_2O_3$) until a pale-yellow colour. Then 1 ml starch solution was added and continued titration until the blue-black colouration disappeared.

Dissolved oxygen (DO) (in mg/l) = ml of sodium thiosulfate (0.025N) consumed.

**Biochemical Oxygen Demand (BOD)**

Biochemical Oxygen Demand was determined by APHA method which involved the measurement of the oxygen concentrations of the samples immediately and that after

incubating it for five days [8]. Then the $BOD_5$ was calculated by taking the numerical difference between the initial and final DO.

$$BOD\ (mg/l) = (Do - D_5) \times \text{dilution factor} \quad \text{----------(3)}$$

Where Do = Conc. of the dissolved oxygen in the sample

$D_5$ = Conc. of the dissolved oxygen after 5 days

**Chemical Oxygen Demand (COD)**

COD in the water samples was determined titrimetrically. The process was achieved by using a strong oxidizing agent (potassium dichromate) under acidic condition. 50 ml sample was transferred into a 250 ml flat bottom flask and 25 ml 0.25 N $K_2\ Cr_2\ O_7$ was added to 50 ml sample it and swirled gently. The reflux system was connected to a heating mantle and 70 ml $H_2SO_4$ was added from the condenser through the water traps to the sample in a flat bottom flask. The heating mantle was set at a temperature of 65 ºC - 70 ºC and heated for two hours. The sample was cooled to room temperature and was titrated with 0.25 M ferrous ammonium sulphate (FAS) containing three drops of ferroin indicator until the end point was reached and the titre value recorded. A blank was prepared alongside the samples following the same procedure using distilled water. The COD of each sample was calculated using the following equation:

$$COD\ (mg/l) = \frac{(b-a) \times N \times 1000 \times 8}{\text{Vol. of Sample}} \quad \text{----------(4)}$$

Where, b = volume of FAS ($FeAmSO_4$) used for titration of blank (ml)

a = volume of $FeAmSO_4$ used for titration of sample (ml)

N = normality of $FeAmSO_4$

**Sulphate, Nitrate and Chloride**

Sulphate was determined by turbidimetric method using barium chloride and the concentration was estimated by using the UV-visible spectrophotometer (Model: UV-1601). Nitrate was determined by phenol disulphonic acid (PDA) method and Chloride ion in the samples was measured titrimetrically using the Mohr's method in which 25 ml sample was titrated with a standard silver nitrate ($AgNO_3$) solution using potassium chromate as indicator. The amount of chloride in the sample was calculated using the following equation:

Chloride ion concentration (mg/l) = $\frac{(A \times N \times 35.5) \times 1000}{V}$----------(5)

Where: A = volume of titrant used

N = normality of silver nitrate

V = volume of sample used (ml).

**Calculation of Water Quality Index (WQI)**

The $WQI$, representing the overall water quality of a groundwater sample, was estimated using Eq. (6).

$$WQI = \frac{\sum WQ}{\sum W} \text{----------(6)}$$

Where, W = unit weight, and Q = quality rating scale. W and Q were calculated using Eqs. (7) and (8), respectively.

$$W = \frac{1}{S} \text{----------(7)}$$

$$Q = \frac{C}{S} x\ 100 \text{----------(8)}$$

Where s = standard values (mg/l) and c = measured concentrations (mg/l).

The water quality classification based on WQI is considered as follows:

Table 1: Water Quality Classification

| WQI | CLASS | GRADE | STATUS |
|---|---|---|---|
| <50 | 1 | Excellent | Safe for drinking |
| 50 – 100 | 2 | Very good | Safe for drinking |
| 100 – 200 | 3 | Good | Safe for drinking |
| 200 – 300 | 4 | Fair | Unsafe for drinking |
| >300 | 5 | Poor | Unsafe for drinking |

Source: Madilonga et al. [25]

**MICROBIOLOGICAL ANALYSIS**

The methods used for the analysis were standard methods for examination of bacteriological characteristics of water and effluent as laid down by the American Public Health Association series [19]. Total Bacteria Count was determined by standard plate count method using the nutrient agar medium while Total Coliform was carried out by standard multiple tube fermentation/ most probable number (MPN) technique [21].

## STATISTICAL ANALYSIS

In order to quantitatively analyse and confirm the relationship among groundwater parameters determined, Pearson correlation analysis was applied to the dataset. All the statistical analyses were performed using statistical software SPSS Windows version 25.0

## RESULTS AND DISCUSSION

The results of the study are presented in Figures 3 to 17 with Descriptive Statistics of the analysed parameters in Table 2.

The temperature of the water samples as depicted in Fig. 3 for the wet and dry seasons ranged from 21.33 – 22.14 $^{o}$C and 27.43 – 27.65 $^{o}$C respectively. As expected, the temperature of the samples during dry season was higher than that of the wet season but both were within the WHO recommended standard of 25 $^{o}$C to 30 $^{o}$C. This is in agreement with similar work previously reported by Ugbaja & Otokunefor [14] which stated that temperature has a significant role to play in both leachate and groundwater. This can affect the value of dissolved oxygen in the water.

The pH of the samples during wet season was between 4.83 in Well D to 5.48 in Well B while the pH during dry season was between 6.22 in Well A to 6.45 in Well D (Fig. 4). This indicated that the pH of the samples during wet season were more acidic in nature than those recorded during dry season though all of them fell below the WHO permissible limits of 6.8 to 8.5 [24] and did not meet the standards. These findings corroborated with works of other researchers [2, 7, 9]. The low pH could be as a result of the breakdown of the organic matter derived from vegetation cover and humus buried in sediments at the dumpsites, and subsequent infiltration of run-off (acid rain) through the porous soil and permeates into the groundwater. High acidic content may lead to health risk such as dermatosis and leachate infiltration to groundwater samples may have resulted in odour and bad taste [12, 16].

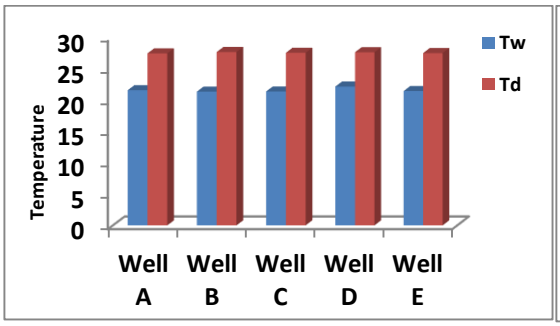



**Figure 3: The Temperature ($^{o}$C) of the Samples**

Note: Subscript w = wet season, d = dry season

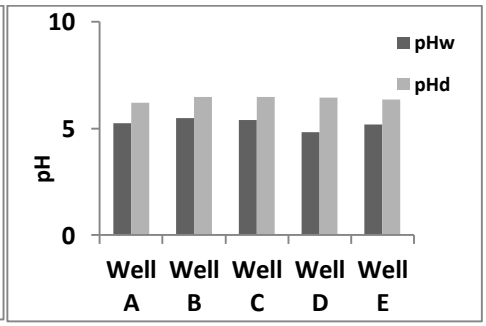



**Figure 4: The pH values of the Samples**

Note: Subscript w = wet season, d = dry season

The electrical conductivity ranged from 925 – 972 µs/cm and 1726 – 1828 µs/cm for wet and dry season respectively (Fig. 5). EC is an indication of dissolved inorganics availability in groundwater [19]. The importance of EC of water is its measure of salinity, which greatly affects the taste consequently. High electrical conductivity values were observed during the dry season and low values in the wet season. High EC values during dry season are due to evaporation resulting in high concentration of ions. The EC values of all the groundwater samples of wet season fell below the WHO standard while those recorded during dry season were above the permissible levels of WHO standards of 1200 µs/cm indicating the impact of leachate on groundwater which may contain more soluble salts.

The total dissolved solids of the water samples in wet season was highest, 4867.73 mg/l in Well B and lowest, 4275.91 mg/l in Well A while those recorded in the course of dry season were between 6841.82 mg/l and 7183.65 mg/l (Fig. 6) indicating that all the samples exceeded the permissible levels of WHO standards which is 500 mg/l. High significant values of TDS could be due to salt water intrusion because of proximity to the dumpsite.

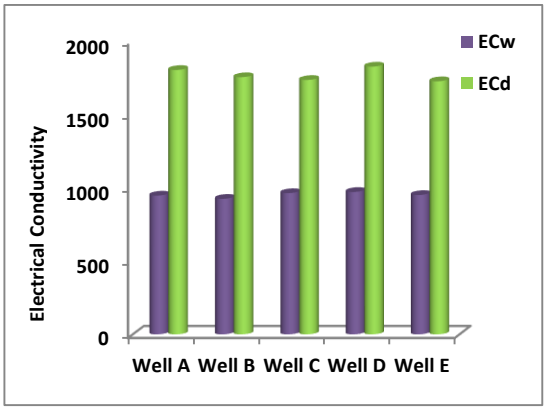



**Figure 5: The EC (µs/cm) of the Samples**
Note: Subscript w = wet season, d = dry season

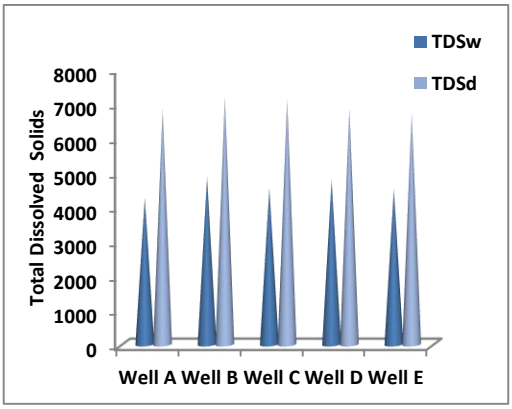
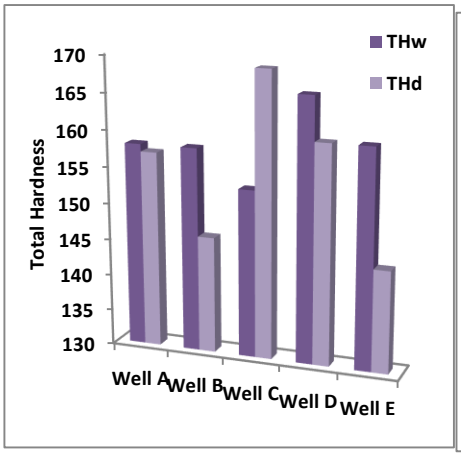



**Figure 6: The TDS (mg/l) of the Samples**
Note: Subscript w = wet season, d = dry season

The total hardness (TH) (Fig. 7) of the samples ranged from 153 – 166 mg/l for wet season and 144 – 169 mg/l for dry season which showed that all the water samples were hard in nature and all were below WHO standard of 200 mg/l. TH is a measure of the mineral content in a water sample that is irreversible by boiling. Hard water with high concentration of minerals may have moderate health benefits. A number of ecological studies have shown a great significant inverse relationship between hardness of drinking water and cardiovascular diseases [5, 11, 16]. However, it can cause serious problems in washing and cleaning due to high mineral content present in hard water which prevents the foaming action of soap and

detergents. Hard water can also cause skin diseases such as eczema which can be developed as a result of the use of hard water in bathing.

The results as presented (Fig. 8) showed that the concentration of dissolved oxygen (DO) during wet season was higher (5.95 – 7.32 mg/l) than the values recorded in dry season (3.58 – 5.46) mg/l. Some of the values of DO recorded in dry season were below the WHO standards of 4 – 15 mg/l except Well D but the values recorded in wet season were within the WHO permissible limits [24]. This could be attributed to the extent of organic pollution and population density of flora and fauna and it is in agreement with similar studies previously carried out [6, 10 ]. DO is extremely useful in self-purification capacity of water bodies. The high oxygen value for the wet season coincides with periods of lower temperature. The amount of DO in water has been reported to fluctuate and not to be constant depending on temperature, depth and amount of biological activities such as degradation [3, 7].



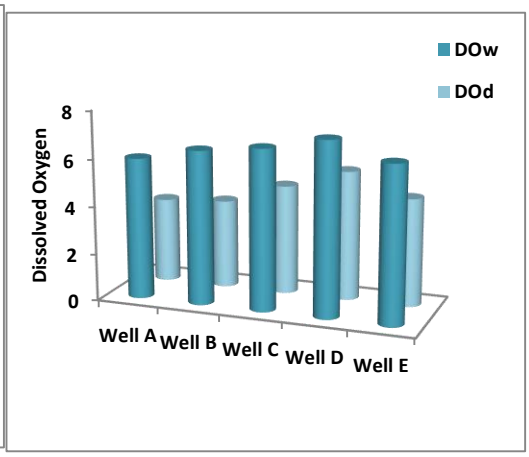




**Figure 7: The Total Hardness (mg/l) of the Samples.** Note: Subscript w = wet season, d = dry season

**Figure 8: The DO (mg/l) of the Samples** Note: Subscript w = wet season, d = dry season

The values of BOD recorded (Fig. 9) were between 26.47 – 31.82 mg/l and 27.35 – 31.27 mg/l for dry season and wet season respectively which were above the WHO recommended limits of 2.5 mg/l. BOD is the amount of oxygen required by microorganisms for stabilizing biologically decomposable organic matter under aerobic conditions [17].When the BOD of water is high the dissolved oxygen concentration will reduce because the oxygen available in the water is being used by the bacteria. Thus the higher the BOD value the greater the amount of organic matter in the water samples [21]. The high BOD in the groundwater samples indicates polluted water by organic matter from the dumpsite leachate, hence the groundwater around the dumpsite may not be safe for human consumption. Water with a high concentration of BOD is a common feature of organically pollutants in the water bodies.

Table 2: Descriptive Statistics of the Groundwater Parameters

| Dry | | | | | Wet | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Parameters** | **Min.** | **Max.** | **Mean** | **Std. Deviation** | **Min.** | **Max.** | **Mean** | **Std. Deviation** | **WHO Standards** |
| Temperature | 27.43 | 27.65 | 27.538 | 0.09094 | 21.33 | 22.14 | 21.56 | 0.33653 | 25 - 30 |
| pH | 6.22 | 6.47 | 6.394 | 0.10738 | 4.83 | 5.48 | 5.232 | 0.25411 | 6.8 – 8.5 |
| EC | 1726 | 1826 | 1768.8 | 43.68867 | 925 | 972 | 951.8 | 18.01943 | 1200 |
| TDS | 6723.62 | 7183.65 | 6946.584 | 197.536 | 4275.91 | 4867.73 | 4602.282 | 235.50433 | 500 |
| TH | 144 | 169 | 155.2 | 10.32957 | 153 | 166 | 159 | 4.69042 | 200 |
| DO | 3.58 | 5.46 | 4.39 | 0.75862 | 5.95 | 7.32 | 6.622 | 0.49545 | 4 - 15 |
| BOD | 26.47 | 31.82 | 28.7 | 2.44844 | 27.35 | 31.27 | 29.816 | 1.71436 | 2.5 |
| COD | 240.7 | 248.81 | 245.114 | 2.90171 | 239.16 | 245.81 | 241.748 | 2.84205 | 2.5 |
| Sulphate | 173.6 | 180.11 | 176.254 | 2.70739 | 175.4 | 184.93 | 181.604 | 3.87686 | 250 |
| Nitrate | 18.84 | 28 | 22.892 | 3.53626 | 43.86 | 48.71 | 46.476 | 2.00273 | <50 |
| Chloride | 128.37 | 145.64 | 136.192 | 6.39601 | 120.5 | 140.32 | 129.162 | 7.29595 | 250 |
| TBC | $1.25x10^4$ | $1.71x10^4$ | 14620 | 2101.666 | $1.25x10^4$ | $187x10^4$ | 15900 | 2902.585 | $1.0 \times 10^2$ |
| TC | 6.4 | 8.35 | 7.198 | 0.7908 | 7 | 8.2 | 7.552 | 0.50097 | 0 |
| FC | 0 | 1.4 | 0.552 | 0.75599 | 0 | 1.42 | 0.778 | 0.71493 | 0 |

The recorded BOD was in agreement with the work of John and Brownson [5] but in contrast with the work of Besufekad et al. [6].The COD values (Fig. 10) of the groundwater samples for wet and dry seasons were 239.16 – 245.81 mg/l and 240.70 – 248.81 mg/l which were above the maximum permissible limit of 2.5 mg/l set by WHO [24]. The high COD values of the water samples indicate the presence of significant chemically oxidizable organic contaminants in the groundwater, which infers that the groundwater under study may not be safe for drinking. The highest COD values of 245.81 mg/l and 248.81 mg/l observed in both seasons is an indication that the dumpsite leachate is contributing to the organic contaminant concentrations of the surrounding groundwater.

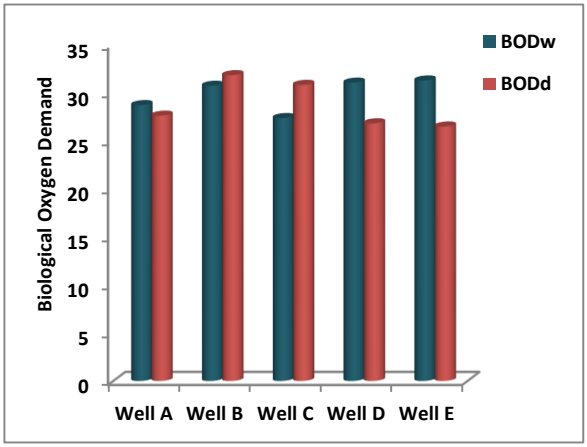



**Figure 9: The BOD (mg/l) of the Samples**

Note: Subscript w = wet season, d = dry season

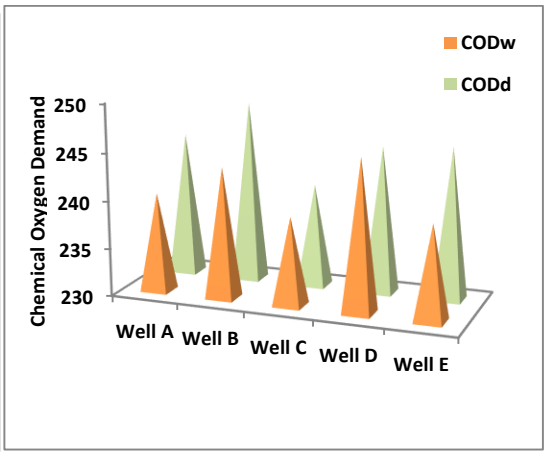



**Figure 10: The COD (mg/l) of the Samples**

Note: Subscript w = wet season, d = dry season

The $SO_4^{2-}$ values (Fig. 11) of the water samples ranged from 175.40 mg/l to 184.93 mg/l during wet season and 173.60 mg/l to 180.11 mg/l during dry season. All the samples of the

study area fall within the permissible limits of WHO standards which is 250 mg/l. The concentrations of sulphate recorded here are in agreement with similar study [13] but the values were higher than those of another finding in Accra (Ghana) showing sulphate concentration between 0.2 mg/l and 25 mg/l [7]. Sulphates naturally occur in groundwater which arises from the leaching of sulphur compounds either as sulphate minerals such as gypsum or sulphite as pyrite or from sedimentary rocks. Excessive intake of $SO_4^{2-}$ can lead to diarrhea, hydration and intestinal irritation, though no health based guideline has been fixed for $SO_4^{2-}$ [18].

The concentrations of $NO_3^-$ in the groundwater samples recorded (Fig. 12) during the wet season ranged from 43.86 – 48.71 mg/l and that of the dry season ranged from 18.84 – 28.00 mg/l which were generally within the WHO standards of <50 mg/l for drinking water, indicating that the groundwater may not pose any danger to human health [23].Nitrate is found in little amounts in natural waters and mostly it is of mineral origin, while most forms are coming from organic and inorganic sources, such as effluent discharge, domestic sewage, runoff from agricultural fields, and leachate from dumpsites. Higher concentration of nitrates (>50 mg/l) in water causes a disease called ‘‘Methaemoglobinaemia’’ also known as ‘‘Blue-baby Syndrome’’. This disease particularly affects infants that are up to 6-month-old [12].

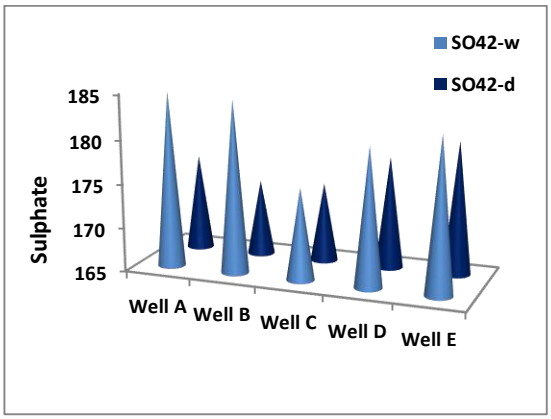



**Figure 11: The $SO_4^{2-}$(mg/l) values of the Samples**
Note: Subscript w = wet season, d = dry season

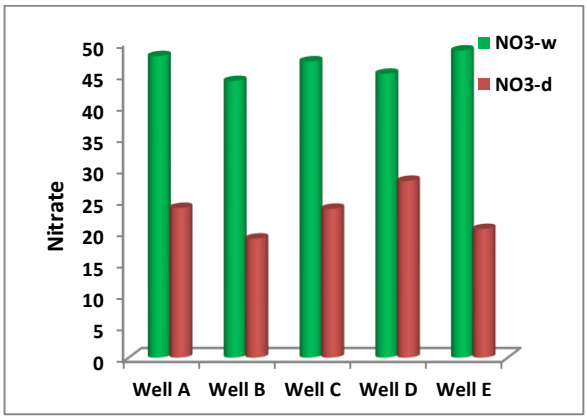



**Figure 12: The $NO_3^-$ (mg/l) values of the Samples**
Note: Subscript w = wet season, d = dry season

The chloride values (Fig. 13) of the groundwater samples ranged from 128.37 mg/l to 145.64 mg/l and 120.50 mg/l to 140.32mg/l during dry and wet seasons respectively. All of the $Cl^-$ concentrations of the water samples fell within the permissible limits of WHO standards of 250 mg/l. This could indicate that bulk of the solid waste received at the dumpsite is non-industrial, as chloride is major anion from food waste. The values recorded in this study are lower than that reported by Useh et al [18] but higher than the study carried out by Ugbajah et

al [14]. High concentrations of chlorides are added to the groundwater from the municipal wastes, which clearly indicate the impact of dumpsite leachate. Other sources include farm drainage and sewage effluents. The mean total bacteria counts (cfu/ml) detected in the water samples collected during wet and dry seasons are represented (Fig. 14).

The microbial counts were high and varied with location. The values ranged from 1.25 x $10^4$cfu/ml to 1.87 x $10^4$cfu/ml during wet season and from 1.25 x $10^4$ cfu/ml to 1.71 x $10^4$cfu/ml during dry season. The total bacteria counts recorded from the two seasons exceeded the WHO standards of 1.0 × $10^2$cfu/ml which is the acceptable limits of total bacterial counts for drinking water [24].

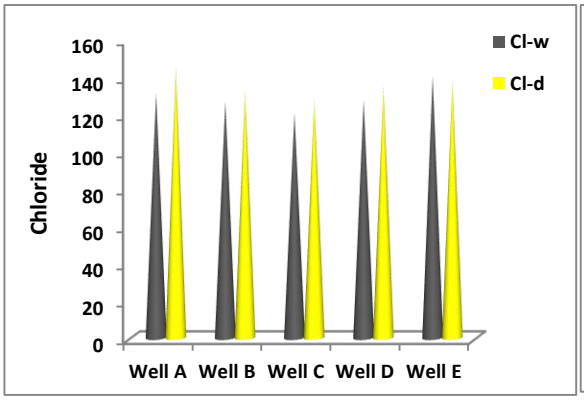



**Figure 13: The Chloride (mg/l) values of the Samples**
Note: Subscript w = wet season, d = dry season

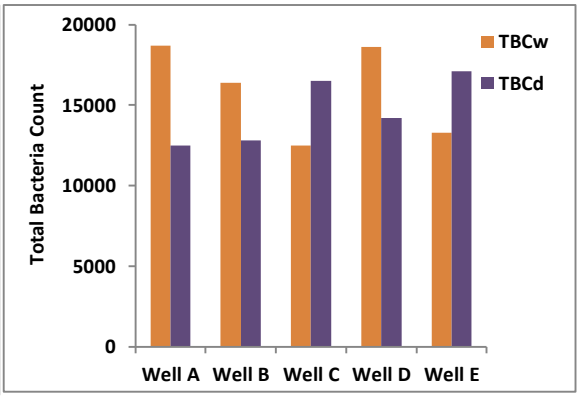



**Figure 14: The TBC (cfu/ml) of the Samples**
Note: Subscript w = wet season, d = dry season

The total coliform counts from two seasons as presented (Fig. 15) showed that the lowest coliform count of 7.00 MPN/100ml was observed in Well E while the counts of 8.20 MPN/100ml was recorded in Well D for the wet season and the lowest coliform count of 6.40 MPN/100ml was recorded in Well E while the highest counts of 8.35 MPN/100ml was observed in Well B for the dry season. The results of the total coliform counts in all the water samples studied exceeded the WHO standards of 0 coliform/100 ml bacteria in water.

The faecal coliform counts for the various sampling sites were presented (Fig. 16). Faecal coliform counts ranged from 1.19 MPN/100 ml obtained from Well A to 1.42 MPN/100 ml in Well D for the wet season. No faecal coliform was detected in Well C and E. For the dry season, the faecal coliform counts were recorded for only Well B (1.40 MPN/100 ml) and Well C (1.36 MPN/100 ml). None was recorded in Well A, D and E. From the results, it was revealed that some of the groundwater samples studied met the WHO (0 coliform/100 ml) standards for faecal coliform in both seasons.

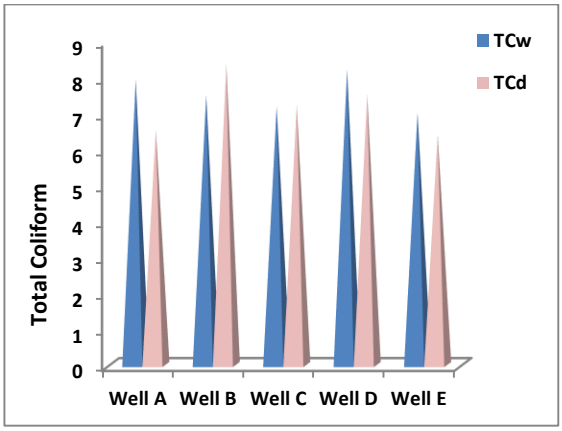



**Figure 15: The TC (MPN/100ml) of the Samples**

Note: Subscript w = wet season, d = dry season

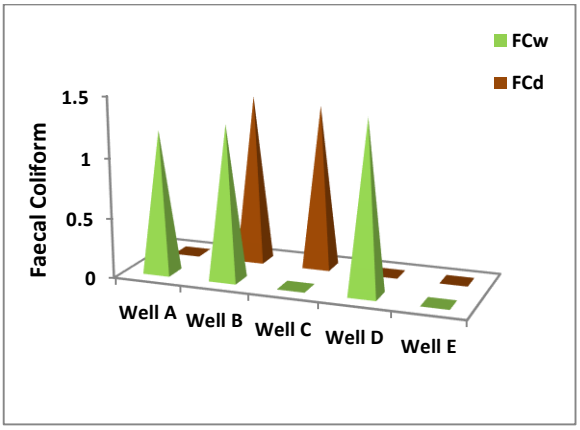



**Figure 16: The FC (MPN/100ml) of the Samples**

Note: Subscript w = wet season, d = dry season

## ASSESSMENT OF THE RELATIONSHIP OF THE ANALYSED PARAMETERS

Tables 3 and 4 display the results of the correlation analysis of the examined groundwater parameters. This analysis was carried out in order to know the relationships that exist between the different parameters. The result obtained showed that positive and negative correlations existed between the examined parameters. Statistically, a high positive correlation (> +0.65) indicates that a change in one parameter will cause a similar change in the other parameter and a high negative correlation (< -0.65) indicates that a change in one parameter will cause a change in the other parameter but in the opposite direction. From table 3, a strong positive significant relationship was observed between TDS versus BOD ($r$ = 0.978, $p$< 0.01), TDS versus FC ($r$ = 0.960, $p$<0.01) and BOD versus FC ($r$ = 0.978, $p$ = 0.01) inferring that they could be from similar source. Further, a moderately positive significant correlation was seen between temperature versus TC in the correlation matrix ($r$ = 0.935, $p$< 0.05). More so, a strong negative significant correlation was observed between pH versus Chloride ($r$ = -0.938, $p$ = 0.05), TDS versus Sulphate ($r$ = -0.928, $p$ = 0.05) and BOD versus Sulphate ($r$ = -0.907, $p$ = 0.05). Also, from Table 4, a moderately positive significant relationship was observed between TBC versus TC ($r$ = 0.937, $p$ = 0.05) and TBC versus FC ($r$ = 0.940, $p$ = 0.05). Then, a strong negative significant correlation was seen between temperature versus pH ($r$ = -0.936, $p$ = 0.05) and pH versus TH ($r$ = -0.883, $p$ = 0.05).

Table 3: Pearson correlation coefficient matrix for the Samples during Dry Season

| | Temperature | pH | EC | TDS | TH | DO | BOD | COD | Sulphate | Nitrate | Chloride | TBC | TC | FC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1.000 | | | | | | | | | | | | | |
| pH | 0.818 | 1.000 | | | | | | | | | | | | |
| EC | 0.117 | -0.266 | 1.000 | | | | | | | | | | | |
| TDS | 0.575 | 0.618 | -0.247 | 1.000 | | | | | | | | | | |
| TH | -0.127 | 0.155 | 0.269 | 0.265 | 1.000 | | | | | | | | | |
| DO | 0.284 | 0.502 | 0.215 | -0.262 | 0.352 | 1.000 | | | | | | | | |
| BOD | 0.475 | 0.531 | -0.393 | .978** | 0.141 | -0.409 | 1.000 | | | | | | | |
| COD | 0.46 | -0.031 | 0.139 | -0.027 | -0.85 | -0.337 | 0.017 | 1.000 | | | | | | |
| Sulphate | -0.346 | -0.317 | 0.046 | -.928* | -0.395 | 0.44 | -.907* | 0.105 | 1.000 | | | | | |
| Nitrate | -0.03 | -0.017 | 0.753 | -0.289 | 0.69 | 0.67 | -0.467 | -0.458 | 0.169 | 1.000 | | | | |
| Chloride | -0.595 | -.938* | 0.433 | -0.679 | -0.354 | -0.429 | -0.615 | 0.322 | 0.419 | 0.039 | 1.000 | | | |
| TBC | -0.239 | 0.294 | -0.651 | -0.236 | 0.105 | 0.514 | -0.2 | -0.535 | 0.448 | -0.051 | -0.446 | 1.000 | | |
| TC | .935* | 0.732 | 0.081 | 0.795 | -0.038 | -0.004 | 0.718 | 0.417 | -0.643 | -0.146 | -0.573 | -0.416 | 1.000 | |
| FC | 0.481 | 0.646 | -0.505 | .960** | 0.188 | -0.26 | .978** | -0.094 | -0.835 | -0.446 | -0.752 | 0.001 | 0.681 | 1.000 |

*. Correlation is significant at the 0.05 level (2-tailed). **. Correlation is significant at the 0.01 level (2-tailed). '-' sign denoted negatively correlated

Table 4: Pearson correlation coefficient matrix for the Samples during Wet Season

| | Temperature | pH | EC | TDS | TH | DO | BOD | COD | Sulphate | Nitrate | Chloride | TBC | TC | FC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Temperature | 1.000 | | | | | | | | | | | | | |
| pH | -.936* | 1.000 | | | | | | | | | | | | |
| EC | 0.636 | -0.693 | 1.000 | | | | | | | | | | | |
| TDS | 0.225 | -0.106 | -0.135 | 1.000 | | | | | | | | | | |
| TH | 0.857 | -.883* | 0.293 | 0.371 | 1.000 | | | | | | | | | |
| DO | 0.616 | -0.609 | 0.643 | 0.662 | 0.514 | 1.000 | | | | | | | | |
| BOD | 0.354 | -0.467 | -0.206 | 0.532 | 0.778 | 0.313 | 1.000 | | | | | | | |
| COD | 0.714 | -0.545 | 0.045 | 0.757 | 0.782 | 0.574 | 0.614 | 1.000 | | | | | | |
| Sulphate | -0.014 | 0.019 | -0.686 | -0.061 | 0.343 | -0.558 | 0.54 | 0.25 | 1.000 | | | | | |
| Nitrate | -0.247 | -0.024 | 0.266 | -0.853 | -0.26 | -0.391 | -0.266 | -0.803 | -0.096 | 1.000 | | | | |
| Chloride | -0.025 | -0.262 | -0.178 | -0.294 | 0.371 | -0.266 | 0.618 | -0.162 | 0.569 | 0.555 | 1.000 | | | |
| TBC | 0.647 | -0.459 | -0.056 | 0.041 | 0.613 | -0.085 | 0.263 | 0.65 | 0.598 | -0.388 | -0.007 | 1.000 | | |
| TC | 0.815 | -0.604 | 0.252 | 0.105 | 0.637 | 0.184 | 0.136 | 0.701 | 0.285 | -0.425 | -0.219 | .937* | 1.000 | |
| FC | 0.55 | -0.303 | -0.22 | 0.329 | 0.557 | 0.007 | 0.32 | 0.788 | 0.573 | -0.669 | -0.174 | .940* | 0.875 | 1.000 |

*. Correlation is significant at the 0.05 level (2-tailed). '-' sign denoted negatively correlated

Many other relationships between various quantitative variables were also seen with the least correlation values. The correlations were more significant in the dry season compared to the rainy reason. These results of correlation can prove useful in understanding the relationships between the physicochemical and biological properties of the groundwater samples.

## ASSESSMENT OF THE WATER QUALITY

The quality of groundwater under consideration in respect of drinking purpose has been established based on the WHO guidelines for drinking water. Fig. 17 summarized the computed WQI of the collected groundwater samples for the two seasons. WQI was calculated in order to know the quality of each groundwater sample. The calculated WQIs were compared with the WQI based on classification (according to Table 1) and all were found to fall within the category of 'unsafe for drinking' class since the values recorded for both seasons were >300. The WQI for all the groundwater samples indicated that the dumpsite leachate had great impact on the quality of the groundwater.

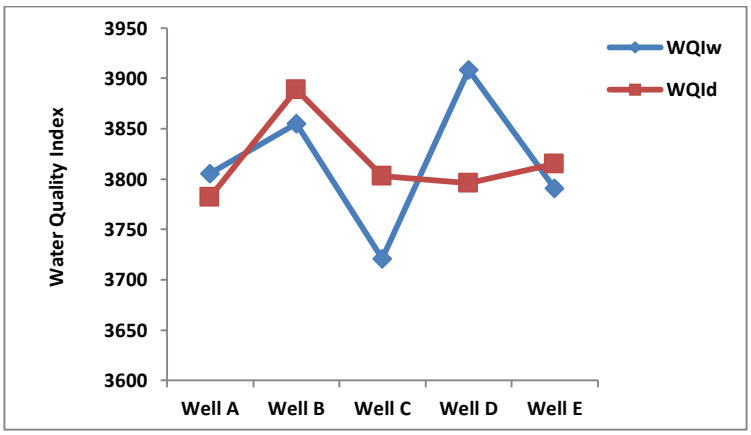



**Figure 17: The Water Quality Index of the Samples**

Note: Subscript w = wet season, d = dry season

## CONCLUSION

The effect of open dumpsite on groundwater quality has been examined using Mpape dumpsite as a case study. The results obtained for the groundwater samples were compared with the World Health Organisation standards for drinking water. The results indicated that the groundwater in the study area was acidic and hard in nature and the BOD, COD and TBC of the samples did not meet the WHO required standards, implying that the groundwater in the study area was severely contaminated with organics. According to the computed Water Quality Index, the groundwater samples under consideration were unsafe for drinking which is critical to human health and so needs urgent attention and treatment.This suggests that the

dumpsite leachate had great impact on the quality of the groundwater. Uncontrolled increase in refuse dumping near the water bodies may worsen the physicochemical and microbiological status of groundwater. If these scenarios continue, pollution may worsen and pose potential health risks in the future. The present study provided a baseline water quality status of the groundwater in Mpape, Abuja and could serve for future water quality assessments.

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