

# Physico-chemical quality of boreholes in Densu Basin of Ghana

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**Abstract** Physico-chemical characteristics of 74 boreholes from communities within Densu Basin were assessed following procedures outlined in Standard Methods for the Examination of Water and Wastewater. The aim was to assess the status of the boreholes water quality for any contamination for management action to ensure the quality of health of the people in the area. The water quality parameters analyzed included conductivity, pH, turbidity, color, major ions, nutrients, and metals. The study showed that most of the physico-chemical constituents were within the WHO guideline limits. pH values ranged from 6.0 to 8.21, while conductivity varied between 117 and 3,500  $\mu\text{S}/\text{cm}$  and turbidity from 0.6 to 19.0 NTU. However, a few of the parameters fell outside the limits prescribed by the World Health Organization (WHO 2004). Fourteen, 9, and 7% of the boreholes exceeded the WHO guideline values for nitrate ( $\text{NO}_3$ ), fluoride ( $\text{F}^-$ ) and iron (Fe), respectively. Locations where high concentration of Fe and Mn occurred, efforts must be made to remove them to discourage the use of surface waters which may be contaminated by harmful bacteria.

**Keywords** Borehole · Ghana · Water quality · Physico-chemical · Densu Basin

## Introduction

Water is essential to the existence of man and all living things. Groundwater occurs almost everywhere beneath the

earth surface not only in a single widespread aquifer, but also in thousands of local aquifer systems and compartments that have similar characters. Man's activities such as food production, nutrition are dependent on water availability in adequate quantities and good quality. Rural communities in Ghana, which form about 56.0% of the total population, rely mostly on groundwater as the main source of drinking water (Ghana Statistical Service 2002). Groundwater accounts for more than 95% extraction through drilled wells for hand pumps or mechanized piped systems in Ghana (Washnews 2009). However, the occurrence of metals such as iron (Fe), manganese (Mn) and arsenic (As) in the groundwater reserves in certain areas of the country is a challenge limiting the extent to which this resource can be exploited. Drilling records have shown that on the average, 20% of wells drilled for domestic water supplies contain high levels of manganese and iron, above the Ghana Standards Board permissible limits of 0–0.1 mg/l (manganese) and 0.3 mg/l (iron) in six regions in Ghana namely Ashanti, Western, Central, Eastern, Volta, and Greater Accra (CWSA 2009).

The task of providing safe drinking water to the inhabitants of rural Ghana is a daunting one. Though Ghana has achieved political stability and fostered economic development over the past decade, not all of its populace has access to good drinking water. Analysis of available data by the Water and Sanitation Sector Monitoring Platform (WSMP) of Ghana showed that there was a considerable increase in the proportion of the population that used improved drinking water sources from 56% in 1990 to 74% in 2006 (Washnews 2009). Access to an improved water source refers to the percentage of the population with reasonable access to an adequate amount of water from an improved source, such as a household connection, public standpipe, borehole, protected well or spring, and rainwater

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collection. Unimproved sources include vendors, tanker trucks, and unprotected wells and springs. Reasonable access is defined as the availability of at least 20 l a person per day from a source within 1 km of the dwelling (World Bank 2004).

Groundwater pollution occurs widely from a variety of anthropogenic sources. These include point sources such as waste disposal facilities, industrial pollution, wastewater treatment works, on site sanitation, cemeteries, and many others. Diffuse pollution includes agricultural practices, atmospheric fallout, and other sources. Changes in land usage, such as the clearing of vegetation, over-abstraction of groundwater, or excavation below the water table, can also contribute significantly to groundwater pollution (Tredoux et al. 2004). Groundwater pollution not only affects water quality, but also threatens human health, economic development, and social prosperity (Milovanovic 2007). River basins are highly vulnerable to pollution due to absorption and transportation of domestic, industrial, and agricultural waste water; therefore, it is significant to control water pollution and monitor water quality (Simeonov et al. 2003).

Work done by Pelig-Ba et al. (1991) focused on trace metal concentrations in the Accra plains and Upper Regions of Ghana. The results showed that more than half of the boreholes sampled had lead (Pb) and chromium (Cr) levels in excess of WHO recommended guidelines. Fifty percent of all the boreholes in the Accra Plains and 35% in Upper West had excess iron (Fe) compared to the WHO guideline of 0.3 mg/l. Kortatsi (2007b) work in the Ankobra basin showed that the groundwater in the basin was mildly acidic. The dominant anion was bicarbonate, but no clear cut dominant cation with low concentrations of trace metals. Earlier published work by Tay and Kortatsi (2007) showed that most of the chemical parameters in the groundwaters of the Densu Basin were within the WHO limits for drinking water, posing no health threat to consumers. However, the levels of nitrates in some areas exceeded the critical value of 10 mg/l. Groundwater in the Ga and Suhum districts was found to be more mineralized, suggestive of heavy impact of human activities and existence of old waters. It has also been shown by Ansa-Asare et al. (2009) during the assessment of groundwater in the Volta region that Fe and Mn exceeded the WHO guideline limits. However, physico-chemical parameters were within the WHO guidelines. Schafer et al. (2010) also did an extensive work on water quality including groundwater in Ghana. High levels of iron and manganese were found in the Volta region and fluoride in other locations of the country.

The Densu Basin in Southern Ghana is confronted with three agents of degradation: bad farming practices, deforestation, and pollution. The activities of farmers (high usage

of fertilizer and other chemicals) both subsistence and large scale commercial farmers in the catchment of the river are causing a lot of challenges both to the water quality and quantity. Thus, causing chemical contamination.

The objective of this paper is to assess the water quality status of selected boreholes in the Densu River Basin to ensure the quality of health of the people in the area.

## Materials and methods

### Study area

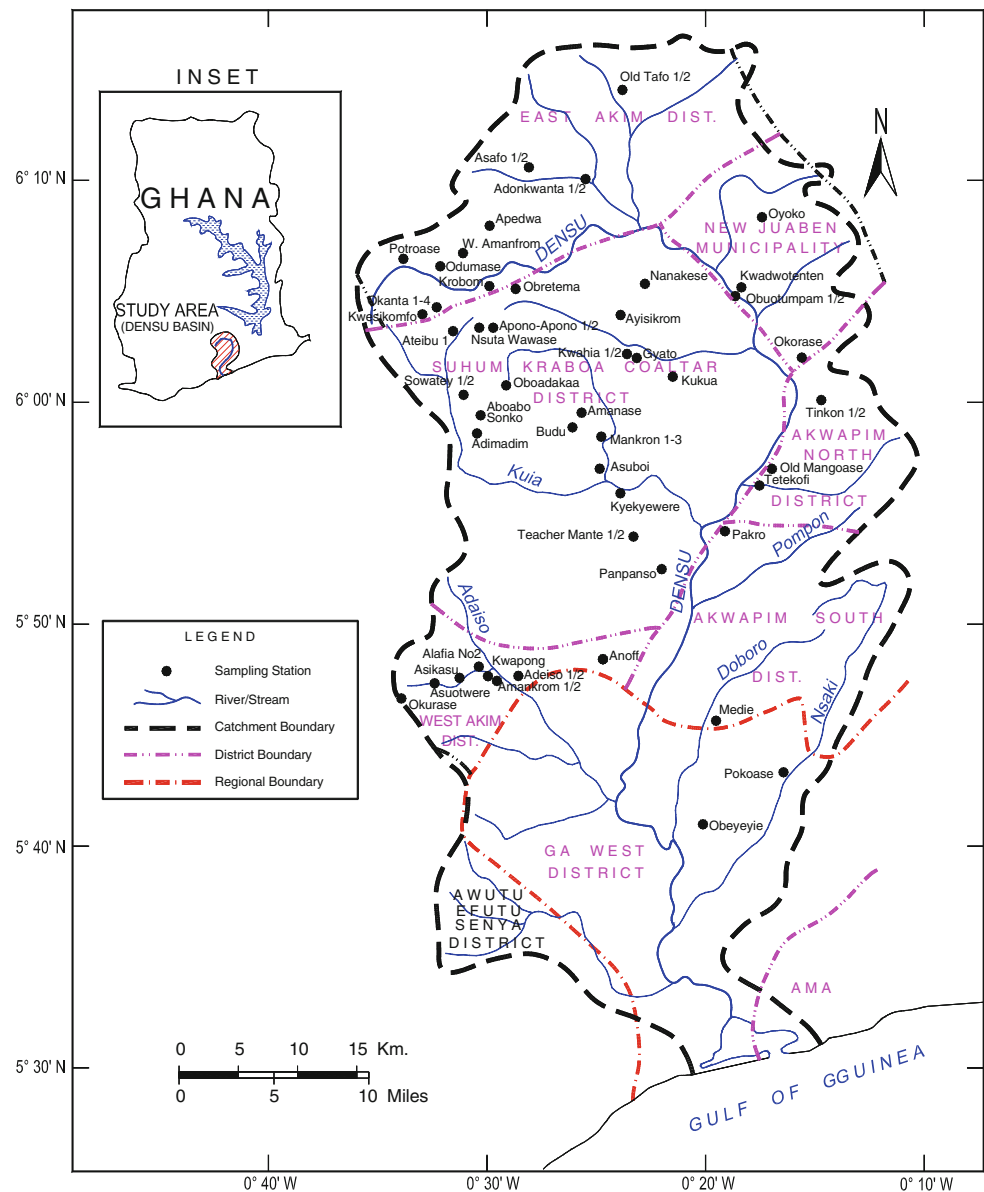
The Densu Basin located between latitudes 5°30'N to 6°20'N and longitudes 0°10'W to 0°35'W (Fig. 1) has an estimated drainage area of 2,488.41 km<sup>2</sup> with an average length of 225.6 km (Kusimi 2008). Its main tributaries are the Kuia, Adaiso, Nsaki, Doboro, and Pompom. The Densu Basin passes through three major regions in Ghana namely: Eastern, Greater Accra, and Central Regions and falls under ten district administrations.

The Greater Accra region is the most industrialized region in Ghana consisting of the two major industrialized cities in Ghana such as Accra and Tema harbor city. The basin plays a critical role in the socio-economic development of these two cities and many towns, satellites villages dotted within it (Afful et al. 2010). Most of the urban centers such as Accra, Koforidua, Nsawam, and Suhum among others get treated water from the Densu River. Other small settlements also depend on untreated water from the Densu River and its tributaries.

The Densu Basin is also intensively used for the cultivation of both cash and food crops. Principal food crops cultivated within the basin are cassava, maize, yam, plantain, banana, and cocoyam. Cash crops include cocoa, oil palm, papaya, pineapple, mangoes, and citrus. Vegetables cultivation also takes place along the banks of the Densu River. Other land-use activities include housing, sand winning, animal rearing, salt mining etc. These activities have seriously depleted the vegetative cover of the basin with hydrological and geomorphologic implications such as flooding, soil erosion, siltation of the river channel, and evaporation (Kusimi 2008). Another economic activity in the Densu basin is fishing. Most of the towns and villages including city dwellers in Accra get their fish supply from the Densu basin. Commercial fishing sites in the basin include Nsawam and Weija (Afful et al. 2010).

The Basin falls under two distinct climatic zones: the dry equatorial climate of the South East (SE) coastal plains and the wet semi-equatorial climate further north from the coast. Both climatic zones are characterized by two rainfall regimes with different intensities (Dickson and Benneh 2004). The major rainy season extends from April/May to

**Fig. 1** Map of Densu Basin showing the sampling sites



July and attains a peak in June. The second rainfall period is a minor one that occurs between September and November. The mean annual rainfall varies from about 800 mm near the coast to about 1,600 mm in the source area. Temperatures are uniformly high throughout the year. The mean annual temperature is about 27°C (WRI 2003), with March/April being the hottest (32°C) and August being the coldest month (23°C).

Densu Basin is predominantly underlain by Precambrian granitoids comprising mostly Cape Coast granite and granodiorites with associated gneisses. Upper Birimian and the formation occurring at the extreme northwest and covering only ~4% of the study area consist mainly of metamorphosed lava, tuff, and pyroclastic rocks (Kesse 1985). The Togo formation (6%) occurs in the southeast. It

is highly folded and jointed and consists of sandstones, quartzites, quartz schist, shale, phyllites, and some tale mica schist. The Cape Coast granitoids are well foliated, often magmatic, potash-rich granitoids that often come in the form of muscovite biotite granites and granodiorites, porphyroblastic biotite gneiss, aplite, and pegmatite. These granitoids are often characterized by the presence of enclaves of schists and gneisses (Kesse 1985).

#### Sampling and analysis

Water samples were collected from boreholes in the Densu River Basin of Ghana between June 2004 and February 2005. In all 74 existing boreholes, water was sampled. In order to collect fresh and representative samples, the

boreholes were pumped on the average 5 min before the samples were collected. The samples were collected into acid cleaned polyethylene 1-l bottles without preservation. The samples meant for heavy metal analysis were acidified to a pH of <2 by the addition of Merck™ ultra pure nitric acid in the field. Electrical conductivity, temperature, and pH were measured in situ using Multi-parameter analyzer, Eijkelkamp model, 8.21.

All the samples were kept in an ice box and transported to the CSIR Water Research Institute laboratory, stored in a refrigerator at a temperature of about 4°C until analysis was completed. All laboratory analyses on the samples were carried out using appropriate certified and acceptable international procedures outlined in the Standard Methods for the Examination of Water and Wastewater (APHA et al. 1998). Sodium (Na) and potassium (K) were analyzed by flame photometric method, calcium (Ca) by EDTA titration, magnesium (Mg) by calculation after EDTA titration of calcium and total hardness, chloride (Cl) by argentometric titration. Nitrate, nitrite, phosphate, fluoride, chloride, and sulphate were determined by ion chromatography (Dionex DX-80 ion analyzer). The analysis of heavy metals was carried out using atomic absorption spectrophotometer (Unicam 969).

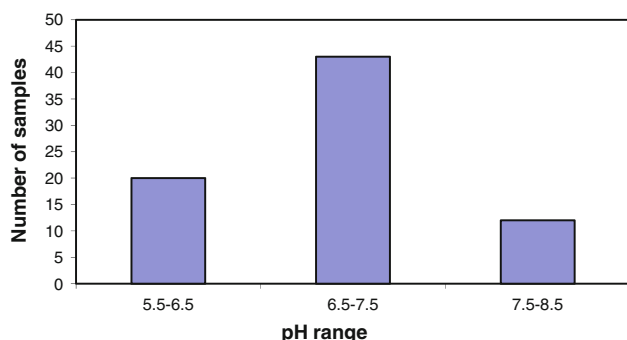
Analytical results were checked by computing the ionic error balance. Results with ionic balance error >5% were rejected in accordance with international standards.

## Results and discussion

### Physical parameters

#### pH

The boreholes were generally acidic to alkaline with pH ranging from 6.0 to 8.2 pH units, displayed in Fig. 2. A total of 19 samples (about 25%) were outside the WHO guideline range of 6.5–8.5 pH units. The lowest pH was found at Obretema and the highest found at Tetekofi. Tay and

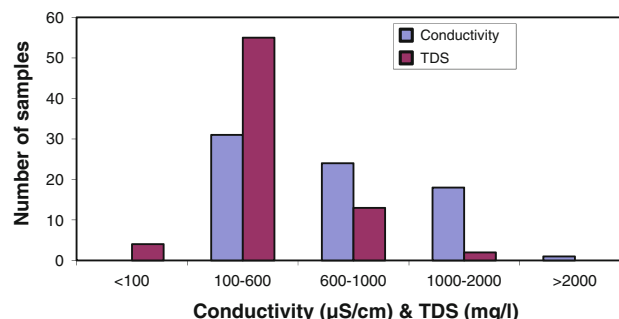


**Fig. 2** Distribution of pH values found in samples

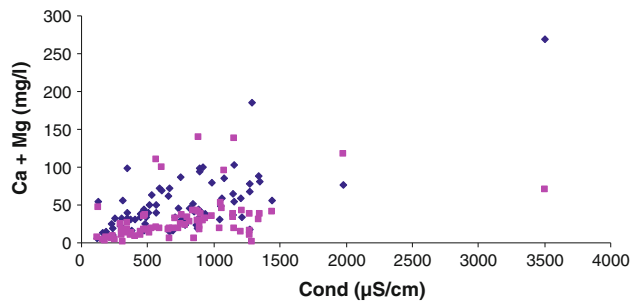
Kortatsi (2007) reported pH range of 4.37–7.40 in the same basin. Though the health impacts of such non-compliance are not clear, values of very low pH would make the water corrosive and hence place further strain on equipment according to Schafer et al. 2010. According to Ansa-Asare et al. (2009), the nature of the geology in an area could account for low-pH values. Acidity increases the capacity of the water to attack geological materials and leach toxic trace metals into the water making it potentially harmful for human consumption. The pH for boreholes in the Accra Plains reported by Pelig-Ba et al. (1991) ranged from 6.9–8.3. Studies on groundwater in the Wassa West district in the Western Region of Ghana by Kortatsi (2007a) showed a pH range of 4.5–6.9, though a few of the boreholes showed strong acidic character (pH range 3.7–4.0). Other reported results are 5.27–7.49 for Akatsi district, 5.70–7.87 for Adidome district and 5.13–8.37 for Ho district, all in the Volta Region (Ansa-Asare et al. 2009).

### Conductivity and total dissolved solids (TDS)

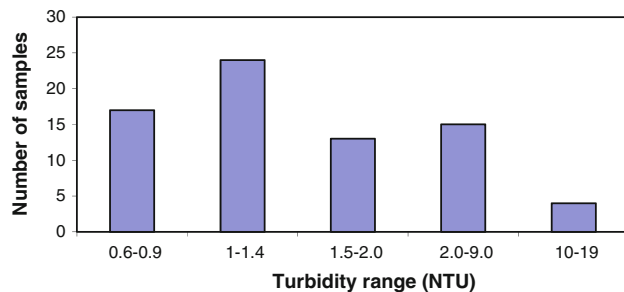
Electrical conductivity is an indication of the concentration of total dissolved solids and major ions in a given water body. The ionic content measured by electrical conductivity (EC) ranged from 117 to 3,500  $\mu\text{S}/\text{cm}$  within the basin. This is indicative for large variability in salinity of the groundwater. The greatest number of samples fell within the range of 100–600  $\mu\text{S}/\text{cm}$  (Fig. 3). Pokuase recorded the highest conductivity of 3,500  $\mu\text{S}/\text{cm}$ . A total of 19 samples (about 25%) exceeded 1,000  $\mu\text{S}/\text{cm}$ . Tay and Kortatsi (2007) also observed conductivity range of 134–7,780  $\mu\text{S}/\text{cm}$  with the highest value of 7,780  $\mu\text{S}/\text{cm}$  occurring at Pokuase. The TDS ranged from 64 to 1,925 mg/l with a mean of 427 mg/l. A health-based value has not been proposed by the WHO; however, a TDS above 1,000 mg/l may be objectionable to consumers. The highest TDS (1,925 mg/l) was observed at Pokuase in the Greater Accra region. Pokuase lies along a contact zone between the Cape Coast Granite and the Togo series. The main rock types underlying the project site are quartzite on



**Fig. 3** Distribution of conductivity and TDS found in samples



**Fig. 4** Scatter diagram of Ca + Mg as a function of conductivity

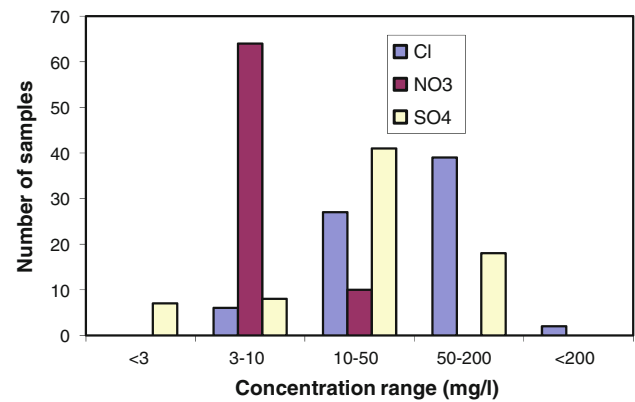


**Fig. 5** Distribution of turbidity found in samples

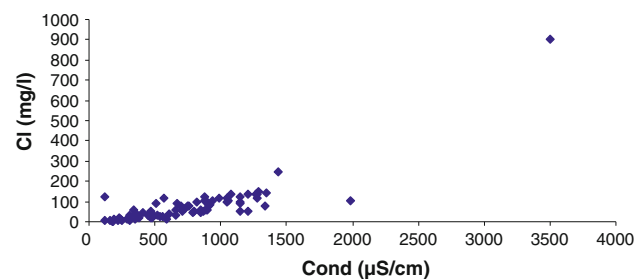
one hand and granite on the other (Kesse 1985). These rocks either weather to form overburden material of coarse permeable sandy sediments or remain massive depending upon the degree of structural deformation that the rocks may have undergone. Like all geologic contact zones, the study area may be subjected to serious tectonic, thermodynamic, and hydrodynamic activities, resulting in mixed waters with diverse chemical content or characteristics. The electrical conductivity was strongly correlated with the concentrations of calcium (Ca) and magnesium (Mg) as indicated in the relationship (Fig. 4).

#### *Turbidity and color*

Turbidity values ranged from 0.6 to 19.0 NTU with a mean of 2.6 NTU. Most of the boreholes (24 samples) tested were in the 1–1.4 NTU group (Fig. 5). Four borehole samples showed turbidities between 10 and 19 NTU. Ten samples from Addonkwanta, Adinam, Aboabo Sonko, Oboadaka, Mankrong, Nsuta Wawase, KwesiKomfo, Aposs (Okasa), Obuotumpan, and Obeyeyie had their turbidity values exceeding 5.0 mg/l. The WHO guideline for turbidity in drinking water is 5 NTU. The high turbidity may be attributed to larger particles such as organic matter and dissolved solids. Schafer et al. (2010) found turbidities in the range of <math><2\text{--}266\text{ NTU}</math> in most bore water throughout Ghana. Color is an important physical property of water because of its implications for water supply and the need to reduce it to acceptable levels by water treatment. The color



**Fig. 6** Distribution of chloride, nitrate and sulphate concentrations in samples



**Fig. 7** Scatter diagram of Cl<sup>-</sup> ion concentration as a function of conductivity

for the boreholes ranged from limit of detection (LOD) of 2.5–25.0 Hz with an average of 7.7 Hz. The highest water color value (25.0 Hz) occurred at Aboabo Sonko and 16% of the samples exceeded the WHO guideline value of 15 Hz. Color in natural water usually results from the leaching of organic materials and it is primarily the result of dissolved and colloidal humic substances (Karikari and Ansa-Asare 2006).

#### Nutrients

The ranges of chloride, nitrate, and sulphate are shown in Fig. 6. Chloride (Cl<sup>-</sup>) and sulphate (SO<sub>4</sub><sup>2-</sup>) do not have health-based guidelines, but may cause concern due to taste if found at higher concentrations. The WHO guideline suggests that Cl<sup>-</sup> levels over 250 mg/l may decrease the acceptability of the water due to taste, as well as leading to corrosion of metals. Cl<sup>-</sup> levels in the samples ranged from 3.0 to 903 mg/l of which 1% of the total samples exceeded the taste guideline. The highest chloride level (903 mg/l) occurred at Pokuase. Chloride showed a fairly strong correlation with conductivity (Fig. 7), which indicates high mineralization. The high chloride may be attributed to natural geochemical activities. Chloride concentration of



boreholes in the Akatsi district of the Volta Region ranged from 6.00 to 993 mg/l as reported by Ansa-Asare et al. (2009). Tay and Kortatsi (2007) recorded chloride levels in the range of 3.4–2,382 mg/l in the Densu Basin. However, very low chloride levels (0.5–121 mg/l) were found in groundwater in the Ankobra Basin (Kortatsi 2007b).

As stated earlier, sulphate ( $\text{SO}_4^{2-}$ ) does not have a health-based guideline value; however, the WHO recommends that levels higher than 400 mg/l should be reported to “the health authorities” due to problems to the gastrointestinal tract (WHO 2004). Sources can be both natural and industrial. The concentrations of sulphate in the samples ranged from 0.2–146 mg/l. The highest concentration of 146 mg/l occurred at Okurase. None of the samples exceeded the WHO recommended guideline. Tay and Kortatsi 2007 recorded sulphate levels between 0.0 to 282.0 mg/l in the Densu Basin. The median values of  $\text{SO}_4^{2-}$  for the Akatsi, Adidome and Ho districts in the Volta Region were 30.4, 27.3, and 39.8 mg/l, respectively (Ansa-Asare et al. 2009).

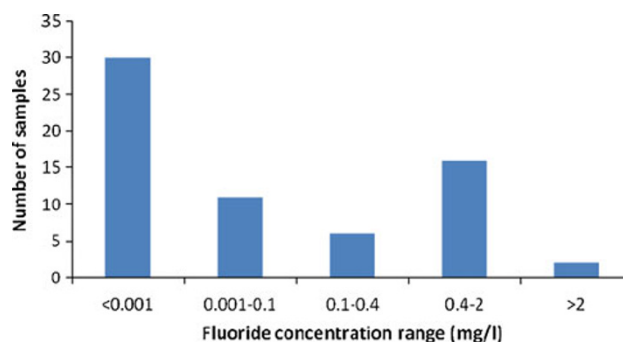
Nitrate is a contaminant that is regulated as it has significant health risks associated with excess nitrate consumption in the human diet. These include methemoglobinemia in infants (“blue baby syndrome”) (Fewtrell 2004). Nitrate concentrations ranged from LOD to 34.3 mg/l. The WHO has adopted the 10 mg/l standard as the maximum contaminant level (MCL) for nitrate–nitrogen. Out of the total number of samples, about 14% of the samples were above the guideline value of 10 mg/l. The high values could be as a result of nitrates from fertilizers being leached below the plant’s root zone and eventually reaching groundwater (Ansa-Asare et al. 2009). The high nitrates may also result from weathering of rocks containing nitrates as a result of geology of the area. Tay and Kortatsi (2007) recorded nitrate levels between 0.1 to 106.0 mg/l in the Densu Basin. Nitrate–nitrogen ( $\text{NO}_3\text{-N}$ ) in groundwater may also result from point sources such as sewage disposal systems and livestock facilities, non-point sources such as fertilized cropland or naturally occurring sources of nitrogen. Nitrite levels ranged from 0.003 to 1.05 mg/l with an average of 0.15 mg/l.

Phosphorus is used as an agricultural fertilizer and in household cleaning detergents as well as in industry. Phosphorus in groundwater is not very mobile in soils, it is considered to be retained in the soil zone. Phosphorus concentration for the boreholes ranged from <0.001 to 3.27 mg/l with an average of 0.23 mg/l. The WHO did not state any guideline value; however, the European Community (EC) maximum allowable concentration for phosphorus in drinking water is 5 mg/l.

Fluoride is one of the most reactive non-metal compounds that are common in groundwater in Ghana. Studies indicate that the proportion of water sources (boreholes)

with fluoride levels higher than 1.5 mg/l is in the range 20–30% (CWSA 2009). The areas with high-fluoride concentrations are where the bedrock geology is dominated by granites and some birimian rocks (BGS 2001). Fluoride ( $\text{F}^-$ ) offers protection against dental caries at low concentrations, but at higher levels causes serious problems such as dental and skeletal fluorosis (Schafer et al. 2010). The concentration levels of the samples ranged from LOD to 25.2 mg/l. The WHO guideline value for fluoride is 1.5 mg/l. About 9% of the samples (from Tinkong, Okanta, Sowatey, Adimadim, Oboadakaa, Amoakrom and Kyekeywere) exceeded the WHO guideline. The highest fluoride level (25.2 mg/l) was found in a borehole in Okanta in the East Akim District. Figure 8 displays the distribution of fluoride concentration in the samples.

The statistics of the major cations is represented in Table 1. The calcium values ranged from 6.4 to 269 mg/l. The median calcium concentration in the boreholes was 41 mg/l and the mode value was 32 mg/l. Magnesium values were between 1.9 to 140 mg/l with mode of 11.0 mg/l and median of 20.0 mg/l. Sodium values for the period of sampling ranged from 6.3 to 210 mg/l. The mode and median values were 25.0 and 42.0 mg/l, respectively. The potassium levels were between 1.1 and 7.4 mg/l and its mode and median were 3.3 and 3.1 mg/l, respectively. The cationic dominance encountered in the Basin was  $\text{Ca} > \text{Na} > \text{Mg} > \text{K}$ . Major cations in the Ankobra basin were generally low. It recorded median values of 13.2 mg/l for Ca, 5.80 mg/l for Mg, 16.3 mg/l for Na, and 1.30 mg/l



**Fig. 8** Distribution of Fluoride concentrations in the samples

**Table 1** Statistics of major cations (all in mg/l) in boreholes in Densu Basin

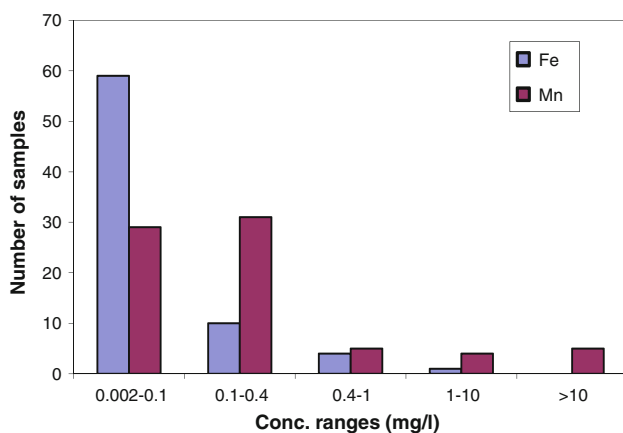
Parameters	Min	Max	Mode	Median
Calcium, Ca	6.4	269	32	41
Sodium, Na	6.3	210	25	42
Potassium, K	1.1	7.4	3.3	3.1
Magnesium, Mg	1.9	140	11.0	20

for K (Kortatsi 2007b). Therefore, the cationic dominance in the Ankobra basin was  $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ .

### Iron and manganese

Iron is present in significant amounts in soils and rocks, principally in insoluble form. However, many complex reactions, which occur naturally in ground formations, can give rise to more soluble forms of iron, which will, therefore, be present in water passing through such formations. Excessive concentrations of iron do not cause health problems, but they are of concern for aesthetic and taste reasons (WHO 2004). Despite not having a health-based guideline for Fe, a value of 0.3 mg/l is mentioned in the WHO drinking water guidelines as a safe concentration, with the comment that taste will often be affected above this level (Schafer et al. 2010). Laundry and sanitary ware will stain at Fe concentrations above 0.3 mg/l. The concentration range of Fe varied widely from 0.002 to 1.19 mg/l (Fig. 9). Wawase in Nsuta recorded the highest concentration of 1.19 mg/l. Out of the total samples, 7% were above WHO guideline value of 0.3 mg/l. This compares favorably with what has been reported by Tay and Kortatsi (2007). Three percent of the samples were above WHO guideline value. In the Adidome district, 50% of the samples had Fe values exceeding the WHO guideline value (Ansa-Asare et al. 2009).

The Manganese concentrations ranged from 0.002 to a maximum of 34.0 mg/l (Fig. 9). The WHO guideline value is set at 0.4 mg/l and 19% of the total samples exceeded the WHO guideline. The highest individual sample concentration for manganese was 34.0 mg/l at a source in Mangoase. The principal objection to the presence of relatively large concentrations of manganese in drinking water is, again, aesthetic. The WHO has set a provisional health-based guideline value of 0.4 mg/l Mn which should be adequate to protect public health (WHO 2004). Twenty-



**Fig. 9** Iron and Manganese distribution of samples

five percent of boreholes and wells within the Ankobra Basin exceeded the WHO guideline value.

Other trace metals analyzed included zinc (Zn), cadmium (Cd) and lead (Pb). Zinc concentrations varied from 0.002 to 0.353 mg/l with a mean of 0.047 mg/l (Table 2). None of the samples exceeded the WHO guideline value (3.0 mg/l) for zinc. Cadmium concentration ranged from 0.002 to 0.007 mg/l with a mean of 0.004 mg/l. The mean concentration of cadmium exceeded the WHO guideline of 0.003 mg/l. The mean concentration of lead was greater than the WHO guideline of 0.01 mg/l. The lead (Pb) concentration ranged from 0.005 to 0.034 mg/l. Twelve percent of the total samples exceeded the WHO guideline for Pb. Pelig-Ba et al. (1991) reported that 25% of boreholes in the Accra Plains had high Zn levels compared to the WHO guideline. Mean level of Pb in the Accra Plains was 0.092 mg/l, while Cd occurred in low concentrations (Pelig-Ba et al. 1991).

### Conclusions

The study revealed that the groundwater in the Densu Basin was of good quality. Although some of the parameters exceeded their World Health Organization guideline values, most of the physico-chemical parameters analyzed were satisfactory. The boreholes were generally acidic to alkaline with pH ranging from 6.0 to 8.21 pH units. About 25% of the total samples were outside the WHO guideline ranging from 6.5 to 8.5 pH units. For the conductivity levels, 25% of the samples exceeded 1,000  $\mu\text{S}/\text{cm}$ . Most of the boreholes had turbidity in the range of 1–1.4 NTU. Chloride levels in the samples were satisfactory. None of the samples had sulphate levels outside the WHO guideline value of 400 mg/l. Fourteen percent of the borehole samples had nitrate levels above the WHO guideline value of 10 mg/l. Fluoride contamination was observed in 9% of the total 74 samples. Although high Fe concentrations may not pose any health hazards to users, the occurrence of the yellowish brown coloration may cause rejection of such waters by communities. Iron and manganese were found in all the samples. Seven and 19% of the total samples exceeded the WHO guideline for Fe and Mn, respectively. Of interest would be for water researchers and other stakeholders in the water sector to carry out more detailed sampling in areas of apparent high inorganic contamination like fluoride since higher levels of fluoride causes serious problems such as dental and skeletal fluorosis. Proper site selection for the location of domestic water wells and proper well construction can reduce potential nitrate contamination of drinking water source. The district assemblies could facilitate the building of iron removal plants to reduce high concentration of Fe and Mn. This will

**Table 2** Statistics of other trace metals (in mg/l) alongside WHO guideline values

Parameter	Average	Standard deviation	Minimum	Maximum	WHO guideline values
Zinc	0.047	0.059	0.002	0.353	3.0
Cadmium	0.004	0.002	0.002	0.007	0.003
Lead	0.013	0.008	0.005	0.034	0.010

discourage the use of surface waters which may be contaminated by harmful bacteria. The Densu Basin secretariat should target public awareness activities on water pollution to enhance water quality in the Basin.

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