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Soluble and particulate metal contaminants in some hand-dug wells in kaduna metropolis

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ABSTRACT

. Water samples were randomly collected within the months of July and August 2011 from hand-dug wells in Sabon Tasha, Kaduna metropolis, Nigeria. Physicochemical parameters (pH, TDS, DO, TSS, Temperature, Conductivity, Turbidity, Hardness, Chloride and Sulphate,) of the samples were analyzed using standard methods. The results show that the pH values were lower than the WHO acceptable range for drinking water, while all other parameters were within the acceptable limits. The concentrations of Ni, Fe, Pb, Mn and Cd in these samples were also determined as soluble and particulate metals using flame Atomic Absorption Spectrometry. The mean concentrations of Cd in both soluble and particulate phases (0.004343 and 0.0048 mg/l respectively) were above WHO maximum limit for drinking water, while those of Fe, Pb, Ni and Mn (0.00087-0.0038 mg/l for soluble and 0.00115-0.0063 mg/l for particulate) were below the limits.

Key Words: Heavy Metals, Particulate Phase, Soluble Phase, Groundwater.

INTRODUCTION

Water is one of the essentials that support all forms of plant and animal life [7]. It is generally obtained from two principal natural sources; Surface water such as rain water, lakes, rivers, streams, etc. and Ground water such as borehole water and well water [9,20]. The groundwater resources of many cities can be rendered unfit for consumption due to contamination both from point and non-point sources. Point sources such as landfills, septic tanks and oil storage tanks can release high concentrations of pollutants whose effects are generally limited to a localized domain within the groundwater system. Unlike point sources, the effects of non-point (diffuse) sources such as fertilizers, pesticides and urban runoff, are unavoidable and very difficult to control [11]. Groundwater quality comprises the physical, chemical, and biological qualities. The physicochemical parameters of groundwater include transparency, temperature, pH, Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Free Carbon Dioxide, Total Hardness, Chlorides, Phosphates and Nitrates [18]. Groundwater generally moves slowly. The movement of a contaminant within an aquifer depends on its physical, chemical, and biological properties. Therefore contamination often remains undetected for long periods of time making cleanup difficult, if not impossible. This often results in poor drinking water quality, loss of water supply, degraded surface water systems, high cleanup costs, high costs for alternative water supplies, and/or potential health problems [21]. It is possible to predict, to some degree, the transport within an aquifer of those substances that move along with groundwater.

In recent time, the magnitude of contamination of aquatic environment by heavy metals in Nigerian cities has increased tremendously [12].For instance, heavy metals, Cr, Yb, Cs, Sb, Lu, Fe, Sm, Dy, Pa and As among others were detected in the soil around the Ikot Abasi Aluminum Smelter Plant, Nigeria [3]. Diseases associated with unclean water and inadequate sanitation accounted for more than 70% of child mortality and morbidity in Nigeria [13]. In Sabon Tasha, a low income high density urban area in Kaduna State, Nigeria, residents depend largely on groundwater (mainly hand-dug well) for drinking and other domestic uses [14]. Like other urban areas of the country, the groundwater system in Sabon Tasha is also vulnerable to contamination from human and natural activities due to poor management of municipal solid wastes [23,11].

Heavy metals are elements having atomic weights between 63.546 and 200.590 and a specific gravity greater than 4.0. They exist in water in colloidal, particulate and dissolved phases [2] with their occurrence in water bodies being either of natural origin (e.g. eroded minerals within sediments) or of anthropogenic origin (eg. solid waste disposal) [8]. Some of the metals are essential to life eg. calcium [2]. However, high concentrations can cause serious health effects with varied symptoms depending on the nature and quantity of the metal ingested [1]. We embarked on this study to ascertain the degree of pollution in the underground water in Sabon Tasha and its impact on the water quality.

MATERIALS AND METHODS

Reagents
All chemicals used were of analytical grade and were used without further purification. Hydrochloric and nitric acids, lead nitrate, copper and zinc chlorides were purchased from BDH Chemical Company while iron and manganese sulfates, nickel and cadmium nitrates were purchased from Aldrich Chemical Company.

Sample Analysis
Thermometer, pH meter, conductivity meter, turbidity meter and DO meter were used to determine the values of temperature, pH, EC, turbidity and DO respectively. TDS was determined according to Kaduna State Water and Sanitation Agency method [10]. Heavy metal concentrations were determined using flame Atomic Absorption Spectrometry (AAS).

Sample Collection and Preservation
A total of sixty samples of underground water (hand-dug wells) were collected in plastic bottles from different sources in Sabon Tasha within three weeks between July and August, 2011. Within the period, three water samples were collected from each sampling point and made up to a gross sample. The bottles were sealed and kept in a cool place. A water level indicator was used to measure the depths of the wells and the average depths were found to be 5m and 9m for the shallow and deep wells respectively.

Analysis of Soluble Metal
Each water sample was filtered through 0.45µm membrane filter paper to remove the particulate metals. A portion (50-100 cm^3) of the sample was used to rinse the filter flask and then discarded. A portion (100 cm^3) of each filtrate was transferred into a beaker and acidified with concentrated HNO_3 to a pH of less than 2 to stabilize the metal content. The content was then evaporated on a hot plate to a volume of about 20 cm^3, allowed to cool and additional 5 cm^3 of concentrated HNO_3 was added. The content was covered with watch glass and heated on a hot plate to give a light coloured and clear solution. The beaker and watch glass were rinsed with deionized water, the sample was filtered and the volume was adjusted to 100 cm^3 with deionized water [6]. The metal concentrations were determined using flame Atomic Absorption Spectrometry (Buck Scientific Model 210).

Analysis of Suspended Metal
Each sample was filtered through a 0.45µm membrane filter. The residue and membrane filter were transferred into a 250 cm^3 beaker and 3 cm^3 concentrated HNO_3 was added. The content was covered with a watch glass and heated gently to dissolve the membrane filter and finally evaporate the water. Then, the solution was cooled and additional 3 cm^3 of concentrated HNO_3 was added. The solution was heated until a light colored digestate appeared, indicating a complete digestion. Then, 2 cm^3 of HCl was added and the content gently heated to dissolve any soluble materials. The beaker and watch glass were rinsed with deionized water and then filtered to remove insoluble materials that could clog the atomizer. Then the filtrate was diluted with 100 cm^3 of deionized water to a concentration within the

range of instrument [6]. The metal concentrations were determined using flame Atomic Absorption Spectrometry (Buck scientific Model 210).

RESULTS AND DISCUSSION

Physicochemical parameters

The results of physicochemical parameters of water samples are presented in Table 1. The pH of a water system is very important in determination of its quality because it affects other parameters such as solubility of metals [19] The pH values recorded were in the range of 3.9 – 6.7 and the mean value was 5.1. This indicates that the water is slightly acidic and this may aid solubility and leaching out of trace metals [5]. The Electrical conductivity (EC) values were in the range of 22.20 – 98.60 µs/cm and the mean value was 58.75 µs/cm, while the temperature values were in the range of 26.00 – 28.60 ^{o}C with the mean value of 27.5 ^{o}C. The TDS values recorded were in the range of 11.10 - 49.30 mg/l with the mean value of 29.40 mg/l, while the TSS values were in the range of 1.20 – 2.70 mg/l and the mean value was 1.77 mg/l. The values of DO were in the range of 2.64 - 2.80 mg/l with the mean value of 2.69 mg/l. This is far below the WHO limit of 73 mg/l. The low level of DO which is an important limnological parameter indicates that the quality of the water is low and it is therefore not recommended for human consumption [17]. The range of turbidity values recorded were 1.45 - 4.60 NTU with the mean value of 2.60 NTU, while those of water hardness range between 76.00 – 198.00 mg/l and the mean value was 136.18 mg/l. The results of concentrations of sulfate and chloride ions were of the ranges of 7.00 – 25.00 mg/l and 12.99 – 174.95 mg/l respectively. The respective mean values were 13.13 and 84.48 mg/l. All the physicochemical parameters were within WHO acceptable limits except the pH which was below the range.

Heavy metals

The results of the concentrations of soluble and particulate metals in the underground water system are shown in Tables 2 and 3 respectively. The mean concentrations of the soluble metals were lower than those of their respective particulate metals. The results revealed that the concentrations of Ni were in the ranges of ND - 0.0022 mg/l and ND - 0.0026 mg/l for soluble and particulate phases respectively with the mean values (expressed as mean ± standard deviation) of 0.001 ± 0.0007 mg/l and 0.00115 ± 0.00085 mg/l for soluble and particulate phases respectively. The concentrations of Pb were in the ranges of 0.00008 - 0.0084 mg/l and 0.0002 - 0.0135 mg/l for soluble and particulate phases respectively with the mean values of 0.00254 ± 0.002 mg/l and 0.00399 ± 0.00382 mg/l for soluble and particulate phases respectively. The concentrations of Mn were in the ranges of 0.0002 - 0.0031 mg/l and ND - 0.0102 mg/l for soluble and particulate phases respectively with the mean values of 0.0087 ± 0.00074 mg/l and 0.00137 ± 0.0022 mg/l for soluble and particulate phases respectively. The concentrations of Cd were in the ranges of 0.0002 - 0.009 mg/l and 0.0002 - 0.0135 mg/l for soluble and particulate phases respectively with the mean values of 0.004343 ± 0.002593 mg/l and 0.0048 ± 0.0027 mg/l for soluble and particulate phases respectively. These values are higher than the WHO limit of 0.003 mg/l and the finding is in agreement with similar studies conducted earlier [4,22]. The high level of Cd in the environment was attributed to domestic and industrial activities. The concentrations of Fe were in the ranges of ND - 0.0014 mg/l and ND - 0.0014 mg/l for soluble and particulate phases respectively with the mean values of 0.00038 ± 0.00036 mg/l and 0.00063 ± 0.0004 mg/l for soluble and particulate phases respectively. This suggests that the water is not contaminated with Fe as reported earlier in a similar investigation [16].

The concentrations of Cd, Pb, Fe, Mn and Ni were compared with the respective WHOs' drinking water standards (see Figure 1). It shows that in both the soluble and particulate phases, cadmium concentrations exceeded the WHO's Maximum Contaminant Level (MCL) of 0.003 mg/l. This, coupled with the low DO recorded may expose the inhabitants of the area to serious health problems [15].

Table 1: Results of physicochemical parameters of well water samples

Parameters	min. value	max. value	mean value	WHO limit
pH	3.9	6.7	5.05 ± 0.8	6.5 – 8.5
DO (mg/l)	2.64	2.80	2.69 ± 0.03	73
Conductivity (µs/cm)	22.2	98.6	58.58 ± 25.2	250
TDS (mg/l)	11.1	49.3	29.29 ± 12.6	500
Temperature (^{o}C)	26.0	28.6	27.55 ± 0.6	25-35
Hardness (mg/l)	76	198	136.1 ± 37.6	150-500
Turbidity (NTU)	1.45	4.6	2.59 ± 1.2	0-5
TSS (mg/l)	1.20	2.70	1.75 ± 0.4	30
Sulfate (mg/l)	7	25	12.8 ± 4.7	500
Chloride (mg/l)	12.99	174.95	83.5 ± 46	250

Table 2: Results of Concentrations of Soluble Metals

Metal	Concentrations of metals (mg/l)			Standard	WHO limit
	Lowest	Highest	Mean	deviation	
Ni	ND	0.0022	0.001	± 0.0007	0.02
Pb	0.00008	0.0084	0.00254	± 0.002	0.01
Mn	0.0002	0.0031	0.00087	± 0.00074	0.5
Cd	0.0002	0.0090	0.004343	± 0.00259	0.003
Fe	ND	0.0140	0.0038	± 0.0036	0.3

ND= Non-detectable

Table 3: Result of Concentrations of Particulate metals

Metal	Concentrations of metals (mg/l)		Standard	WHO limit	Lowest
	Highest	Mean	deviation		
Ni	ND	0.0026	0.00115	± 0.00085	0.02
Pb	0.0002	0.0135	0.0039	± 0.00382	0.01
Mn	ND	0.0102	0.00137	± 0.0022	0.5
Cd	0.0002	0.0092	0.0048	± 0.0027	0.003
Fe	ND	0.014	0.0063	± 0.004	0.3

ND= Non-detectable

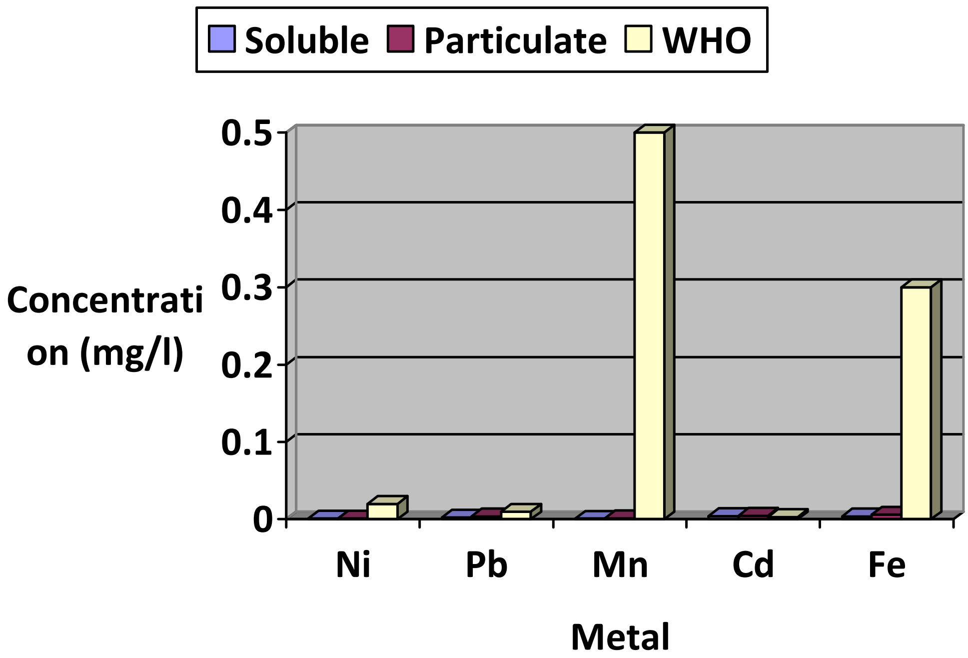

Figure 1: Comparison of mean concentrations of metals with WHO acceptable limits.

CONCLUSION

The physicochemical parameters measured were within WHO acceptable limits except the pH and DO values that were lower than WHO acceptable range. This indicates that the water system was slightly acidic. Similarly, with the exception of cadmium whose concentrations in both the soluble and particulate phases exceeded the WHO limits, the concentrations of all the metals analyzed were within WHO limits.

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