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Quality of Groundwater in the Kwahu West District of Ghana

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Abstract: The quality of ground water in the Kwahu West district of Ghana was determined by the use of physicochemical parameters together with trace metal contamination as indices of quality. Standard methods for physicochemical determinations were employed. Atomic absorption spectrophotometer was also used for the measurement of Ni, Pb, Zn, Cu and Fe. Nitrate, chloride, alkalinity and phosphate were also determined. Results were compared with global averages for freshwater and international water quality standards for drinking water (World Heath Organisation). Evaluation of physicochemical parameters revealed that the water samples were within the maximum permissible limits for consumption. All elements except iron, lead and nickel were well within the safety limits recommended by who. The low level of industrialization in the study area has kept the water relatively free from heavy metal contamination.

Key words: Contamination, physicochemical, trace metals, water, evaluation, permissible

INTRODUCTION

Water is the most important natural resource in the world since without it life cannot probably exist and industry cannot operate. Unlike many raw materials there is no substitute for water in many of its uses (Sylverster, 2003).

Groundwater is the most important source of the domestic industrial and agricultural water supply in the world. The preference for ground water to surface water must be due to the purification of the latter prior to distribution (Adeyeye and Abulude, 2004).

Although, it is easily accessible from lakes, rivers streams and springs, borehole water are of better quality. A number of factors influence water chemistry. Gibbs (1970) proposed that rock weathering, atmospheric precipitation, evaporation and crystallization control the chemistry of water. The influence of geology on chemical water quality is widely recognized (Gibbs, 1970; Lester and Birkett, 1999). The influence of soils on water quality is very complex and can be ascribed to the processes controlling the exchange of chemicals between the soil and water (Hesterberg, 1998). The water chemistry of the groundwater will mainly consist of inorganic chemicals and suspended solids as a result of urban run-offs (McGregor *et al*., 2000).

The quality of water may be described according to their physico-chemical and micro-biological characteristics. The quality of ground water is never constant; it is constantly changing in response to daily, seasonal and climatic rhythms. For effective maintenance of water quality through appropriate control measures, continuous monitoring of large number of quality parameters is crucial because the changes in properties of water have far-reaching implications directly to the biota and indirectly to man. Water quality data are thus, essential for the implementation of responsible water quality regulations for characterizing and remediating contamination and for the protection of the health of humans and ecosystem.

Developing countries are witnessing changes in ground water which constitute another source of portable water. The water pollution by heavy metals has become a question of considerable public and scientific concern in the light of the evidence of their toxicity to human health and biological systems (Anazawa *et al*., 2004). In the United States many thousands of wells have been closed in the late 20th century because of contamination by various toxic substances. Industrial activities within the catchment impact negatively on groundwater quality therefore rendering it unwholesome for domestic purposes. Essentiality and toxicity of trace metals in water depends on the concentration of the metal below a certain level they could be considered as essential for biochemical processes but in the case of a high accumulation in organism in toxication may occur. The toxicity of metals is dependent on their solubility and this in turn depends on pH and on the presence of different types of anions and other cations. The level of trace metals in the environment at a high percent depends on

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the extent of pollution. Trace elements in natural waters can be present in different physico-chemical forms, varying in size, charge and density properties. Knowledge of speciation is essential for understanding the transport, distribution and biological uptake of trace elements in the environment.

The present research was carried out to determine the physicochemical parameters and levels trace metals in ground water from Kwahu west district. This planned research will be helpful to assess the impact of mining and industrial activities on the quality of surrounding water bodies.

MATERIALS AND METHODS

Description of study area: The Kwahu-west district is located in the Eastern region of Ghana and it lies between latitudes 6°30 North and 7°North and longitudes 0°30 West and 1° West of the equator covering an area of about 414 km^2. The district capital, Nkawkaw is located about 214 km North-West of Accra. The district is bounded to the north by the Kwahu-South district to the west by Asante-Akim South district. To the east, it is bounded by the Fanteakwa district and to the south by the Birim North and Atiwa districts. The district lies within the wet-semi equatorial region. As such, it experiences a double maximal rainfall pattern with average monthly relative humidity ranging between 75 and 80% during the two rainy seasons. Mean monthly temperature values as high as 30°C are often recorded between the month of March and April but declines to 26°C in August. The district comes under the influence of two air masses namely the tropical Maritime air mass (MT) and the tropical Continental (CT). The tropical maritime air mass hits the district twice a year thereby causing the two rainy seasons. The two occasions are May-August and then September-October. Between the months of November and March, the district is affected by tropical continental air mass making the area warm and dry (Fig. 1).

Sampling: Water samples were collected in plastic containers previously cleaned by washing in non-ionic detergent rinsed with tap water and later soaked in 10% HNO_3 for 24 h and finally rinsed with deionised water prior to usage.

During sampling, containers were rinsed with sampled water three times and then filled to the brim. The samples were labelled and transported to the laboratory where filteration was carried out through a 0.45 micron filter and stored in the refrigerator at about 4°C prior to analysis. The composition of the water collected was a representative of the water body.

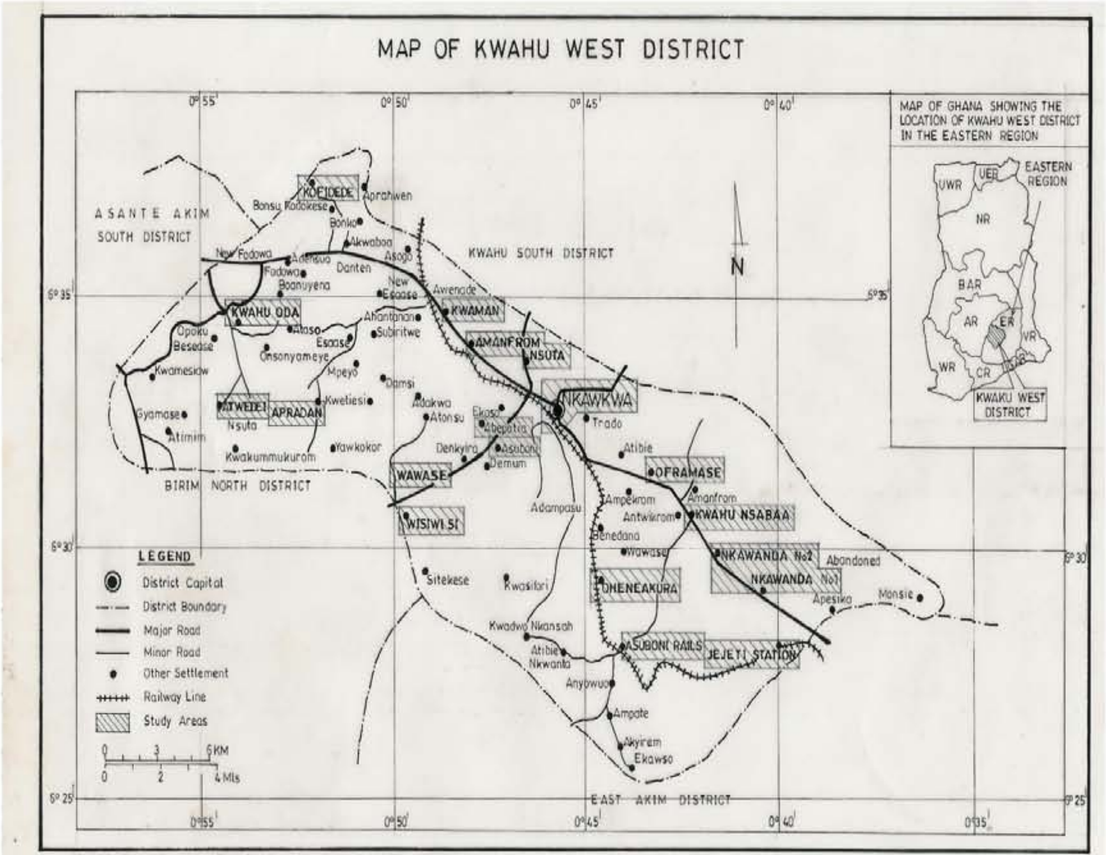
Measurement of physicochemical parameters: The electrode of the pH meter (Beaker, model 3150 pH meter (53800)-JENWAY) with a temperature sensor was immersed in the sample contained in a beaker and the stable read. Analysis of samples was carried out at 25°C. The pH meter was calibrated by immersing the electrode in two buffer solutions of pH 4.01 and 7.00 prepared from capsules of BDH buffer. The pH meter was adjusted to correspond to the standard buffers (4.01 and 7). The water sample was placed in a beaker and the electrode was rinsed with distilled water and lowered into the sample. The pH meter was allowed to stabilize and the pH of the sample read.

The specific conductance and TDS of sample were measured by a conductivity meter with cell constant of 1.0. Instrument was kept clean and standardized with KCl solution before use. The electrode was rinsed with distilled water and lowered into the sample in the beaker. The conductivity in μS cm^{-1} of the sample was recorded. TDS was also measured by selecting the TDS key while the electrode remained in the water sample used to measure conductivity and the TDS value in mg L^{-1} was recorded.

Turbidity values were taken using Hanna instrument; LP2000 Turbid meter. The Turbid meter was calibrated with the 1000, 100, 10 and 0.02 NTU standards. The cuvette was rinsed three times with the sample to be tested. The light shield cap was replaced and all outside surfaces cleaned and made dry. The cuvette was pushed firmly into the optical well and index to the lowest reading. The NTU values were measured by pressing and releasing the arrow button and the value recorded.

Alkalinity was determined by measuring 50 mL sample into a conical flask. About 2 drops of phenolphthalein indicator was added and the resulting mixture titrated against a standard 0.10N H_2SO_4 solution until the pink colour disappeared. The burette reading was recorded and five drops of methyl orange indicator was added to the solution and titrated against the standard 0.10N H_2SO_4 solution to the first permanent pink colour at pH 4.5 (APHA, 1992).

Determination of total hardness was carried out by measuring 50 mL of the water sample into a 250 mL conical flask. About 4 mL of the buffer solution and 6 drops of eriochrome black T indicator solution were added prior to titration. The content in the conical flask was titrated against 0.01M EDTA to the end point indicated by a distinct blue coloration. Titration was repeated for consistent titre values from which an average titre was calculated (APHA, 1992).



SOURCE: Town and Country Planning Dept. Nkawkaw, EASTERN REGION (2008)

Fig. 1: Map of the Kwahu west district showing sample locations

To determine the concentration of chloride, 50 mL of filtered water sample was pipetted into a 250 mL Erlenmeyer flask. The pH of the diluted water sample was determined. About 1 mL of 0.25 M potassium chromate was added to the flask. Water sample was titrated against the standard $AgNO_3$ solution slowly while stirring the sample using a magnetic bar and stir plate. The end point was indicated by the persistence of a red-brown color through the yellow solution for about 30 sec. Blank (Distilled water) was titrated using the same procedure. Volume of $AgNO_3$ for the blank was subtracted from the average used for the sample. This volume was used to determine the concentration of Chloride in the water sample.

In the determination of phosphate, a coloring reagent (vanadate-molybdate solution) was developed. Standard phosphate solution was prepared by dissolving 87.8 mg of anhydrous potassium dihydrogen phosphate (KH_2PO_4) with100 mL distilled water. About 0, 2, 4 and 10 ppm calibration standards were diluted to 100 and 10 mL of colored reagent was added to each. The absorbances of these solutions were measured with the spectrophotometer at 440 nm. About 50 mL of the samples were also diluted to 100 and 10 mL of the colored reagent was added to each. The absorbances were taken at the same wavelength. The concentration of phosphate in water was determined graphically.

Nitrate in water was determined by dissolving measuring (0, 5, 10, 15, 20 and 25) mL of standard NO_3^- and diluting to 50 mL. About 1.0 mL of HCl was added and the absorbances were measured at 220 and 275 nm. The uv-vis spectrophotometer was zeroed at both wavelengths. The quartz cell was cleaned carefully and the procedure was repeated with samples.

Perkin Elmer (5100) Atomic Absorption Spectrophotometer (AAS) with deuterium background corrector was used in the determination of trace metals. Determinations were carried out in air/acetylene flame using hollow cathode lamps of each metal used as radiation source. Prior to analysis the AAS was calibrated according to the manufacturer's manual. Calibration curves were established using internal and external standards. Recovery value were nearly quantitative (>95%) for all the metals. Limits of detection of the analysed metals were determined as thrice standard deviation of the lowest detectable concentrations by the AAS from the mean of three replicate analyses. Procedural blanks and duplicates were run alongside as part of the quality assurance program.

RESULTS AND DISCUSSION

The samples analyzed were taken from different sources such that they could represent the Kwahu west district. In this view, discussion of the results is intended to tell the quality of the groundwater body used in the whole district. Because of the large size of some of the areas, two or more samples were picked from different sites to represent that area within the district.

The pH of the water ranged from 6.67-7.35. Values of the samples picked from the same area fell within the general range quoted for the district. An average value of 6.9 which falls within the acceptable WHO range of 7.5+/-1 represents a fair distribution of the Hydrogen in concentration in the water body.

It can be discussed that the levels of calcium and magnesium ions in the water samples were very low (probably insignificant), since the values of total hardness which is chiefly dependent on the concentrations of calcium and magnesium metals never exceeded 20 ppm. Total hardness recorded values as low as 7.00 ppm with an average value of 11.37 ppm representing that of the whole district. Since hardness generally enters groundwater as its percolates through minerals containing calcium and magnesium, it could be discussed that the groundwater in the district either does not percolate through such minerals at all or percolates through minerals with very low concentrations of these metals. Some of the users of the groundwater interviewed, said that users do not have problems with the water, lathering easily with soap. This claim is confirmed by the relatively low total hardness which falls within the soft category of classification (0-60 ppm) as set by who.

Direct measurement of conductivity is potentially a very sensitive procedure for measuring ionic concentrations, since conductivity depends on ionic concentration, their mobility etc. The limiting ionic conductivities at 25°C is in the order; H^+>Na^+>K^+ for singly charged cations. Ca^{2+}>Mg^{2+}>Cu^{2+}>Zn^{2+} for doubly charged metals. OH>F^-etc, CO_3^{2-}>SO_4^{2-} and PO_4^{3-} for singly, doubly and triply charged anions, respectively.

From the pH values, it could be deduced that there is a very small concentration of hydrogen ions present. The same could be said of calcium and magnesium ions, looking at the very low values of total hardness. From the results on trace metals, copper and zinc happens to be the only metals with concentrations below their who set limits.

Hardness is a measure of calcium and magnesium in the form of their carbonates and sulphates. Since their concentrations are small, it could be discussed that the concentrations of carbonate and sulphate are comparatively small. These are the probable reasons why conductivity, recorded low values ranging from 8.49-99.2 μS cm^{-1} with an average of 52.70 μS cm^{-1}. This value is even far below the molar conductivity of hydrogen ions alone (349.8 $\Omega^{-1}/cm^2/mol$) in water.

From the discussion above, alkalinity which depends chiefly on the concentrations of carbonates, bicarbonates and hydroxide ions is not expected to have very high values. This deduction is confirmed by the fact that alkalinity which has a standard WHO acceptable value of 200 ppm had values which ranged from 17.5-142.5 ppm with an average of 70.86 ppm. These values tell of relatively low concentration of carbonates, bicarbonates and hydroxides. The highest alkalinity values were recorded for the samples picked from OF and the lowest for JS and AT.

Turbidity, a measure of how clear the water is recorded very low values ranging from 0.00-1.34 NTU with eighteen of the samples below detection limit (indicating complete clarity). This gives a reflection of the total suspended solids to which turbidity is inversely related. Turbidity is also an indication of clay or other inert suspended particles in drinking water. The sources from which the samples were picked are such that the wells have their inside walls, coated with mortar (cement). This prevents clay/sand from the surrounding earth from getting into it. They also had very fitting coverings that were always put in place after use. Total dissolved solids in mg L^{-1}, recorded values that ranged from 5-67 ppm.

The concentration of chloride ion ranged from 1.77-57.40 ppm with an average value of 21.41 ppm. Compared to the WHO acceptable value of 250 ppm, the levels of chloride concentration can be tolerated, since they can cause no harm to consumers. These low concentrations also confirm the earlier discussion on conductivity.

The concentrations of nitrate determined for the samples ranged from 0.125-7.875 ppm with an average value of 2.1197 ppm. It could be discussed that none of the samples recorded a value that exceeds the acceptable value o f 10 ppm. With an average value of 2.1197 ppm which is far below the tolerable value and also represents the nitrate level of the groundwater bodies in the district, it could be said that disorder due to nitrate are not likely to be encountered by users of the water. Phosphate also recorded an average value of 2.652 ppm from a range of 1.25-4.17 ppm.

According to Tode, a heavy metal is a chemical element with a specific gravity that in at least, 5 times the specific gravity of water which is 1.0 at 4°C. However, in medicine, heavy metals are loosely defined to include all toxic metals, irrespective of their atomic weight. In the light of these definitions, the metals determined in this project work, fall into the heavy or toxic metal category e.g., iron has a specific gravity of 7.9, Lead = 11.34. In this reference, some of these metals in tolerable concentrations are very beneficial to consumers. Iron for example is made a portion of some multivitamin drugs and products.

On the other side, they become toxic when in excess or not they are not metabolized by the body and they accumulate in the soft tissues. In cooperation with the U.S Environmental Protection Agency (EPA), the Agency for Toxic Substances and Disease Registry (ATDR) has compiled a priority list called the Top 20 hazardous substance. On this list, Lead (Pb) remains second to arsenic. Lead happens to be the only metal amongst the five which is believed to have no known vital or beneficial effect on organisms. The average values recorded for the metals are Ni (0.1896), Pb (0.0811), Fe (0.9617) and Cu (0.175) all in ppm. From the values listed above, it could be discussed that Zinc and copper recorded average values that are below the maximum allowable as set by the World Health organization which are 3, 2 ppm, respectively.

The highest value, recorded for zinc was 0.388 ppm for AD whereas the highest value recorded for copper was 0.633 ppm for AS. These might be attributed to natural existence in the earth, since there are so far no known anthropogenic factors that could introduce these metals into the water bodies.

Whereas zinc and copper recorded values below their maximum allowable values, metals like iron with an average concentration of 0.9617 ppm exceeded the WHO limit of 0.3 ppm. From the Table 1 and 2 of results, only four of the thirty samples recorded values that were below 0.3 ppm.

Some of the samples recorded values are high as 2.232 ppm (NW) whereas the others ranged between 0.31-1.68 ppm. This actually presents a high risk to consumers. Since there are no known industries in the district to contribute to the high levels of iron by means

Table 1: Physicochemical parameters

Name of sample WHO	pH	Conductivity/ μS/cm	TDS $mg\ L^{-1}$	Turbidity NTU	Total hardness/ mg/L	Chloride/ mg/L	Alkalinity $mg\ L^{-1}$	Nitrate/ mg/L	Phosphate/ mg/L
AM1	6.89	68.40	46	1.03	9.00	12.41	142.50	2.433	2.50
AM2	6.67	18.00	12	0.00	10.00	10.64	32.50	2.266	1.25
AM3	6.82	51.40	35	0.00	10.00	26.59	70.00	1.766	2.50
AS1	6.74	25.70	18	1.00	9.00	17.73	33.30	2.908	2.50
AS2	6.75	25.80	18	0.61	10.00	10.64	37.50	6.697	2.50
AS3	6.96	78.50	53	0.30	13.00	40.77	112.50	5.115	2.50
AB1	6.74	47.80	33	1.34	9.00	23.04	47.50	2.773	2.92
AB2	6.95	65.90	45	0.53	10.00	12.40	140.00	7.974	2.50
NS1	6.84	50.10	35	0.42	13.00	19.50	87.50	0.539	2.50
NS2	6.87	50.50	35	0.18	8.00	17.73	82.50	2.783	2.50
NKK1	6.79	75.10	51	0.05	10.00	57.40	20.00	1.898	3.33
NKK2	6.74	74.00	50	0.07	10.00	40.77	22.51	5.441	2.50
NK1	6.67	85.90	58	0.00	20.00	56.72	45.00	0.546	2.08
NK2	6.69	75.00	51	0.00	10.00	53.18	22.50	8.039	3.75
NK3	6.80	87.70	60	0.00	12.00	54.95	65.00	7.615	2.08
OF1	6.86	45.40	31	0.00	10.00	5.32	110.00	4.049	2.50
OF2	6.87	42.10	29	0.00	13.00	7.09	107.50	3.227	3.75
OF3	6.86	41.90	29	0.00	20.00	3.55	107.50	2.671	3.33
OF4	6.86	45.80	29	0.00	18.00	1.77	100.00	3.388	2.50
OF5	6.86	42.00	31	0.00	11.00	8.86	102.50	4.184	4.17
NW	6.84	58.20	39	0.24	8.00	15.95	37.50	1.470	1.25
JS	7.03	36.80	25	0.00	9.00	5.32	17.50	4.184	2.50
KN	7.35	8.49	5	0.00	7.00	24.82	25.00	2.447	1.25
OK	6.82	59.70	41	0.17	10.00	3.55	170.00	1.924	2.08
AR	6.94	37.00	25	0.00	9.00	28.36	77.50	7.875	3.75
AD	6.97	37.00	18	0.00	8.00	1.77	77.50	0.125	2.92
DT	7.20	58.30	39	0.00	15.50	54.95	20.00	1.441	3.75
KD	7.07	46.90	33	0.00	13.00	8.86	90.00	1.612	3.33
KO	7.11	41.80	29	0.00	10.00	3.55	105.00	2.414	1.25
AT	7.32	99.20	67	0.00	16.50	14.18	17.50	1.934	3.33

Table 2: Results for trace metals

Sample name WHO	Ni (0.02)	Pb (0.3)	Zn (3.0)	Cu (2.0)	Fe (0.02)
AM1	(0.039±0.006)	0.142±0.021	0.023±0.006	0.161±0.003	0.310±0.003
AM2	0.040±0.008	0.161±0.026	0.021±0.000	0.105±0.001	0.978±0.009
AM3	0.049±0.008	0.170±0.012	0.008±0.002	0.097±0.002	0.329±0.006
AS1	0.173±0.011	0.145±0.012	0.115±0.011	0.082±0.004	1.255±0.006
AS2	0.129±0.004	0.157±0.025	0.061±0.049	0.633±0.013	0.351±0.008
AS3	0.107±0.006	0.178±0.008	0.056±0.039	0.116±0.000	0.335±0.011
AB1	0.255±0.009	0.149±0.010	0.137±0.057	0.076±0.004	1.332±0.003
AB2	0.179±0.005	0.131±0.030	0.174±0.003	0.119±0.004	0.575±0.005
NS1	0.257±0.005	0.122±0.031	0.056±0.002	0.173±0.008	1.428±0.010
NS2	0.099±0.005	0.127±0.020	0.033±0.004	0.061±0.009	0.521±0.013
NKK1	0.246±0.008	0.107±0.011	0.197±0.005	0.308±0.004	1.251±0.002
NKK2	0.099±0.008	0.111±0.027	0.198±0.003	0.134±0.005	1.227±0.013
NK1	0.142±0.002	0.156±0.022	0.154±0.011	0.307±0.255	1.594±0.003
NK2	0.290±0.003	0.114±0.011	0.124±0.036	0.160±0.007	1.614±0.007
NK3	0.256±0.006	0.183±0.037	0.142±0.005	0.126±0.002	0.084±0.007
OF1	0.093±0.004	0.270±0.015	0.180±0.007	0.122±0.007	0.338±0.011
OF2	0.100±0.008	0.137±0.022	0.087±0.055	0.199±0.001	0.069±0.012
OF3	0.139±0.008	0.156±0.034	0.030±0.006	0.075±0.002	0.101±0.008
OF4	0.101±0.006	0.139±0.015	0.015±0.005	0.155±0.004	0.299±0.004
OF5	0.236±0.003	0.614±0.015	0.034±0.004	0.104±0.002	1.548±0.016
NW	0.239±0.006	0.129±0.022	0.047±0.002	0.102±0.006	2.232±0.022
JS	0.269±0.004	0.104±0.007	0.033±0.006	0.168±0.002	1.561±0.024
KN	0.224±0.012	0.139±0.025	0.047±0.006	0.122±0.003	0.557±0.011
OK	0.255±0.007	0.134±0.064	0.027±0.005	0.082±0.007	1.680±0.014
AR	0.413±0.009	0.112±0.022	0.027±0.002	0.546±0.008	1.025±0.012
AD	0.269±0.008	0.188±0.015	0.388±0.004	0.351±0.008	1.561±0.004
DT	0.270±0.009	0.162±0.010	0.015±0.003	0.329±0.008	1.521±0.024
KD	0.203±0.005	0.123±0.018	0.001±0.006	0.065±0.006	0.560±0.020
KO	0.249±0.006	0.088±0.007	0.000±0.008	0.055±0.005	1.245±0.014
AT	0.267±0.008	0.151±0.047	0.002±0.002	0.108± 0.004	1.371±0.013

± values are expressed as Mean±SD

of industrial effluent, anthropogenic factors could be attributed to sewage, land fill leachate and wear and tear from rejected machine, cars (hardware) etc. These levels of iron are likely to form deposits within pipes (in case where pipes are used to draw the water) and break off as black particles that give an unpleasant appearance and taste to the water. Iron can also cause rust flakes and cause staining in laundry.

Lead (Pb) on the other hand also recorded an average value that exceeded the WHO tolerable value of 0.01 ppm. Actually, none of the thirty samples recorded a value below 0.01 ppm. The range was from 0.088-0.188 ppm. This shows the presence of relatively high distribution of lead in the district. It is evident that lead is used in paints (as pigment), PVC plastics, pencils, batteries, pesticides etc. which happens to be the human activities that introduce lead into the environment. Since the communities are farming areas, it appears that the use of pesticides is likely to be the greatest cause of the high levels of lead in the water. The careless use of fuels like petrol can also be a factor contributing to the high levels of lead in the earth affecting the water bodies. According to the oxford dictionary of chemistry, 5th edition, Pg 281, lead in petrol and metal ions can leach by acid rain and introduce lead and other metals into water bodies.

The last of the metals determined, nickel also recorded an average value above the WHO allowable limit of 0.2 ppm. Nickel recorded values within the range of 0.03-0.290 ppm with an average value of 0.1896 ppm. From the range quoted, it could be seen that none of the samples recovered a value that is below the tolerable value of 0.02 ppm. This value compared to lead represents the extent to which nickel is also widely distributed in the district. It presents a view of the risks to which consumers of the water are exposed. Larger doses of nickel are carcinogenic and toxic affecting among others the skin, bones and teeth of consumers. The concentration of the heavy or toxic metals analyzed, nickel, lead, zinc and copper recorded values below 0.2 ppm even though nickel and lead with these seemingly small values exceeded their maximum tolerable values as set by the World Health Organization (WHO) for drinking water. From the values, three metals (Ni, Pb, Fe) recorded individual and average values that exceeded their allowable limits. For some heavy metals, toxic levels can be a concentration just above the background concentration naturally found in nature.

Scrap metal from the work of blacksmiths, pesticides used by the farmers and the rocky nature of the district, among several other reasons are likely to be the cause of the high levels of metals, widely distributed in the earth, affecting the well water bodies. Pollution could also be due to the availability of trace metals in the cement and other materials (e.g., Iron rods) uses to smoothen and decorate the inside of the wells. These sources have a continual access to the water and can really affect the water. Mention can also be made of the fact that the history of this district is such that there were wars in the olden days that involved the use of ammunitions which introduced some metals like lead etc.

CONCLUSION

In the light of the parameters determined, it can be concluded that users of the groundwater body in the Kwahu west district of the Eastern region are not likely to have any adverse effect as far as parameters like (pH, alkalinity, conductivity, total hardness, total dissolved solids, nitrate, phosphate, turbidity, copper, zinc and chloride) are concerned. This is because, these parameters recorded values that were below or within their allowable ranges.

On the other hand, effects due to Ni (0.093-0.413 ppm), Pb (0.088-0.270 ppm) and Fe (0.069-1.689 ppm) are likely to be encountered because almost all the samples recorded values that exceeded their maximum WHO allowable limits for these metals. Most of the values especially for iron exceeded the WHO limit of 0.3 ppm eg. OK-1.680 ppm.

The maximum value recorded for lead, (0.270 ppm), exceeded the WHO limits (0.01 ppm). Also for nickel, the maximum value recorded (0.413 ppm) exceeded the WHO limit (0.02 ppm). However, it is highly recommended that further research be done to verify these levels of iron, nickel and lead as well as other microbiological indicators so that the necessary treatment can be done on the water before consumption.

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