Physico-Chemical Properties and Heavy Metals Content of Groundwater around a Municipal Dumpsite in Gombe, Nigeria

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Abstract: ***The study examined the physico-chemical properties and heavy metals content of groundwater samples around a municipal solid waste dumpsite in Gombe, Nigeria. The samples were collected twice during the wet and dry seasons 2015. The samples were analysed for the following parameters: pH, temperature, turbidity, conductivity, salinity, Dissolved oxygen (DO), Chemical oxygen demand (COD), Biochemical oxygen demand (BOD_5), Total dissolved solids (TDS), Total suspended solids (TSS), anions (PO_4^{3-}, NO_2^-, NO_3^-, SO_4^{2-}, Cl^-, NH_4^+-N) and heavy metals (Fe, Mn, Co, Zn, Cu, Cr, Cd, Pb). The results of the study revealed that most of the physical parameters recorded increased in content during the wet season over the dry season, due to the surface run off from storm water, while the chemical parameters increased during dry season and most of the parameters recorded in both seasons were below the WHO international standards for drinking water, except for high PO_4^{3-} content (1.13 to 2.17 mg/L) recorded for the water samples in both seasons and Cr (0.01 to 1.2 mg/L) which exceeded the WHO permissible limit of 0.1 mg/L and 0.05 mg/L respectively. The water samples recorded significant increase ($P<0.05$) in Fe, Cr, Mn and significant decrease in SO_4^{2-} contents during the dry season.***

Keywords: Municipal solid waste, Dumpsie, Groundwater, Physico-chemical parameter, Heavy metal

1. Introduction

Rapid increase in population and industrialization in Nigeria have resulted in a dramatic increase in the generation of municipal solid waste (MSW). It includes domestic as well as commercial waste that accounts for a relatively large part of the total solid waste in developing countries. Municipal solid wastes (MSW), commonly known as trash or garbage, are the solid wastes generated from different municipals. Some of these wastes have been proved to be extremely toxic and infectious. Municipal solid waste heaps dot several parts of major Nigerian cities blocking roads, alleys and pavements [1]. Municipal Solid Waste is useless unwanted material discharged as a result of human activity. Most commonly, they are solids, semi solids or liquids in containers thrown out of houses, commercial or industrial premises [2].

Physical, chemical and biological processes occurring simultaneously at the municipal solid waste dumpsites result in waste decomposition as well as generation of leachates and landfill gas. Chemically contaminated leachates are one of the byproducts in landfill degradations reactions. One of the severe problems associated with the open dumps is infiltration of leachates into surrounding environment, with subsequent contamination of land and water [3-4]. In recent times, the impact of leachate on groundwater and other water resources has attracted a lot of attention because of its overwhelming environmental significance. Leachate migration from wastes sites or landfills and the release of pollutants from sediments (under certain condition) pose a high risk to groundwater resource if not adequately managed [5].

It is essential to protect soil, surface and groundwater contamination due to leachates percolation in and around the dumpsite [6]. Groundwater is an important source of drinking water for human being. It contains over 90% of the fresh water resources and is an important reserve of good quality water. Groundwater, like any other water resource, is not just of public health and economic value; it also has an important ecological function [7]. Protection of groundwater is a major environmental issue since the importance of water quality on human health has attracted a great deal of interest lately [8-10].

However, this research work examined the groundwater (drinking water) quality around a municipal solid waste dumping site at Gombe metropolis, with a view of creating environmental awareness for both the Government and the public about the effect of municipal solid waste.

2. Materials and Methods

Study area

The study area is Gombe metropolis, the capital of Gombe state, situated in the North-Eastern part of Nigeria. It is located on latitude 10°17′05.88"N and longitude 11°10′36.78"E. The LGA has an area of 52km^2 and a population of 266,844 persons according to 2006 population census. Today the population is projected to be 399,531 persons using 3.2% growth rate [11]. It is characterized by a tropical climate with two distinct seasons; a rainy season (May-October) and a dry/harmattan season (November-April). Based on the vegetation classification of Nigeria, the study area falls into Sudan savanna climate. The monthly mean temperature records show a range from 18 °C to 39 °C, with an average annual rainfall of 850 - 954mm [12]. The relative humidity ranged from 70% to 80% in August, and decrease to 15 to 20% in December. The geology Gombe is part of the central highland with flat landscape [13]. The open dumpsite was originally an abandoned land and it been in existence since 1998.

Figure 1: Map of Gombe metropolis showing Dump site. Source: Google Map (2015).

Sample Collection

Water samples were collected from three different boreholes whose depth varied from 20-35m, around the dumpsite twice a month for period of three months in the wet season and another period of three months in the dry season into 500 ml sterile bottles. A total of thirty six different samples were collected for the study as shown in fig 1. The water samples are chemically analyzed. The analysis of water sample was done using procedure of standard methods.

Physiochemical Analysis

pH and conductivity, were directly measured on site using a portable multipurpose field meter WTW pH Electrode. Total dissolved solids (TDS) and Total suspended solids (TSS) were determined gravimetrically. Dissolved oxygen (DO), Chemical oxygen demand (COD), Biological oxygen demand (BOD_5) and chlorides (Cl^-) were determined by titrimetric method. Turbidity was determined with a HACH 2100P Turbidity meter. Nitrate, nitrite, sulphate, phosphate and ammonium nitrogen contents were colorimetrically analysed using DR890 Colorimeter. Heavy metals (Fe, Mn, Co, Zn, Cu, Cr, Cd, Pb) were determined using Atomic absorption Spectrophotometer (AAS, Unicam 969).

Data Analysis

The data obtained from this study were analysed using SPSS software version 20. The mean values were used to compare with the WHO (2006) standards whereas the independent t-test values were used to compare the mean values obtained during the wet season with values obtained during the dry season at $P<0.05$.

3. Results and Discussion

The results for the various physico-chemical parameters and heavy metals content obtained in the water samples from the boreholes in Gombe Metropolis are presented in Tables 1 and 2. The pH of the water samples ranged from 5.59 - 6.09 during wet season and 5.40 - 5.67 during dry season. The mean pH value in all the samples during the wet season was slightly increased (fig 2). Generally the pH values obtained were slightly below the WHO standard of 6.5 - 8.5 (WHO, 2006). This indicates that the borehole water samples were slightly acidic during both wet and dry seasons. These findings are in accordance with that of Ayers et al. [15] and with previous research reported by Ahmed et al. [16] on the groundwater in Gombe shown similar trend in the acidic nature of groundwater. Turbidity stems from the reduction of transparently due to the presence of percolate matter such as clay silt, finely divided organic matter etc. The turbidity values obtained in this study ranged from 0.48 - 1.25 NTU during wet season, while it ranged from 0.62 - 0.73 NTU during dry season, are all within (WHO, 2006) limits of 5 NTU. However the turbidity values were generally lower during the dry season. The increased values during the wet season could be attributed to surface ran off and erosion carrying soil/silt and partially dissolved/un-dissolved organic matters [17]. Conductivity indicates the presence of dissolved solids and contaminates especially electrolytes but does not give inspiration about specific chemicals. The conductivity of the water samples from the boreholes varied from 37.40 - 62.90 µS/cm during wet season and 42.33 - 47.80 µS/cm during dry season. The conductivity of the water samples was within the acceptable standard for drinking water. This reveals the presence of low dissolved inorganic species or total concentration of ions.

The results of DO obtained in this study ranged from 5.13 - 6.0 mg/L during wet season and 5.34 - 5.77 mg/L during dry season. The threshold value for DO is 4.0 mg/L for drinking water. This observation is in line with what was reported by Jonathan et al. [18]. The BOD_5 values obtained ranged from 0.50 - 0.51 mg/L during dry season and 0.67 - 0.74 mg/L during wet season. The samples were quite below the permissible limits of 5 mg/L in both seasons, which represent the amount of oxygen that microbes need to stabilize biologically oxidizable matter. The COD values obtained ranged from 0.07 - 0.08 mg/L and 0.09 - 0.11 mg/L during wet and dry season respectively, were quite below permissible limit of 250 mg/L. These findings are lower than thus reported by Odiba et al. [19]. The test is commonly used to indirectly measure the amount of organic compounds in water. The Total suspended solid (TSS) measures the physical observable dirtiness of a water resource; are those solids which can be filtered out on an asbestos mat or filter papers, i.e, suspended solids are non filterable solids. The TSS obtained varied from 0.36 - 0.38.11mg/L during wet season and 0.40 - 0.45 mg/L during dry season was within acceptable limit. The Total dissolved solids (TDS) are an indication of the degree of dissolved substances such as metal ions in the water. The TDS results obtained in study ranged from 51.17 - 59.30 mg/L during wet season and 51.27 - 53.30 mg/L during dry season. This observation is in line with what was reported by Olatunji et al. [20]. The TDS was within the acceptable standard of 500 mg/L from all the water samples in the season (WHO, 2006). The higher values obtained during the wet season may be due to surface run off.

Table 1: Physico-chemical parameters of the groundwater samples during wet and dry seasons

	Seasons	Wet season			Dry season		
S/No	Parameters	BH1	BH2	BH3	BH1	BH2	BH3
1	pH	6.09 ± 0.30	6.03 ± 0.34	5.69 ± 0.17	5.53 ± 0.24	5.67 ± 0.17	5.40 ± 0.33
2	Turbidity	0.48 ± 0.19	0.75 ± 0.19	1.25 ± 0.54	0.65 ± 0.12	0.62 ± 0.18	0.73 ± 0.16
3	Conductivity	62.9 ± 3.83	37.4 ± 4.79	46.0 ± 5.0	47.8 ± 3.39	46.17± 4.77	42.33± 4.26
4	Salinity	0.22 ± 0.08	0.18 ± 0.09	0.19 ± 0.07	0.65 ± 0.03	0.50 ± 0.06	0.59 ± 0.01
5	DO	5.93 ± 0.42	6.00 ± 0.20	5.13 ± 0.62	5.77 ± 0.61	5.73 ± 0.37	5.43 ± 0.37
6	BOD_5	0.09 ± 0.03	0.11 ± 0.06	0.11 ± 0.09	0.07 ± 0.01	0.07 ± 0.01	0.08 ± 0.01
7	COD	0.68 ± 0.15	0.67 ± 0.32	0.74 ± 0.74	0.51 ± 0.07	0.50 ± 0.05	0.50 ± 0.02
8	TSS	0.40 ± 0.36	0.31 ± 0.13	0.45 ± 0.26	0.37 ± 0.04	0.38 ± 0.08	0.36 ± 0.02
9	TDS	55.16±0.72	59.30±6.47	51.17± 8.19	53.3 ± 1.71	52.3 ± 1.63	51.27± 1.49
10	NO_3^-	4.53 ± 0.54	4.27 ± 0.18	4.67 ± 0.47	6.10 ± 0.70	5.60 ± 0.59	6.20 ± 0.59
11	NO_2^-	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.01
12	NH_4^+-N	0.38 ± 0.04	0.31 ± 0.07	0.38 ± 0.04	0.62 ± 0.14	0.66 ± 0.14	0.59 ± 0.19
13	PO_4^{3-}	1.95 ± 0.11	2.17 ± 0.13	1.82 ± 0.29	1.19 ± 0.45	1.13 ± 062	1.15 ± 0.57
14	SO_4^{2-}	3.32 ± 0.62	3.37 ± 0.53	3.55 ± 0.49	0.89 ± 0.41	1.45 ± 0.41	1.36 ± 0.79
15	Cl^-	3.09 ± 0.13	3.17 ± 0.32	2.97 ± 0.10	4.25 ± 0.67	4.08 ± 0.52	3.80 ± 0.74

All the parameters expressed in mg/L, except pH, Turbidity(NTU) and EC (µS/cm). BH = Borehole

The nitrate content of water samples in the study ranged from 4.27 - 4.67 mg/L during wet season and 5.60 - 6.20 mg/L during dry season. The concentration of nitrate in the study area was within the recommended standard of 50 mg/L (WHO, 2006). This suggests that the water samples were not affected by leachate from the body of the dumpsite. The water samples recorded low nitrite concentrations with the value of 0.01 mg/L in both seasons. The value was however low when compared with a similar study done on groundwater in Gombe, Nigeria [16]. There was no significant difference ($p>0.05$) in nitrite concentrations in water samples during the wet and dry seasons. The permissible limit for ammonium ions in drinking water is 0.5 mg/L. The ammonium ion concentrations obtained in this study during wet season ranged from 0.31 - 0.38 mg/L were below permissible limit, while during the dry season the values were slightly increase from 0.59 - 0.66 mg/L above the permissible limit. This might indicate the presence of nitrogenous contaminants which could have come from human faeces. The phosphate obtained in both seasons which ranged from 1.13 - 1.19 mg/L and 1.82 - 2.17 mg/L during dry and wet season respectively, the values of phosphate were above the permissible limit. This observation is in line with what was reported by Odiba et al. [19]. This may suggest the presence of high phosphate bearing rocks in the groundwater aquifers. The sulphate concentrations recorded ranged from 0.89 - 1.45 mg/L and 3.32 - 3.55 mg/L during dry and wet seasons respectively. The values recorded in this study are lower than that reported by Ahmed et al. [16]. All the samples in both seasons were below the permissible limit of 250 mg/L. Chlorides are mineral salts and therefore are not affected by biological actions. The chloride concentration of 250 mg/L and above, impart a particular taste to water. In the present study, chloride ion content of the groundwater samples obtained ranged from 2.97 - 3.09 mg/L during wet season and from 3.80 - 4.25 mg/L during dry season. The values recorded in this study however, are lower than that reported by Odiba et al. [19]. The chloride content was within the WHO recommended standard of 250 mg/L (WHO, 2006).

The concentrations of iron obtained in this study (Tables 2), ranged from 0.01 - 0.04 mg/L during wet and dry seasons. There was no significant increase at ($p>0.05$) in iron concentrations in water samples during the dry season. Lead, cadmium and nickel were below the detected level in the water samples in both seasons. The concentration of zinc obtained in this study in both seasons, ranging between 0.01 - 0.05 mg/L during wet and dry seasons. The chromium concentrations in this study ranged from of 0.01 - 0.33 mg/L during wet season and 0.01 - 1.2 mg/L during dry season. The copper concentrations recorded in the water samples with values of 0.01 - 0.04 mg/L during wet and dry season (fig 3). The manganese concentrations recorded in this study was 0.01 mg/L during wet season and ranged from 0.01 - 0.03 mg/L during dry season. The values recorded in this study are lower than that reported by Ahmed et al., [16]. There no significant increase at ($p>0.05$) in the concentration of manganese in water samples during the dry season.

Table 2: Heavy metals content in groundwater samples during wet and dry season

	Seasons	Wet season			Dry season		
S/No	Parameters	BH1	BH2	BH3	BH1	BH2	BH3
1	Cd	ND	ND	ND	ND	ND	ND
2	Cu	ND	ND	ND	0.04 ± 0.02	0.01 ± 0.01	ND
3	Mn	0.01 ± 0.01	ND	ND	0.03 ± 0.01	0.02 ± 0.01	0.01 ± 0.01
4	Fe	0.02 ± 0.01	0.01 ± 0.01	ND	0.04 ± 0.01	0.04 ± 0.03	0.03 ± 0.01
5	Pd	ND	ND	ND	ND	ND	ND
6	Zn	0.03 ± 0.01	ND	ND	0.05 ± 0.01	0.02 ± 0.01	0.01 ± 0.01
7	Ni	ND	ND	ND	ND	ND	ND
8	Cr	0.33 ± 0.07	0.05 ± 0.01	ND	1.20 ± 0.02	0.13 ± 0.03	ND

All the parameters expressed in mg/L. BH = Borehole. ND = No detection

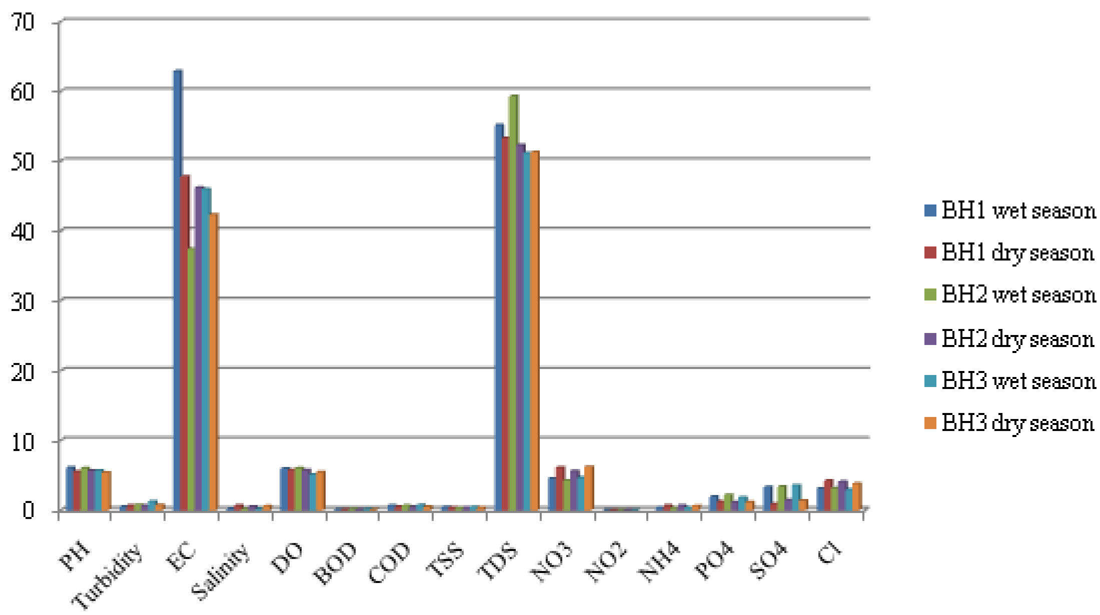

Figure 2: Seasonal variation of Physico-chemical parameters of the groundwater samples

Paper ID: ART20161075 DOI: 10.21275/ART20161075

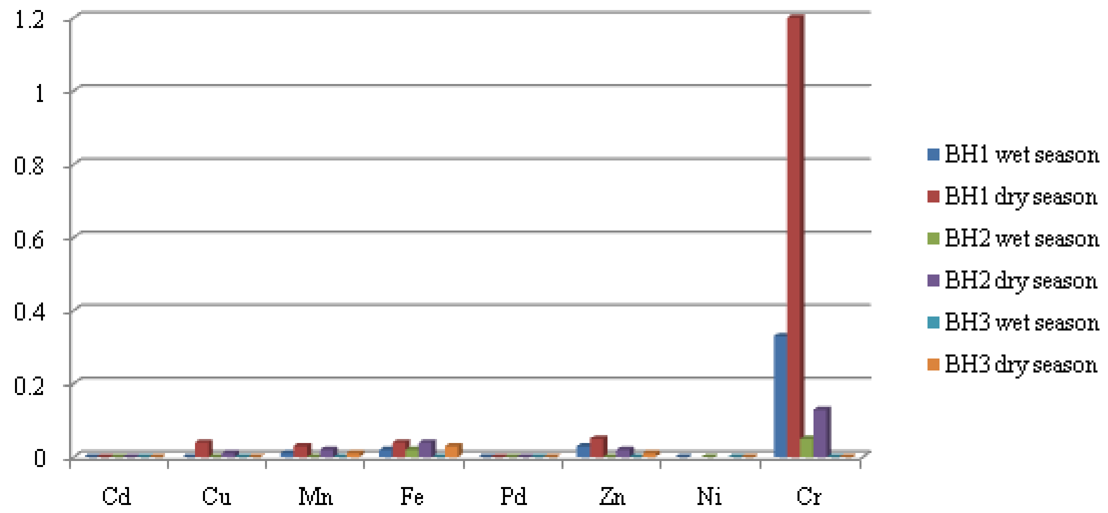

Figure 3: Seasonal variation of heavy metals concentration of the groundwater samples

4. Conclusion

The results of this study assessed the of physico-chemical and heavy metal contents of groundwater around a municipal solid waste. The analysis carried out by taking certain important parameters like pH, TSS, TDS, BOD_5, COD, Nitrate, Cl^-, PO_4^{3-} and heavy metals. The results of the study revealed that most of the parameters analysed, were not above the limit of WHO international standard for drinking water in both seasons, except for high PO_4^{3-} content (1.13 to 2.17 mg/L) recorded for the water samples in both seasons and Cr (0.01 to 1.2 mg/L) which exceeded the WHO permissible limit of 0.1 mg/L and 0.05 mg/L respectively.

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