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Physico-Chemical and Heavy Metal Analyses of Some Ground Water in Bunza, North Western, Nigeria

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Abstract: Water contaminants such as chemicals, household waste or microorganism are known to be dangerous to human health and other living organism, thus the basis for this study. The physico-chemical parameters and heavy metal contents of four different well water in Bunza, North Western Nigeria were analyzed. The pH of the well waters ranged from 4.31 - 5.9, Magnesium and Calcium content of the well water ranged from 4.54 - 5.40 and 53.58 - 66.42 mg/L, Cadmium content of the well waters ranged from 0.017 - 0.021 mg/l, the pH values and Calcium content obtained falls below the permissible limit of 6.50 - 9.00 and 150 - 200 mg/l respectively as given by WHO, while the Cadmium content was observed to be higher than the permissible limit (0.003 mg/L). This study infers that well water in the studied area may not be safe for human and animal consumption.

Keywords: Contaminant, Heavy Metal, Well, Concentrations, Hazardous

1. Introduction

Adequate purity of water is of paramount importance to living things. It is the life blood of species. Every race and tribe everywhere and everyday makes use of water. Health experts have suggested and stressed the need to drink two litres of water every day. Water occupies about 70% of the earth's surface and composes 65% of the human body [1]. Water is essential to urban and rural life. Water is man's most precious resource that cannot be compared to anything even crude oil [2]. It is needed for both domestic and industrial purposes. According to [3] sources of water can be classified into rain water, surface water (such as oceans, seas, streams, rivers, ponds and lakes) and underground surface water.

Water is typically referred to as polluted when it is impaired by anthropogenic contaminants and either does not support human use, such as drinking water and undergoes a marked shift in its ability to support its constituents biotic communities such as fish. There are many causes for water pollution, but two general categories exist namely; Direct and indirect sources. Direct sources include effluent outfalls from factories, refineries, waste treatment plant etc.,that emits fluids of varying quality directly into urban water supplies. Indirect sources include contaminant that enters the water supply from soils/ground water systems and from the atmosphere via rain water. Soils and ground water contains the residue of human agricultural practices (fertilizers, pesticides etc.) and improperly disposed of industrial wastes. Atmospheric contaminants are also derived from human practices (such as gaseous emissions from automobiles, factories and even batteries). Many drinking water contaminants including various chemicals, physical, microbiological and radiological are known to be hazardous to health [4]. This calls for the adoption of international standards for drinking water quality and developing national standards that meets local needs. According to [4] a number of factors need to be considered in developing national standards, including the geology of the region, types of human activities around the area, local or national, environmental, social, economic and cultural conditions.

The use of water has been reported to increase with growing population putting increasing strain on these water resources. Finding adequate supplies of fresh water to meet the ever increasing needs and maintaining its quality is becoming a problem, although water availability is not a problem on a global scale, it may be a problem finding high quality freshwater at the required place in the required quantity [5]. Water pollution has become a serious problem, as it threatens the aquatic life and deteriorates water bodies;

it also affects human health because of the harmful substances that accumulate in aquatic animals such as fish, which has been one of the main sources of protein for man [1]. [6] reported a pH of 7.01 and total hardness was reported to be 37.11 mg/l, they also observed the total dissolved solid (TDS), Fe and Mg concentrations to be above the NDWQS limit (500, 0.3 and 0.2mg/l) respectively for drinking water. A study by [7] on the physico-chemical parameters of ringed and unringed wells showed conformity with WHO standards.

2. Materials and Methods

2.1. Sampling Area

The sampling site was Bunza, Kebbi State. It is located between latitude $12^0\,05^1\,04^{11}$ – N and longitude $4^0\,01^1\,16^{11}$ in North Western Nigeria. Bunza town is located in the Sudan Savannah zone 13^0 N and 16^0 E, it has limited rainfall from mid May to mid-September and is subjected to the Sahara's harmattan (dry, dust-laden wind) from November to March. It has a population of 121,461 as reported by [8]. Well water samples were collected from the following points; Low-cost, Zogirma road, Tundun wada and Sabon gari areas of Bunza Local Government respectively.

2.2. Sample Collection

Water samples were collected in the month of June, 2012. A total number of 4 water samples were collected randomly from different well waters within the study area. Samples were collected in well rinsed plastic container of one (1) litre each. The samples were collected at around 05.00 GMT (in the morning) before it was disturbed and later around 17.00 GMT (in the evening) after much fetching activity has taken place on the wells. Water samples collected in the morning and evening from each well was mixed together in a one litre and taken as representative for each sample.

2.3. Sample Treatment

Digestion of the sample was done to preserve the sample from bacterial activities and to release metals into the analytic solutions according to the method of [9]. From each sample, $50\,cm^3$ was measured into an evaporating dish and $5cm^3$ of concentrated HNO_3 was added. The samples were digested for about 30 minutes using digestion block in a fume cupboard until the solution was reduced to about 5 - 6 mls, the appearance of a characteristic colour indicates complete digestion. Each digest was then allowed to cool and transferred to a $50\,cm^3$ acid washed volumetric flask and the volume was made up to the $50\,cm^3$ mark with distilled water. The diluted digest was then filtered and kept in sample bottles ready for analysis [10]. The level of each metal in the three samples were determined using bulk 205 model FAAS while result was presented as mean value for triplicate analysis.

2.4. Physico-Chemical Parameters Determination

The physico-chemical parameters which include pH,

temperature, conductivity, bicarbonate, calcium, chloride in mg/l and SO_4^{2-} in mg/l were analyzed. The analysis were carried out as follows;

2.4.1. Determination of pH

The water sample pH was measured using a digital mobile pH meter (Mettler Toledo model). The meter was switched on and allowed to warm for about 15 minutes. It was standardized with three buffer reference solutions of pH 4.0, 6.8 and 9.18 respectively. The electrode was introduced into the water sample and measurement was taken after a stable reading was obtained. The electrode was rinsed with deionized water before taking the next measurement [11].

2.4.2. Determination of Temperature

The temperature of the water sample was determined at the point of sample collection by immersing mercury in glass thermometer into the sample water. Reading was taken after a steady flow of the mercury was obtained.

2.4.3. Determination of Conductivity

Conductivity of water sample was measured using a digital conductivity meter (4010 JENWEY MODEL). The meter was switched on and allowed to warm for about 15 minutes. This was then sterilized with $0.01\,mol/dm^3$ KCl solution and conductivity reading of 1413 micro-siemen per centimeter was obtained. The electrode was then immersed into the water sample and the conductivity reading was obtained and recorded [12].

2.4.4. Determination of Total Hardness

Total hardness in the water sample was determined by using Complexometric titration method [11], 50 mls of the water sample was measured and immediately 1ml of ammonium buffer solution was added to give a pH of 10.0 - 10.1. Few drops of crystals dye (mixture of eriochrome black-T (sodium salt of 1-(1-hydroxyl-2-naphtanylazo)-5-nitro-2-naphtol-4-sulfonic acid) was added. The sample was titrated against standard EDTA solution until the reddish colour disappeared giving rise to a blue colour at the end of the titration, the titre value was recorded and the calculation was done as follows;

$$\text{Hardness as mg/l CaCo3} = A \times N \times 5000 \qquad (1)$$

Where: A = volume of the titrant EDTA used for the water samples. N = mg $CaCo_3$ equivalent to 1ml EDTA titrant.

2.4.5. Determination of Nitrate Ion

About $10\,cm^3$ each of the water samples were measured into two different conical flasks, $0.5\,cm^3$ of brucine solution and $20\,cm^3$ of conc. H_2SO_4 solutions were added into each of the two conical flasks. The mixture containing the sample was titrated with 0.1 M KNO_3 solution until the appearance of a colour similar to that of the mixture containing the water.

2.4.6. Determination of Total Dissolved Solids

An empty beaker was weighed and recorded. A small quantity of the water sample was evaporated to dryness

inside the weighed beaker; it was then allowed to cool and weighed again. TDS was calculated as follows;

$$TDS = W2 - W1 \qquad (2)$$

Where: W1 – Represents the weight of the empty beaker and W2 represents weight of cooled beaker after evaporation of the water sample [12].

2.4.7. Determination of Chloride Ions

About 100 ml of the water sample was measured and the pH was adjusted to ranges of 7-10, and about 1.0 ml of potassium chromate (K_2CrO_4) indicator solution was added. The sample was titrated against standard silver nitrate (0.0141 M) to a pinkish yellow (flesh colour) end point. The silver nitrate titrant was standardized and the reagent blank value was established by the titration method outlined above. Chloride ion in the water sample was calculated as follows;

$$Mg/l\ Cl^- = (A - B)\ x\ N\ x\ 35,\ 400\ x\ 100 \qquad (3)$$

Where A = ml titration for sample. B = ml titration for blank. N = normality of $AgNo_3$ (0.0141N)

$$Mg/l\ Nacl = mg\ Cl\ x\ 1.65$$

2.4.8. Determination of Calcium and Magnesium Ions

This was carried out instrumentally using FAAS (Perkin – Elmer Corporation, USA.2010 model AA 400).

2.5. Determination of Heavy Metals

The residue obtained from the evaporation of six litres samples were digested with 0.1m HNO_3 and filtered into 25 cm^3 volumetric flasks for analysis. A hollow cathode lamp of the desired metal was installed into the AAS (Perkin-Elmer Corporation, USA. 2010 Model Analyst 400), and the wavelength characteristics of the metal was then set. Slit width and the amount of current applied to the hollow cathode lamp were all set according to the manufacturer's instruction. The instrument was then switched on and allowed to warm up until the energy source stabilizes. The oxidants and the fuel passes (air and acetylene) were then allowed to flow and then ignited while the flow rate was adjusted as specified by the manufacturer [14].

3. Results and Discussion

The values of the physico-chemical parameters are presented in Table 1. The pH values obtained were observed to be between 5.00±0.33 to 5.9±0.08, the conductivity was observed to be between 24.6±1.01 to 28.2±2.60 µs/cm, while the concentration of Magnesium and Calcium were between 4.54±0.78 to 5.4±0.87 and 53.593.76 to 66.42±2.33. The pH, Conductivity, Magnesium and Calcium values were below the permissible level, (pH = 6.5 - 9.5, conductivity = 1000 µs/cm, magnesium and calcium 150 –200mg/l) as set by the World Health Organization [1]. The low conductivity may be as a result of low solubility of minerals in the geological region. The low level of magnesium and calcium could be attributed to low level of weathering of rocks like lime stone, dolomite and gypsum which are not common in the study area. The chloride and sulphate values were found to be between the ranges of 7.10 11.66 mg/l and 7 - 10 mg/l. Chloride in the three water samples were observed to be above the desirable limit i.e. 2.5 mg/l and permissible limit i.e. 2.5mg/l for WHO standards, the high chloride level could be attributed to the salt deposits which are found in the study are. The sulphate was also above the desired level as given by WHO which (0.1 mg/l). The Total Dissolved Solid ranged between 24.6 to 25.6 mg/l this falls between the permissible limits of 500 mg/l [15] and 1200 mg/l [16]. Analysis of variance showed significant difference across all the four sampling site.

Table 1. Physico-chemical parameters of well water

Parameters	Sample A	Sample B	Sample C	Sample D	WHO
Ph	5.56±0.36[ab]	5.00±0.33[b]	5.31±0.76[b]	5.9±0.08[a]	6.5 – 9.5
Temp. (^0C)	30.6±0.98[b]	31.5±2.02[a]	31.0±1.97[b]	31.0±1.98[b]	-
Conductivity (µs/cm)	24.6±1.01[b]	27.5±1.99[ab]	28.2±2.60[a]	25.6±2.03[b]	-
TDS (mg/l)	24.6±0.77[b]	24.6±2.07[b]	24.5±1.99[b]	25.6±2.66[a]	200
Magnesium (mg/l)	5.02±0.59[a]	4.54±0.78[a]	5.4±0.87[a]	5.1±1.12[a]	0.1
Calcium (mg/l)	66.42±2.33[a]	53.59±3.76[c]	60.00±3.04[b]	60.46±3.43[b]	-
Chloride (mg/l)	11.66±1.06[a]	8.12±1.01[b]	8.62±1.33[b]	7.10±1.59[b]	250
Sulphate (mg/l)	7.00±1.02[c]	8.00±1.07[b]	10.00±1.74[a]	8.00±1.59[b]	250

n=3. Superscripts with the same letters in the same roll are not significantly different at p≥0.05.

Table 2. Concentration of some heavy metals (µg/cm) in well water

Heavy metals	Mean concentration (µg/cm)				WHO
	Sample A	Sample B	Sample C	Sample D	
Lead (Pb^{2+})	0.028±0.01[a]	0.004±0.001[c]	0.015±0.001[b]	0.028±0.01[a]	0.01
Chromium (Cr^{2+})	0.011±0.005[a]	0.015±0.003[a]	0.01±0.002[a]	0.022±0.01[a]	0.05
Iron (Fe^{2+})	0.209±0.01[b]	0.470±0.05[a]	0.021±0.004[b]	0.078±0.02[b]	0.3
Manganese (Mn^{2+})	0.070±0.01	0.082±0.02[a]	0.059±0.001[b]	0.052±0.03[b]	0.5
Cadmium (Cd^+)	0.017±0.002[a]	0.018±0.005[a]	0.018±0.002[a]	0.021±0.01[a]	0.003
Nickel (Ni^+)	0.067±0.02[a]	0.0712±0.007[a]	0.0470±0.01[b]	0.0520±0.01[b]	0.02

n=3. Superscripts with the same letters in the same roll are not significantly different at p≥0.05.

Table 2 presents concentrations of some heavy metals. The concentration of lead ranged between 0.004±0.001 to 0.028±0.01 mg/l. The lead concentration in the well waters are very negligible, they were observed to be far more lower than the maximum permissible limits of 0.01 - 0.05mg/l (WHO) and 0.01(SON). This could be attributed to the fact that there was no mechanical activity taking place in the area. The concentrations of chromium and iron ranged between 0.011±0.005 to 0.022±0.01 mg/l and 0.0209±0.01 to 0.470±0.05 mg/l, they were observed to be within the maximum permissible limits (0.05 mg/l) for drinking water [14, 15]. The concentration of Nickel and Manganese in the well waters ranged from 0.047±0.02 to 0.0712±0.007 mg/l and 0.052±0.03 to 0.082±0.02 mg/l, the level of Nickel and Manganese in the water samples compared with WHO standards were also observed to be within the recommended value (0.02 mg/l for Nickel and 0.5 for Manganese). The concentration of cadmium in the well water ranged from 0.017- 0.021 mg/l, the concentration of cadmium was observed to be above the range of the maximum permissible limit of 0.003mg/l [14, 15]. Analysis of variance (ANOVA) showed significant difference across the entire sampling site except in Cadmium where there was no significant difference.

4. Conclusion

The problems associated with physico-chemical constituent of drinking water arise primarily from their ability to cause adverse health effects after prolonged period of exposure. Particular concern is contaminants that have cumulative toxic properties, such as heavy metals substances that are carcinogenic [15]. The most undesirable constituents of drinking water are therefore, undoubtedly those that are capable of having a direct impact on public health, and for which guideline values have been developed. Compliance with drinking water quality standards based on these guidelines should provide assurance that the well water is safe for human consumption [15]. The concentrations of Chromium and Iron, and the values of Total Dissolved Solids (TDS), Conductivity and pH were all below the WHO/SON threshold limits. However, the elevated concentration of chloride could be attributed to the salt deposit found in the study area. The concentrations of Lead, Cadmium, Nickel, Manganese and Calcium above WHO/SON permissible limits in some of the well waters studied could pose serious health issues.

Physiological and environmental factors have been reported to be the cause of differences observed in the concentrations of trace elements in water [17]. Water being one of the most important solvent that sustain the existence of live on earth, in its purest form ought to be colourless, odourless and tasteless, but human activities such as dumping of waste, effluent from chemical factories and manufacturing companies most often contaminates these water bodies [18, 19, 20, 21], other sources of contaminant include mining and dissolved gases [22]. High heavy metals concentration has been reported could affect enzymatic and hormonal activities, as well as impede growth rate and may also increase mortality rate [23], thus the need to always assess water quality especially in the rural areas where groundwater such as well is the predominant source of water for domestic use.

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