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Determination of Heavy Metal Content and Physicochemical Parameters of Ground and Surface Water near Landfills in Makurdi Metropolis, Benue State, Nigeria

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ABSTRACT

This study was carried out to assess the quality of ground and surface water situated near landfills. Three groundwater (GW1, GW2 and GW3) as well as surface water samples (SW1, SW2, and SW2) near landfills were collected from different locations in Makurdi, Benue State, Nigeria. Some physicochemical parameters, namely, temperature, pH, electrical conductivity (EC), salinity, total dissolved solid (TDS) and turbidity, were determined in-situ, while BOD, COD, chloride, phosphate, nitrate, sulphate, chlorine and heavy metals (lead, iron, manganese, cobalt, nickel, chromium, zinc, arsenic, mercury, and cadmium) were analysed in the laboratory in accordance with standard procedures. The results for physicochemical parameters determined were below acceptable standard limits (WHO, EPA, NSDWQ), except for electrical conductivity value of GW1 of 1274 µS/cm, phosphate with value >0.1mg/L in all water samples except for SW1 and nitrate with high values of 56mg/L in GW1. The results obtained for heavy metals followed the trend Fe>Pb>Hg>Cr>Co>Ni>Cd>Zn>Mn>As. The results showed that the open dumpsites have a significant impact on the groundwater with the most significant impact on GW1 and surface water within its vicinity. It is also revealed that proximity of water sources to landfill sites has significant effect on level of its pollution.

Keywords: Groundwater, Heavy metal, Landfills, Physicochemical parameters, Surface water.

INTRODUCTION

The sustenance of life depends greatly on water. Therefore, the demand for portable water increases continually in line with world population growth. Water shortage or its pollution can cause severe decrease in productivity and deaths of living species [1-3]. Recently cities have undergone unprecedented growth in population through migration from rural areas. Increase in population has led to increased generation of waste and reduced area of land for waste disposal.

These waste lead to the generation of toxic fluids in form of leachates which flow to the nearest water course.

One of the most common waste disposal methods is unsanitary landfilling (open dumpsite) due to its favorable economics. It may lead to the sources of groundwater and soil pollution. The contamination of the soil, water, and air with heavy metal even at low concentration are known to have potential impact on the environment and human health is hazardous. Majority of the municipal solid waste disposal sites in Nigeria are still open dumps. Solid waste disposal poses a threat to ground and surface water quality. Leachate generally comes into existence during dissolution in the landfills. The environment can be polluted by the leachate which occurs at the end of decayed solid waste, mixed with precipitates of surface water. As a result, surface water collection systems (rivers, creeks, and lakes), groundwater reservoirs and different soil layers have been seriously polluted by leachate [4].Areas near landfill (open dumpsites) have a greater possibility of groundwater contamination because of the potential pollution source of leachate originating from the nearby site. Such contamination of groundwater resource poses a substantial risk to local resource user and to the natural environment. The impact of landfill leachate on the surface and groundwater has given rise to several studies in recent years [5-9].

A number of scholars [10-13] had examined the possible water contamination around municipal landfills by using microbiological examination and physicochemical analysis of leachate and ground water. The focus of these scholars has been to find out the impact of landfills on ground water quality, quantitative analysis of level of water contamination and the identification of possible threats to the local environments and residents as well.

Groundwater is the major source of potable water supply in the study area and its contamination is a major environmental and health concern. Since the quality water is directly related to health and is important for determination of water utility, it is very essential and important to test the quality of the water before it is used for drinking, domestic, agricultural or industrial purposes.

The utility of river water for various purposes is governed by physicochemical and biological quality of the water [10]. Water for human consumption must be free from microorganisms and chemical substances in concentration large enough to cause environmental imbalance and disease.

At present, private borehole operators in Makurdi metropolis seam to sell untreated water to members of the teaming population in the area and so there is no quality standard that has been established in this area. Boreholes and hand dug wells which are located near waste dumps, latrines or soak away pit are likely to be contaminated by materials from these places [10].

The aim of this work is therefore to determine the concentration of heavy metals and physicochemical parameters of groundwater as well as surface water near dumpsites in Makurdi metropolis, Benue state, Nigeria.

EXPERIMENTAL

Site Description

Makurdi metropolis is the headquarters of Makurdi Local Government Area (LGA) which was created in 1976. Today, Makurdi serves as a dual purpose city as both local government headquarters and the state capital of Benue, within latitudes 7^0 45^0N and longitudes $8^0 26^0$E, $8^0 36^0$E. It is bounded in the North by Guma LGA; in the east by Gwer-West LGA; in the south by Gwer LGA and the west by Tarka LGA.

Makurdi metropolis, located in the river Benue valleys, experiences a tropical climate with two distinct seasons, wet and dry seasons. The annual rainfall in Makurdi is about 15 0mm.

River Benue is one of the major rivers in Nigeria. It is needed for domestic, industrial, and agricultural purposes and it is been subjected to waste from abattoirs, open dumpsites [14].

Sampling

Ground water samples were collected using 1L plastic bottles which has been cleaned by soaking in 10% nitric acid and rinsed three times with distilled water. The bottles were rinsed three times with groundwater to be sampled prior to filling and bottles labelled GW1-GW3. GW1 – hand dug well, a groundwater source situated around Wadata area. GW2- hand dug well, a groundwater source situated at Northbank area. GW3-borehole groundwater situated at Gyado villa area, Gboko road, Makurdi. All selected water sampling sites are located within close proximity with landfill (open dumpsites) sites, except for GW3-borehole groundwater situated at

Gyado villa area, Gboko road, Makurdi, which is the control sample due to farther location of landfill site (pollution source) as compared to the other sampling sites in this study.

Three different samples were collected from surface water along Wadata area (SW1), Northbank area (SW2) and Gyado villa area, Gboko road (SW3). Figure 1 is a map of the study area, Makurdi town, showing the respective sampling locations.

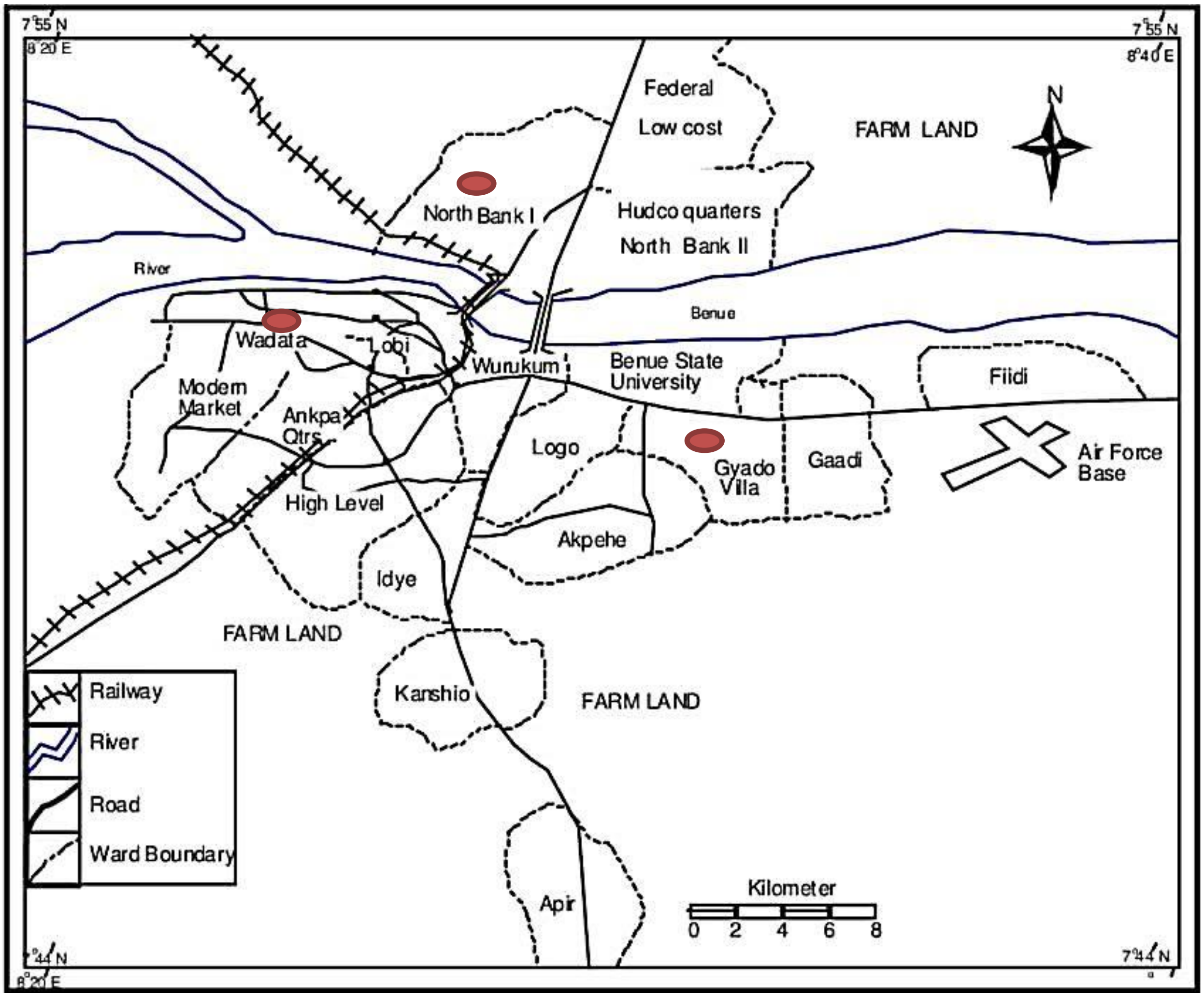

Figure 1: Map of Makurdi Town Showing the Study Areas (Benue State Ministry for Lands and Survey).

Analytical Methods

After sampling, the surface and groundwater samples were quickly transferred to the laboratory and stored at a temperature of 4 ^{o}C in a refrigerator. The analysis were carried out on water samples without delay in the laboratory based on the priority of the analysis parameters as prescribed by the standard methods for examination of water and wastewater [15]. The analyses covered physical and chemical parameters. The qualitative analyses were carried out at Ahmadu Bello University, Multi-User laboratory, Chemistry Department, Zaria, Kaduna State. The physical parameters tested were: odour, taste, colour, turbidity, electrical conductivity, salinity and temperature. Chemical parameters analysed were pH, total dissolved solids (TDS), total hardness, dissolved oxygen, biological oxygen demand (BOD), chemical oxygen demand (COD), sulphate, chloride, nitrate, phosphate. The analysis of heavy metal concentrations (Fe, Pb, Hg, Cr, Mn, Zn, Ni, Co, As, and Cd) of surface and groundwater samples were determined using fast sequential atomic absorption spectrophotometer AA240FS (AAS). The pH was determined using pH by direct measurement, analog mercury thermometer was used for temperature measurements, a HACH 2100A turbidimeter was used for turbidity determination and electrical conductivity, salinity and total dissolved solids were determined using conductivity meter with model No. sension 5 HACH instrument. The samples were also analysed in the water laboratories for total hardness, dissolved oxygen, biological oxygen demand, chemical oxygen demand, sulphate, chloride, nitrate, phosphate using standard methods for the examination of water [15].

RESULTS AND DISCUSSION

Physico-chemical Parameters

Inadequate control of open dumpsites where leachates generated is allowed to escape to the surrounding and underlying water body is a major threat to boreholes and hand dug wells. The chemical composition according to Akinbile *et al.* [10] depends in the nature of landfills, the leachate rates and age of dumpsite.

The odour, taste and colour of all surface water samples (SW1, SW2, SW3) and ground water samples (GW2 and GW2) showed indication of presence of pollutants as they were below permissible standards of water quality, while that of GW3 was in agreement with the required water quality standards of the Nigerian Drinking Water Standard Quality (NDWSQ) and WHO permissible limits for potable drinking water. These may be as a result of migration of leachates from open dumpsites to the water source, thereby causing dissolution of heavy metals that caused alteration in the aesthetic of water sources. The good quality of GW3 might be due to its distance from the pollution source (landfills or open dumpsites). This suggests the negative implication of situation of landfills proximately to water sources.

The temperatures for groundwater samples taken at sampling point ranged from 29 ºC to 27.6 ºC and that for surface water samples ranged from 30.7 ºC to 29.8 ºC.

The pH values of groundwater measured at the source (in-situ) ranged from 7.2 to 8.1. The values are consistent with the Nigerian Drinking Water Standard Quality and WHO permissible limits for potable drinking water. Samples GW1 had the maximum value of 8.101, followed by GW2 with 8.044 and then GW3 with 7.177. The pH of surface water ranged from 6.8 to 7.1. SW1 with 6.816, SW2 with 7.12, and SW3 with 7.06 (Table 1). The pH has no obvious effect on the consumers [16]. The normal pH of pristine water ranges from 6.5 to 8.5. pH values beyond this range is a strong indication of abnormality in the water [17].

The electrical conductivity (EC) of water is a reflection of the quantity of ionic constituents dissolved in it. Conductivity indicates the presence of dissolved solids and contaminants especially electrolytes but no indication about specific chemicals [14].

The obtained EC ranges from 1274 µS/cm to 326 µS/cm for groundwater samples, whereas the surface water samples have values that varied from 29.80 to 22.70 µS/cm. The maximum value of 1276 µS/cm was measured for GW1. The value is higher than the recommended standard by NSDWQ and WHO but below that of EPA for portable drinking water. GW2 has a value of672.0 µS/cm and GW3 326.0 µS/cm. GW1 with the highest value of EC is closest to the dumpsite. The high value recorded is probably an indication of the effect of leachate on its quality. The high level of EC may be attributable to percolation of leachate from unlined refuse dumpsite into the groundwater beneath it. For surface water sample, the low value of EC maybe as a result of absence of precipitation from landfills.

The concentration of TDS in water assists to know the quality and its salinity. The obtained concentration of TDS in groundwater in the study area vary between 326.0 mg/L and 630.0 mg/L, whereas those for surface water range between 13.6mg/L and 10.3mg/L. A high value of 630 mg/L was measured for GW1, followed by GW3 with 326.0mg/L and the least value of 156.6 mg/L for GW2 (Table 1).

Table 1: Physicochemical parameters of the sample

Parameters	**GW1**	**GW2**	**GW3**	**SW1**	**SW2**	**SW3**
Odour	Objection -able	Objection -able	Unobjection-able	Objection -able	Objection -able	Objection-able
Colour	Not clear	Not clear	Clear	Not clear	Not clear	Not clear
Taste	Not agreeable	Not agreeable	Agreeable	Not agreeable	Not agreeable	Not agreeable
Temperature (°C)	29 ºC	28.4 ºC	27.6 ºC	30 ºC	30.7 ºC	29.8 ºC
EC (µS/cm)	1274	326	672	29.8	26.2	22.7
Salinity (‰)	0.6	0.2	0.3	0.0	0.0	0.0
TDS (mg/L)	630	156.6	326	13.6	26.2	10.3
pH	8.101	8.044	7.177	6.816	7.127	7.066
Turbidity	10.0	12.0	6.0	80.0	426.0	87.0
BOD (mg/L)	144	192	150	150	168	180
COD (mg/L)	320	560	240	360	400	480
Chloride (mg/L)	225.00	14.08	40.50	195.20	240.60	950.0
Sulphate (mg/L)	72.0	27.0	53.0	1.0	2.0	0.0
Chlorine (mg/L)	0.02	0.04	0.01	0.00	0.11	0.11
Nitrate (mg/L)	56.00	0.43	0.00	0.87	1.25	1.02
Phosphate (mg/L)	1.85	0.12	0.14	0.00	0.35	0.39

According to WHO [18], high levels of TDS maybe responsible for reduction in the palatability of water, inflict gastrointestinal inconveniences in human and may also cause laxative effect particularly on transits. These TDS values tend to decrease with distance of groundwater wells from the refuse dumpsite along water flow paths. According to the work of Olaniya et al. [19] has established measureable high level of TDS concentration as an indication of contamination of groundwater near landfills. The salinity values were relative to TDS values of water samples. Samples with high TDS values also have high values of salinity. The maximum value of salinity recorded for GW1 was 0.6 ppt, followed by GW3 with 0.3 ppt, and the least with 0.2 ppt, while the values for surface water were all negligible. The turbidity values for groundwater range from 6.0 and 12.0, and the surface water 72.0 and 426.0, with SW2 having the maximum value of 426.0, SW with 87.0, and SW1 with the least 80.0. These indicate the presence of suspended colloidal particles or organic matter.

In terms of hardness, the groundwater samples in this study are predominantly soft test of hardness was not indicated. It has been known that consumption of water with calcium ion may lead to concretion in kidney and bladder stones and also cause irritation in the urinary passage [21].

The occurrence of nitrate may originate from different sources such as municipal waste disposal, engineered landfills and industrial waste waters. High concentration of nitrate is known to inhibit the distribution of oxygen within the human body [21-23].

The phosphate in GW is significantly above GW2, GW3, SW1, SW2, SW3, with the values for GW ranging from 1.9 to 0.12mg/L and for SW ranging from 0.00 to 0.4mg/L. The high values of phosphate in ground and surface water except for SW1 is a reflection of the impact of leachate. The phosphate content in GW1 may pose threat to groundwater. A minute amount of phosphate as low as 0.001mg/L results in water being slimy and also promotes the growth of algal [23]. The abundance of algal and slime in surface waters in SW2, SW3 underline this statement.

The range of concentration of sulphate in groundwater sample varied from 27.0 to 72.0 mg/L and was slightly higher in GW1 than the others. The obtained values are lower than the standard of 100 mg/L stipulated by NSDWQ [17] and 250 mg/L by WHO [18] for potable drinking water. On the other hand, the concentration obtained for the surface water samples are evidently lower than those of groundwater, this may be as a result of less migration of leachate from open dumpsites to surface water. The values range from 0.0 to 2.0 mg/L and essentially higher in SW2. High quantity of sulphate in water is dangerous as it causes dehydration and diarrhea in children [10].

The concentration of chloride were in the range of 8.40 to 225 mg/L and significant portion was found in GW1, whereas the measured values obtained for surface water varied from 40.50 to 240.50 mg/L (Table 1). The values are evidently low compared to the 250 mg/L standards stipulated by NSDWQ [17] and WHO [18] for potable drinking water. Higher chloride was utilized as proxy of pollution and as tracer for groundwater contaminants. Domestic effluents, fertilizers, septic tank and natural sources such as rainfall and dissolution of fluid inclusion are some sources that may contribute to high chloride concentration in groundwater pollution. According to WHO [18], high chloride is detrimental to people with heart diseases and kidney problems. Also chlorine concentrations are below the recommended standards of 5mg/L by WHO [18]. Chlorine is a disinfectant of water but large concentration can be hazardous to human health.

The BOD of the water samples was relatively low. In groundwater BOD values ranged from 144.0 to 192 mg/L, with maximum value in GW2 (192.0 mg/L), and GW3 (150 mg/L) and the least in GW1 with 144.0 mg/L. The amount of putrescible organic matter present in groundwater was relatively low, thereby showing not highly polluted water, whereas for surface water BOD ranged from 150 to 180.0 mg/L with maximum at SW3 (180 mg/L). BOD values are dependent on dissolved oxygen in water.

The COD of water expresses the quantity of oxygen that is equal to the organic matter content of it which is prone to oxidation by a strong oxidant. Consequently, COD can be utilized as a proxy for organic pollution in water. COD of the groundwater varied from 240 and 560mg/L, while those for surface water varied from 360 and 480mg/L. The maximum COD value was recorded in SW3 for surface water and GW2 for groundwater. The values reflect the presence of organic contaminants in both surface and ground water which may have been caused by leachate from waste dumpsite.

Heavy Metals

Among the heavy metals only iron (Fe^{2+}) and lead (Pb) had the highest concentrations, with values of iron ranging from 0.77 and 1.096 mg/L, while that of lead ranges from 0.78 and 1.084 mg/L (Table 2, figure 2). The colour of the groundwater was brownish compared to GW3 that was colourless. This however, conforms to Rowe *et al.* [24] findings that a change in colour often expected in groundwater which contains Fe^{2+}. This strongly indicates that leachates from the landfill may have impacted on the quality of GW1 and surface water. Also, high concentration values were obtained for nickel, chromium, cadmium, cobalt mercury in ground and surface water samples with values > than 0.1 mg/L which are above the permissible amount stipulated by WHO [18]. Minute concentrations of the following heavy metals were detected in the groundwater sample and are below the required standard for potable drinking water of NDSWQ [17] and WHO [18]. These heavy metals include manganese and zinc with maximum concentrations of 0.08 mg/L for zinc and 0.01 mg/L for manganese values (Table 2). Manganese was not detected in GW2 and GW3 as well as arsenic was not detected in any of the samples.

High concentration of heavy metals may pose threat to the quality of groundwater found near the dumpsite.

Table 2: Heavy metals concentration of the samples

Heavy metals	**GW1**	**GW2**	**GW3**	**SW1**	**SW2**	**SW3**
As	ND	ND	ND	ND	ND	ND
Pb	0.782	0.849	0.983	1.008	1.037	1.084
Mn	0.008	ND	ND	0.004	0.014	0.013
Ni	0.141	0.133	0.126	0.130	0.124	0.123
Zn	0.040	0.007	0.051	0.012	0.045	0.088
Fe	0.865	0.773	0.799	0.894	1.096	0.916
Co	0.090	0.096	0.130	0.165	0.148	0.174
Cr	0.186	0.297	0.241	0.217	0.260	0.199
Cd	0.023	0.018	0.022	0.025	0.020	0.022
Hg	0.444	0.161	0.083	0.238	0.131	0.098

ND- Not detected, unit is mg/L

The high concentrations of heavy metals in water samples is an indication of the effect of leachate from landfills as a result of biochemical as well as natural processes that take place in the landfills and infiltration into the vadoze zone, hence, polluting the ground and surface water in the vicinity along landfills. The low concentration of some heavy metals recorded in the study underpins the roles played by occurrence of organic soils and clayey soils underneath the municipal waste dumpsite in the sorption of heavy metals [21, 24-25].

CONCLUSION

This study conducted revealed that the concentration of waste materials in the landfill site had systematically polluted the ground and surface water over time. The effect of such pollution as determined from this study declined away from the polluting source (landfill or open dumpsite. Results of water analyses of all samples indicated presence of heavy metals. This implied that the contamination of the groundwater was more dependent on the proximity to the dumpsites. Smaller dependence has been attributed to the influence of topography, type, state of waste disposal systems and to some extent, hydrogeology of the area. However, results indicated poor sanitation and pose detrimental effects to humans and animals, if the surrounding well water and boreholes are used for domestic and agricultural activities. Water sources therefore require proper treatment as a result of high contamination of wells and boreholes. Health problems such as typhoid fever are imminent when such water is consumed.

Remedial measures suggested include protection of water sources, control of all land use polluting activities, and treatment of water before is used for consumption. Governmental environmental policies on the waste disposal and management should be enacted and strictly enforced. Landfills or dumpsites should be situated faraway from residential areas to minimize the pollution of nearby water sources such as; well waters, boreholes, streams and rivers. Proper handling of wastes and treatment before disposal are encouraged. Re-designing of sanitary landfill with clay or plastic liners to prevent leachate from getting to the water table, adoption of clean technology for recycling greenhouse gases emanating from the landfill is recommended.

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