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Comparative Analysis of the Hydrochemical Characteristics of Ground Water Sources Found within the Kassena Nankana East District of the Upper East Region of Ghana

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Abstract Water is an essential component of life that is impossible to do away with. Just like its numerous uses, water has a variety of sources which include those that are stored in ice caps and glaciers, surface water, and ground water. The Kassena Nankana East District is one of nine districts in the Upper East Region of Ghana and has three main potable water sources; pipe-borne, borehole and wells, with the last two being the most readily available sources especially as you move away from the central business district, where most of the commercial activities takes place. These ground water sources within the district are used for both domestic, industrial (cottage industry), agricultural, and recreational purposes. Metals do occur freely in nature either as a combination with other minerals or on their own in these water sources. In as much as they come with other minerals that are of economic importance, they cannot be left behind taking only the important one. Such metals enter our water system either by natural disturbance like when water flows over them or by man-made disturbances especially through the mining process. Because of the levels of toxicity some of these metals exhibit, this study was designed to estimate their concentrations in ground water which is used directly without treatment within the district. It was revealed that both sources were mildly acidic to mildly basic (6.84- 7.58 for wells and 6.85- 7.69 for boreholes). Concentrations of most metals were found to be low and within acceptable standards. However, there were more well samples that were very hard than borehole samples. In the exception of Cd, both sources reflected similar trends of Cu, Zn, Ni and Cr concentrations.

Keywords: *borehole, wells, heavy metals, concentration*

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1. Introduction

The Kassena Nankana District is one of nine districts of the Upper East Region of Ghana and is inhabited by the Kasem and Nankam people. The main economic activity is subsistence farming. The major food crops produced are corn, millet and sorghum. They also produce tomatoes, pepper and other vegetables that they export to other regions of the country and neighboring West African countries. Most farms are irrigated especially during the dry season and there is a heavy use of herbicides, pesticides and other agro chemicals, which may contain heavy metals, in the district.

Other sources of ground water contaminants such as used motor oils and lubricants which also contain heavy metals are disposed of by pouring directly onto the ground or into nearby drains which eventually find their way into the ground water by leaching. Furthermore, some heavy metals like cadmium occur free in natural soils and may find their way into ground water over the years through weathering. Though there are many sources of water depending on the use, a majority of potable water sources is obtained from ground water sources through either boreholes or water wells.

As documented by Gyau-Boakye and Dapaah-Siakwan [4], communities with smaller populations (500-2000) are to be helped with either hand dug wells or boreholes fitted with hand pumps for water extraction. Due to the scattered nature of settlements within the district with a majority rural settlements, boreholes and wells have for many years been a well-known source of domestic water supply for the people of the district.

Though it important to know and appreciate what makes up the substances we consume, it has been observed that not much work has been done to investigate the hydrochemistry of boreholes and well water within the District which incidentally shares boundaries with districts where fluoride rich waters and higher concentrations of heavy metals exists [1]. This study was therefore designed to assess and compare some physico-chemical parameters of groundwater sources extracted from boreholes and wells and evaluate their toxicity by comparing them to already established standards.

2. Materials and Methods

2.1. The Study Area

The Kassena Nankana District is located between latitude 11°10’ and 10°3’ North and longitude 10°1’ West. It covers an area of approximately 1674 km^2 which stretches 55km North-South and 53km East-West. (which included both the Kassena Nankana East and West districts) [2] with a population of 109,944 [3] The population is about 90 % rural and 43 % of the total population is below 15 years with a population growth rate of about 1 % [11]. The district is covered with the Sudan and Sahel savanna types of vegetation with grasslands separating deciduous trees. As one of the nine districts of the Upper East region, the district is made up mainly of crystalline rocks underlying its soil types [4]. It comprises mainly of granite and shale although some other rock types may exist. Two main soil types cover the land mass of the district; the Savanna ochrosols and the ground water laterite.

2.2. Sampling

Samples were taken at ten different locations throughout the district for each ground water source into cleaned, prepared plastic containers. Averagely, the depth of wells ranged between 3 to 10 meters while boreholes within the district were averagely about 35 meters deep. The district was first divided into five clusters based on their location and activity and two samples each for borehole and two for well were collected from each cluster. At each sampling location; for both boreholes and wells, two different samples were collected for analysis. The first was treated with few drops of concentrated nitric acid for heavy metals analysis but the second untreated sample was for pH and EC determination. After collection, both samples were immediately kept in ice and sent to the lab for analysis.

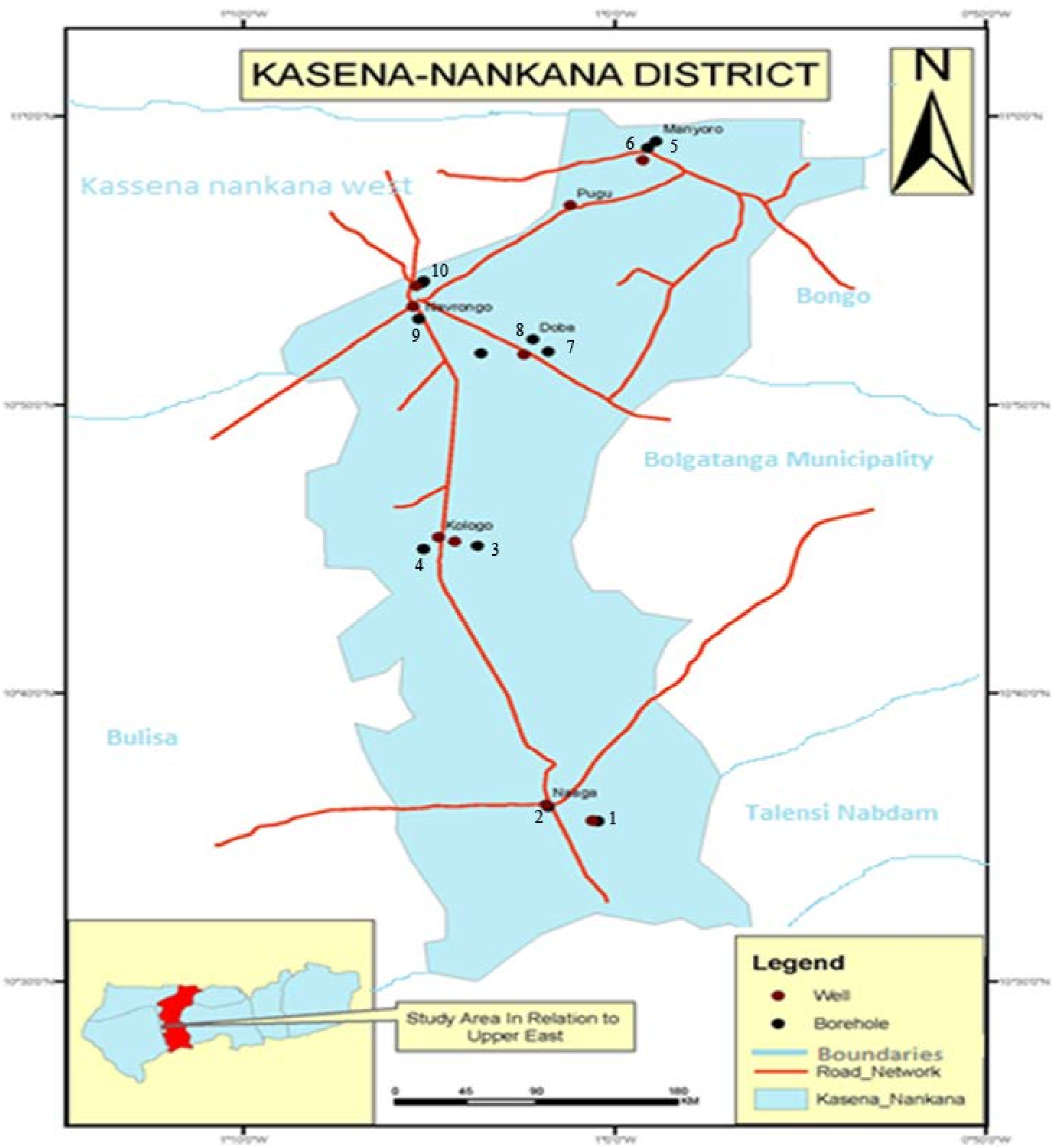

Figure 1. Map of Study area showing sampling sites

2.3. Laboratory Analysis

The samples were allowed to thaw to room temperature before analysis. The pH reading of the samples were then taken using the Metrohm 691 pH meter calibrated to 2 significant figures. Conductivity readings were also taken in micro seimens per centimeter (μS/cm) using the Metrohm Herisau conductometer E587.

Samples were analyzed for heavy metals using the Perkin Elmer A Analyst 400 atomic absorption spectrometer under standard operating conditions. For each given element, a corresponding lamp was chosen that produces a wavelength of light that is absorbed by the element. Standard solutions of the elements to be determined were then aspirated to calibrate the machine for the analysis. The samples were then aspirated into the flame and the reading taken in triplicates. The average of the three readings was recorded as the amount of metal present. All readings were taken in milligram per liter (mg/l) or parts per million (ppm).

3. Results and Discussion

pH, although may not directly impact the quality of water, it influences many other properties of the water. According to WHO [7], the optimum pH may vary depending on the nature of the water and the construction materials used and it is usually in the range, 6.8 to 8.5. Comparatively, all samples for both well water and borehole water had pH that ranged from slightly acidic to slightly basic. Well had pH ranging from 6.84 to 7.58 while borehole ranged 6.85 to 7.69. The nature of the pH range in the samples for both sources may be due to underlying rock types.

It was however observed the readings for conductivity was unlike the trends shown for pH. Because water shows significant conductivity when dissolved salts are present, conductivity can be said to be directly proportional to the amount of salts present in the water [5]. On the average, well water had higher electrical conductivity than borehole water. In the exception of sample location 1 (Naaga Chaba) and sample location 8 (Pungu Junction), all well samples had higher conductivity than those of boreholes. Well water conductivity ranged between 260μS/cm to 520 μS/cm while borehole samples ranged from 130μS/cm to 490μS/cm. High conductivity of well water samples may be due to the introduction of ions from anthropogenic sources as the water is being drawn daily by different people who may have touched different chemical substance and transferred it to the water knowingly or unknowingly.

Total dissolved solids (TDS) also followed a similar trend as it is directly proportional to conductivity readings. As recorded by Stevens (2011) multiplying the conductivity value by a constant of proportionality (0.67) gives the resultant TDS reading in ppm. This is a reflection of the concentration of organic and inorganic salts present in the water and thus influences the water palatability. As water with TDS less than 600 ppm can be said to have a good palatability (WHO 2011), water from both well and borehole sources within the district were palatable and none had TDS equal to or greater than 600 ppm except for sample location 8 for boreholes.

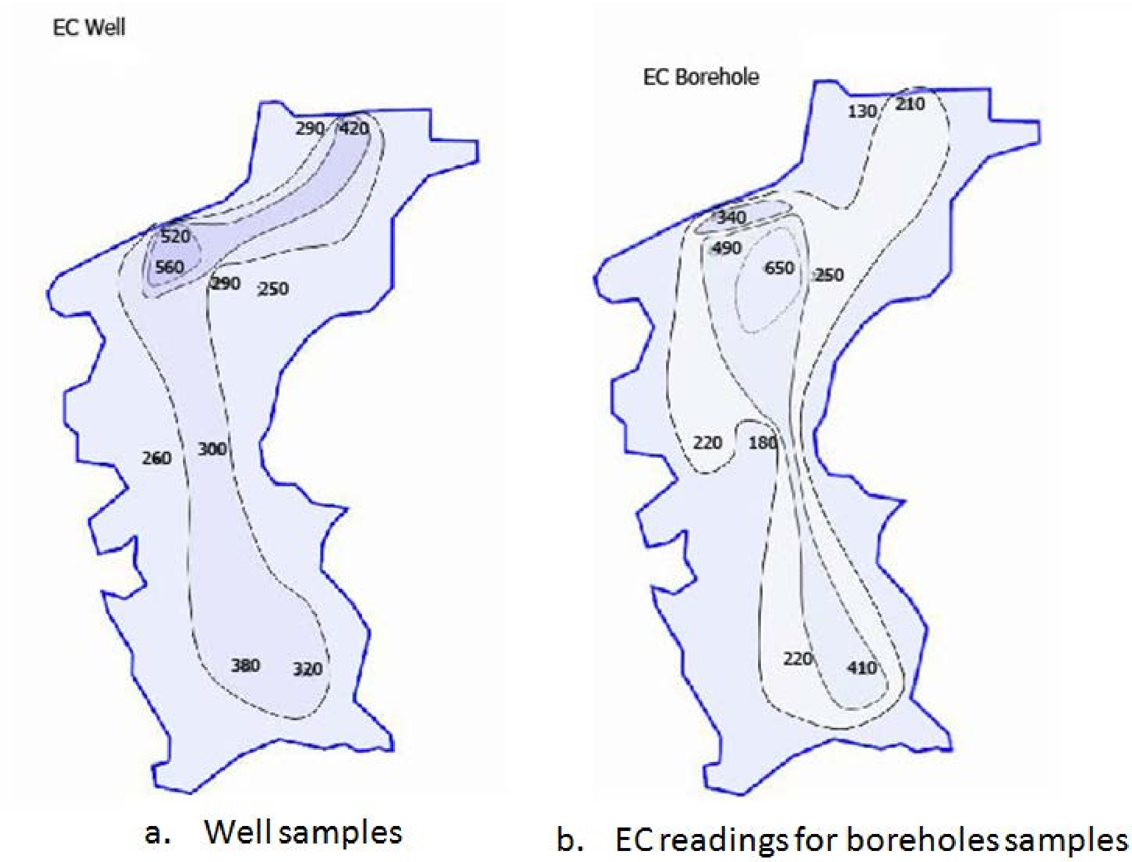

Figure 2. EC readings of samples from boreholes and Well within the Kassena Nankana district

As essential micro nutrients, calcium and magnesium are important to the body because their deficiency can impair the smooth functioning of the body. Whereas almost all (about 99%) of the body's Calcium is found within the bones and the teeth, magnesium is a cofactor for over 350 cellular enzymes in the human body. Within the district, well water was found to be richer in the Ca than boreholes. In the exception of sample locations 1 and 8 (Naaga Chaba and Pugu Junction respectively), all other samples for calcium obeyed this trend. For wells, Ca concentrations ranged from 5.871ppm to 73.3 while that for borehole from 0.9ppm to 62.27. Mg however showed a little variation as samples 3, 4, 7, 8 and 9 had borehole ma\Mg concentrations higher than wells. Borehole sample concentrations ranged from 0.8 to 13.2 ppm while that of well was from 4.211 to 22.27ppm. As documented by Lenntech (2012) and United States Environmental Protection Agency (2010),

$$\text{TOTAL HARDNESS} = \text{CALCIUM HARDNESS} + \text{MAGNESIUM HARDNESS}.$$

From the molar masses of $CaCO_3$, Ca^{2+}, and Mg^{2+}, the ratios can be calculated as;

$$Mcaco_3 / M_{Ca} = 100.1/40.1 = 2.5 M_{CaCO3} / M_{Mg} = 100.1/24.3 = 4.1.$$

From the above formula, water hardness as equivalent of $CaCO_3$ can be calculated as;

$$\left[CaCO_3\right] = 2.5\left[Ca^{2+}\right] + 4.1\left[Mg^{2+}\right].$$ [9]

Consequently, the hardness of the water samples as an equivalent of CaCO3 revealed similar trends as that for Ca concentrations. Apart from sample locations 1 and 8, all other well samples were harder than their corresponding borehole samples. This is revealed in Figure 3 below as well samples had hardness from 31.9 to233 ppm while borehole from 5.6 to 209 ppm.

Apart from Ca and Mg, Na is another nutrient essential for human development. Though concentrations obtained from water sources is very small as compared to that obtained from dietary sources, Na concentrations in clean water usually does not exceed 100mg/l. Within the district, Na concentrations were higher in well samples than in Borehole samples. In the exception of sample location 1, 3, 7 and 8, all other locations had well water with concentrations higher than that of borehole water. The concentrations ranged from 12.3ppm to 31.4 ppm in well water and 11.7 to 30.9ppm in borehole water.

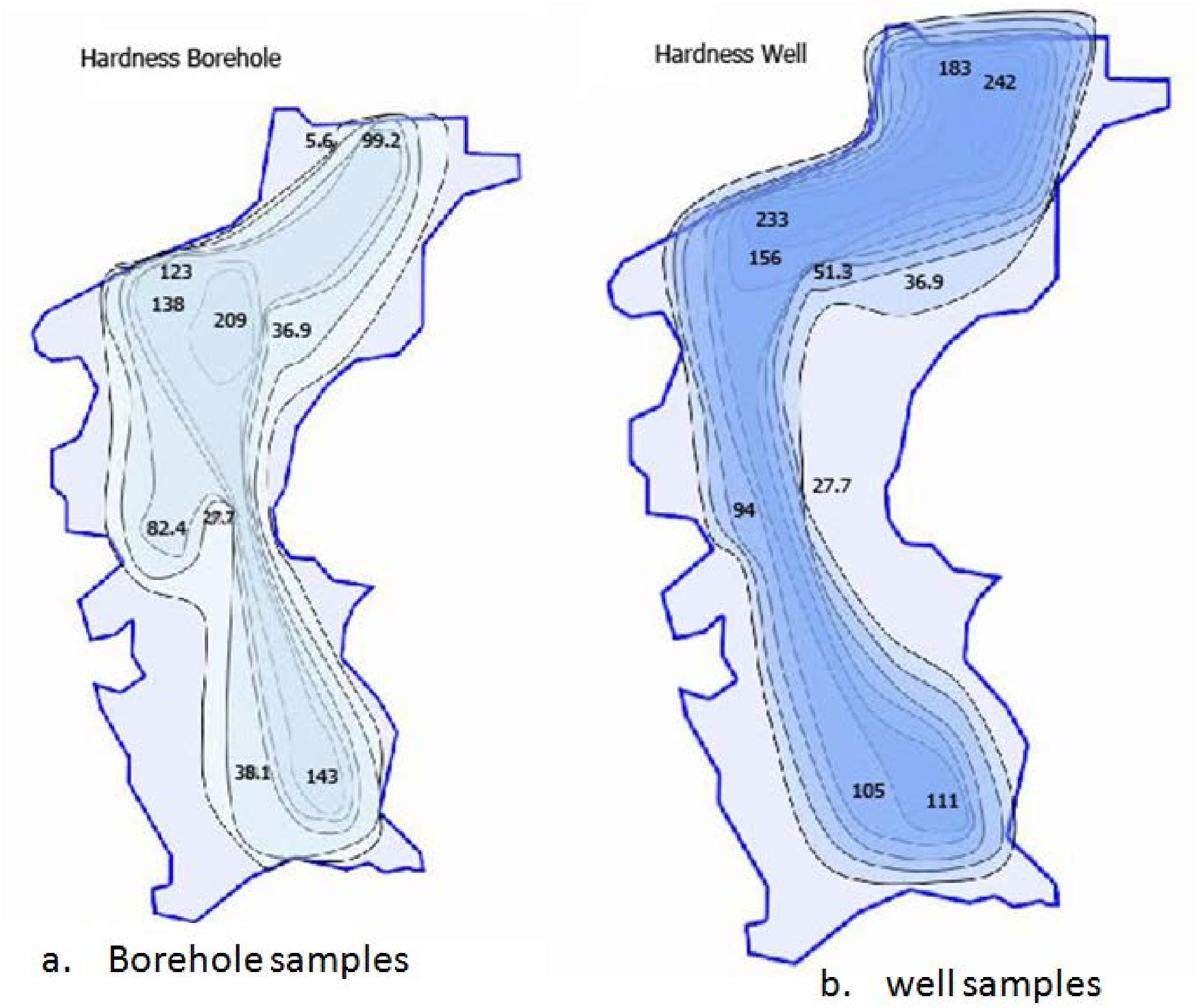

Figure 3. Water hardness of Samples collected

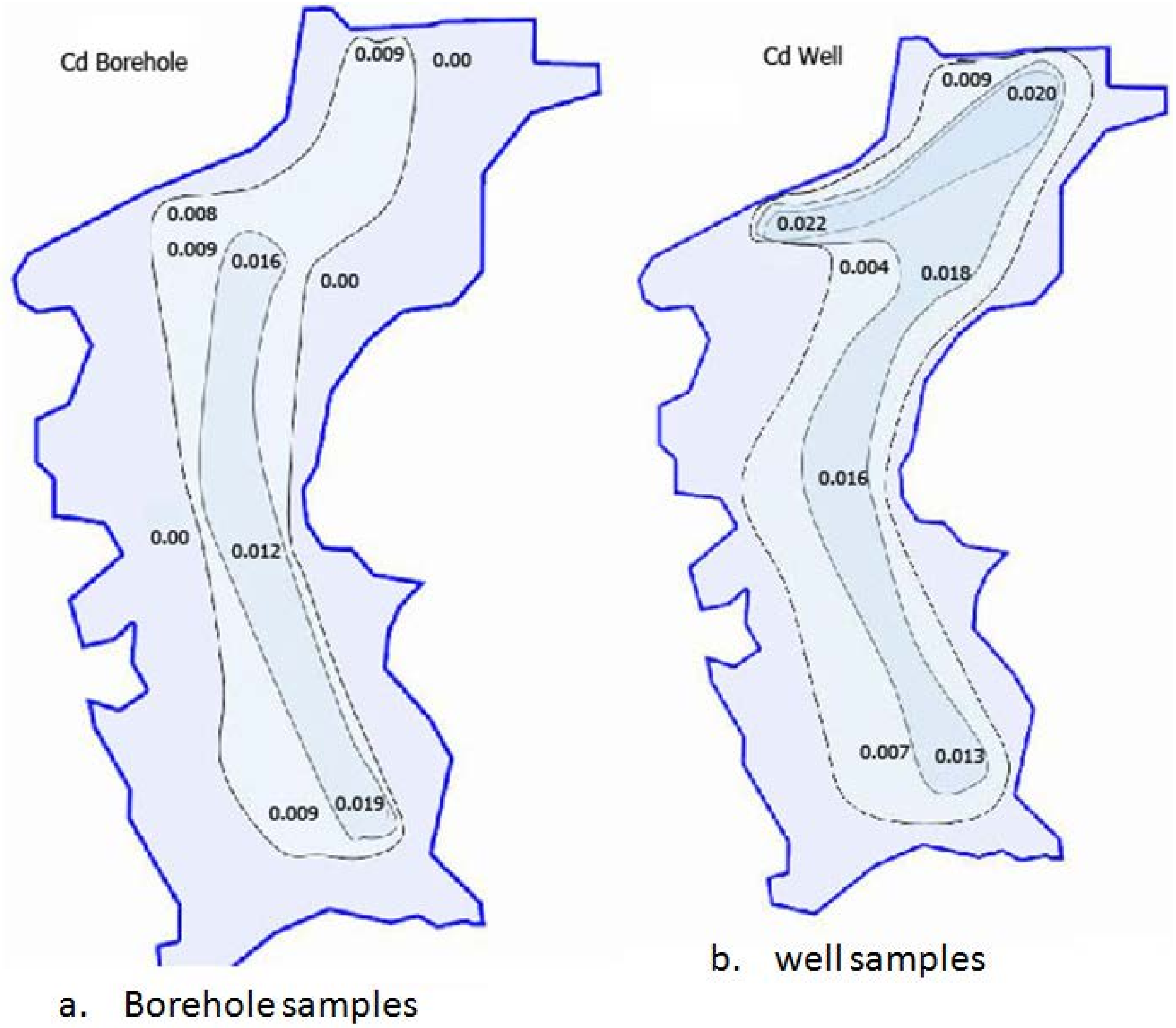

Figure 4. Cadmium concentrations in samples

Unlike neighboring Bongo District which is known to be rich in Fluoride, the concentration within the district was lesser for both wells and boreholes [10]. The highest concentration observed for both sources was 0.01ppm. However, WHO [7] has guideline value for drinking water as 1.5 ppm, below which the concentration is in safe levels. However, Cd showed a different trend. With an allowable daily intake between 0.01 and 0.03 mg, and a recommended guideline concentration of 0.003mg/l, the district recorded a minimum Cd concentration of < 0.0008 mg/l and a maximum of 0.022mg/l. There were 3 borehole samples below the WHO guideline concentration while only one well sample was below this guideline value. All these 4 samples had concentrations less than 0.0008mg/l. Among the well water samples, the concentration ranged from <0.0008 to 0.022mg/l while borehole sample concentrations ranged from <0.0008mg/l to a maximum of 0.019mg/l. As Cd has its source from both natural and anthropogenic sources, high concentrations of the metal in both sources may be due to both factors though anthropogenic influences may have contributed to more well samples having concentrations above the WHO guideline value than boreholes.

Cu and Zn concentrations in both boreholes and well samples were all below 0.0015mg/l while those of Ni were below 0.006mg/l in both sources. Cr was no different as it also recorded concentrations for both boreholes and wells.

4. Conclusion

It was indicated from the study that both boreholes and well water had pH that ranged from slightly acidic to slightly basic. However, there were more well water samples with conductivity higher than their corresponding borehole samples. Though more well samples were harder than borehole samples, both sources served as a good source of Ca and Mg for inhabitants. Cd however showed higher concentrations as a majority of the samples were above WHO guideline values for both water sources. Apart from that, Cu, Zn, Ni and Cr all recorded concentrations within limits acceptable by WHO in drinking water for both boreholes and wells.

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