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Quality and Potential Health Risk Assessment of Groundwater in Asante Akim Central Municipality, Ghana

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Abstract

This study assesses the quality of groundwater for drinking and irrigation, and its potential health risk to the populace in an area where illegal artisanal mining is prevalent and known to have polluted streams and rivers, making groundwater their key potable water source. The methods employed involved well-distributed sampling of the groundwater in both wet and dry seasons, determining their physicochemical and bacteriological constituents, and assessing its suitability for domestic and irrigation purposes. Statistical analysis, Piper and Gibb's diagrams were used to reveal the hydrogeochemical characteristics of groundwater, World Health Organization (WHO) guideline values and Water Quality Index (WQI) was applied to assess its overall suitability for drinking while Magnesium Hazard (MH), Residual Sodium Carbonate (RSC), Sodium Adsorption Ratio (SAR), Percent Sodium (% Na) and Permeability Index (PI) were utilized to assess the suitability of the groundwater for irrigation. The results indicate Ca-HCO_3 and mixed Ca-Mg-Cl as the prevalent water types in the area in both seasons. The calculated WQI classed 95 % of the water as excellent and good for domestic use in both seasons while the remaining 5 % was classed as very poor due mainly to high arsenic (As) levels. Computed non-carcinogenic and carcinogenic risks of the As through ingestion exposures showed children were more vulnerable to potential cancer risk than adults. On the other hand, the groundwater was generally found to be suitable for irrigation in both seasons. Thus, the study provides useful information for groundwater use and pollution control in the area.

Keywords: Ghana, Groundwater Quality, Water Quality Index, Irrigation, Wet Season, Dry Season

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1 Introduction

In developing countries like Ghana, drinking polluted water is a major health threat to the majority of the populace in rural communities. Thus, many have resorted to the use of groundwater since it is generally considered to have suitable quality for human consumption compared with other alternatives because it is largely protected from pollution by the geological media in which they are found (Asare-Donkor *et al.,* 2016). However, there are cases where groundwater systems can be susceptible to pollution (Appelo & Postma, 2004). Generally, groundwater quality is influenced by the source and path of recharge, mineralogy of the aquifer media and the impacts of anthropogenic activities; these may sometime lead to the groundwater being contaminated and unsafe for use as reported in many studies (Wu *et al.*, 2015; Arveti, 2016; Li *et al.*, 2017; etc.).

Therefore, a holistic assessment of the parameters that influence groundwater quality as well as the identification of the sources of these pollutants is essential before the use of groundwater for any purpose (Rather *et al.,* 2017). Commonly, the WHO guideline values for drinking water are used in evaluating the suitability of water for human consumption and has been applied successfully in many studies worldwide (e.g., Gyamfi *et al.,* 2019a; Li *et al.*, 2018; Gharahi & Zamani-Ahmadmahmoodi, 2020; Thapa *et al.,* 2020). This approach involves a comparison of measured water quality parameters from a sampled water source with either the WHO guideline values or national standards for drinking water to verify whether it meets the specification for drinking. It is used widely because of the ease of its application and serves as the base for most of the other approaches.

Water Quality Index (WQI) is another approach, which has been applied successfully in assessing groundwater suitability for drinking and other industrial purposes in many parts of the world (Stamatis *et al.,* 2011; Ravikumar *et al.,* 2013; Hamlat & Guidoum, 2018; Gyampo *et al.,* 2019; Fadel *et al.,* 2021). This index, determined from the chemical constituents of water by converting them into a single value (Idowu *et al.,* 2022; Sarkar *et al.,* 2022), is one of the most effective techniques for obtaining the overall view of water quality (Tyagi *et al.,* 2013) and communicating water quality information to decision-makers and the public (Tiwari *et al.,* 2017). It also aids in the assessment of changes in water quality trends and has become extremely important in worldwide water resource management (Hamlat & Guidoum, 2018; Sarkar *et al.,* 2022).

Groundwater, often polluted by many trace elements from natural and artificial processes, can have significant health consequences. In their studies, Rahman *et al.* (2018) pointed out that certain trace elements are imperatively indispensable to the well-being of the growth of the human body, but elevated levels could harm health resulting in hypertension, cancer, lung disease, gastrointestinal bleeding, neurological disorder and shortness of breath. Signs such as weight loss, fatigue, and joint pain attested by Bodrud-Doza *et al.* (2019) and Ghosh *et al. (*2020) are attributed to elevated iron (Fe) concentrations in water. Ingestion of high fluoride ion (F^-) can cause dental fluorosis in children 8 years of age and younger as well as skeletal fluorosis (WHO, 2004; Karthikeyan & Lakshmanan, 2011). According to Mora *et al.* (2017), elevated concentrations of nitrate ion (NO_3^-), a contaminant found mainly in groundwater sources, triggered blue baby syndrome or methemoglobinemia in infants. This, as confirmed by Manassaram *et al.* (2006), may also cause stomach cancer.

This study, therefore, seeks to comprehensively evaluate the quality of the groundwater for domestic and irrigation purposes as well as the potential risks associated with its consumption in the Asante Akim Central Municipality (AACM) of Ghana. The majority of the populace in the area depend entirely on groundwater for their various activities. In the past thirty years, the area has witnessed the growing use of pesticides in crop farming, which together with increased illegal artisanal mining activities have polluted the surface water in the area. Studies done in similar areas report elevated levels of arsenic in surface water bodies, groundwater, soils and plants (Asante *et al.,* 2007). Thus, the study would provide extensive baseline information on the suitability of the groundwater for drinking and irrigation purposes and potential dangers linked with its usage to avoid any future health implications on the populace.

2 Materials and methods

2.1 Study area description

The study area, AACM, is located within latitudes 6° 30 'N to 7° 30' N and longitudes 0° 15 'W to 0° 20' W **(Fig. 1)** and has a total land area of approximately 400 km^2. The topography of the area is typically undulating with elevations between 152 m and 610 m. Several rivers and streams drain the municipality; prominent amongst them is the Anuru, Owerri and Bomire rivers. The area is located within a semi-equatorial moist belt with a double maximum rainfall trend ranging from 1700 to 1850 mm. The first rainy season, which is the main season, lasts from May to July while the second season takes place every year from September to November. The region also experiences a heavy dry season, which is normally between December and April (Boadi *et al.,* 2013). The temperature in the area is consistently high throughout the year and it is averagely 26 °C per annum.

Two significant geological formations lie beneath the study area; the Birimian and the Tarkwaian formations **(Fig. 1)** intruded by granitoids, consisting of granites, granodiorites, and granite-gneisses from the Cape Coast and Dixcove Suites, which are characterized by crystalline basement hydrogeologic conditions (Boadi *et al.,* 2013). The extent of weathering and the presence of joint and fracture systems control groundwater availability in the area. The most common aquifer systems are jointed and fractured phyllite, fractured schist, and fractured meta-volcanic rocks. The best aquifers in the area are along the slopes of synclinal troughs where decomposed materials have accumulated in substantial amounts.

Artisanal gold mining through the open-pit mining approach is very popular in the area; this has harmed the environment and contaminated the rivers in the area. Crop cultivation is the main farming activity in the area, with pesticides and fertilizers being applied directly to the farmlands to grow maize, cassava, plantain, cocoyam, and cocoa. Excessive use of these chemicals on farms is washed away as runoff, contributing to pollution of the rivers in the area.

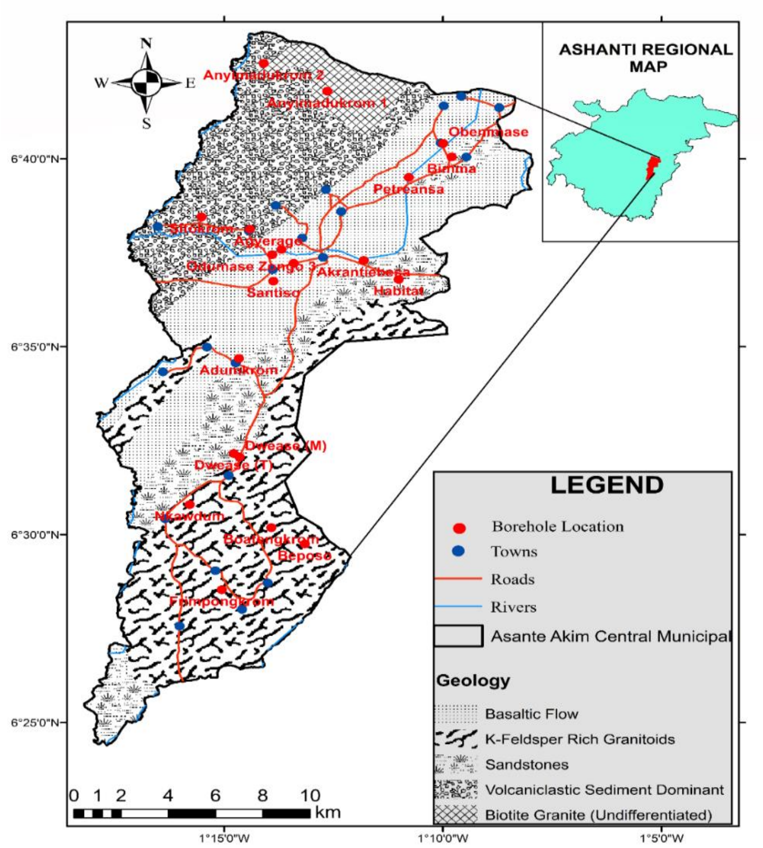

Fig. 1 Study area location with geology and distribution of boreholes

2.2 *Groundwater sampling and analysis*

All the boreholes in the study area were mapped using the Garmin eTrex 30x worldwide handheld GPS and plotted on the study area map to have the first information of their distribution (see Fig. 1). Following that, a total of 20 well-distributed boreholes were sampled taking into account their conditions and activities around them. The samples were first taken from all the boreholes in the dry season and later repeated in the wet season following the recommended standard protocols for water sampling and storage (APHA, 2012). In-situ measurements of Temperature, EC, and pH were made on the field using Waterproof Pocket EW-35634-35 Premium 50 Series meter. Also, the samples were sent to the laboratory for determination of their physicochemical and bacteriological constituents using the standard analytical methods presented in Table 1.

Table 1: Standard methods followed in the laboratory examination of water samples

Parameter	**Method**	**Reference**
Total Alkalinity (TA)	Titration	S M 2310 - B
Turbidity	Nephelometer	S M 2130 - B
TDS	Ion Selective Electrode	S M 2540 - B
Total Hardness	Titration	S M 2540 - B
Nitrate	Spectrophotometric	S M 4500 - NO3 H
Calcium Hardness	EDTA Titration	S M 3500 - Ca D
Potassium	Spectrophotometric	S M 3500 - K B
Manganese	Spectrophotometric	S M 3121
pH	Ion Selective Electrode	S M 4500 - H
Total Iron	Spectrophotometric	S M 3120
Conductivity (EC)	Ion Selective Electrode	S M 2510 - B
Magnesium	EDTA Titration	S M 3500 - Mg E
Magnesium Hardness	Calculation	S M 3500 - Mg E
Chloride	Titrimetric	S M 4500 - Cl B
Calcium	EDTA Titration	S M 3500 - Ca D
Fluoride	Spectrophotometric	S M 4500 - F D
Arsenic	HACH method of total Arsenic	S M 3114 - B
Sulphate	Spectrophotometric	S M 4500 - SO4 E
Total Coliform (TC)	Plate count	S M 9221 D

To assess the accuracy of the laboratory results, charge balance errors (CBE) was computed using Equation (1):

$$\text{CBE}= \frac{|\sum(\text{Cation concentration})|-|\sum(\text{Anion concentration})|}{|\sum(\text{Cation concentration})|+|\sum(\text{Anion concentration})|} \times 100\% \qquad (1)$$

where mEq/L is the unit of measurement for ionic concentrations.

The computed CBE values were all within the range of ±5%, indicating the analytical results were acceptable (Appelo & Postman, 2004). The IBM SPSS software version 26 was then used for the statistical analyses of the collated analytical results and creating scatter plots of the water composition on the Gibbs diagram. Also, AquaChem 2014.2 software was used to evaluate the hydrochemical facies of the groundwater.

2.3 Groundwater quality assessment for domestic purposes

The groundwater in the area was assessed for its suitability for drinking and other household needs by (1) comparing the measured water quality parameters of each sample with the WHO (2017) guidelines values, and (2) computing the WQI of each sample for evaluations. **Table 2** presents the influential parameters (IPs) used in computing the WQI with their assigned weights following the Sahu and Sikdar (2008) and Tiwari *et al.* (2014) methods given by Equations (2)-(4). These IPs were selected based on the illegal artisanal mining and agriculture activities in the study area and their potential effect on the groundwater.

$$\mathrm{WQI} = \sum\left(\left(q_i\right) \times (\mathrm{WI})\right) \tag{2}$$

$$q_i = \frac{Ci}{Si} \times 100 \tag{3}$$

$$\mathrm{WI} = \frac{W_i}{\Sigma W_i} \tag{4}$$

Where WI is the relative weights of the selected parameters, W_i is the weight assigned to the individual parameters based on its impact on the overall water quality with the human health implications, q_i is the water parameter ratings, Ci is the concentration of an IP in groundwater and Si is the corresponding guideline value of the (WHO, 2017).

Table 2: Influential Parameters and their weights **(WHO, 2017)**

Parameter	**WHO GV**	**Weight (Wi)**
pH	6.5 - 8.5	2
Turbidity	5	2
Ca	75	2
Mn	0.1	2
Mg	100	2
Cl	250	3
NO3	50	3
EC	500	3
TDS	600	3
TA	200	3
Fe	0.3	4
F	1.5	5
As	0.01	5

2.4 Groundwater quality assessment for irrigation

Sodium Adsorption Ratio (SAR), Percent sodium (% Na), Permeability Index (PI), Residual Sodium Carbonate (RSC), and Magnesium Hazard (MH) were computed to assess the suitability of the water for irrigation. The SAR is a highly essential parameter for identifying groundwater suitability for irrigation because it measures the number of sodium ions in the water extracted from a saturated soil paste with calcium and magnesium. The SAR was computed for the samples using three cations (i.e., Mg^{2+}, Na^+, and Ca^{2+}) as expressed in Equation (5).

$$\mathrm{SAR} = \frac{(Na^+)}{\sqrt{(Mg^{2+} + Ca^{2+})/2}} \tag{5}$$

Sodium percent (Na %) can have a significant impact on soil permeability and structure, resulting in minimal to no plant growth (Domenico & Schwartz, 1990; Arveti *et al.,* 2014). Thus, its levels in the groundwater were computed to assess the irrigation suitability using Equation (6).

$$\mathrm{Na\%} = \frac{Na^+}{Na^+ + K^+ + Ca^{2+} + Mg^{2+}} \times 100\% \tag{6}$$

The sodium content, total dissolved salts, and the concentration of bicarbonate all influence soil permeability when irrigation water is used continuously. Thus, the Permeability Index (PI), which combines these parameters was computed using Equation (7) after Doneen (1964).

$$\mathrm{PI} = \frac{(Na^+ + \sqrt{HCO_3^-})}{\left(Ca^{2+} + Mg^{2+} + Na^+ + K^+\right)} \times 100 \quad ` \tag{7}$$

A negative RSC indicates that sodium build-up is unlikely since sufficient calcium and magnesium are more than what can be precipitated as carbonates. A positive RSC shows that sodium builds up in the soil is possible. Elevated RSC in irrigation water causes plant leaves to burn and reduces crop yield (Toumi *et al.,* 2015); thus, it was computed using Equation (8) given as:

$$RSC = \left(HCO_3^{-} + CO_3^{2-}\right) - (Ca^{2+} + Mg^{2+}) \qquad (8)$$

Magnesium is an important nutrient for plant growth since a lack of it causes yellowing as well as a decrease in crop growth and yield, and its content in water is a crucial factor in assessing the quality of water used in agriculture (Sappa *et al.,* 2014). Thus, the Magnesium hazard of water for irrigation was determined using Equation (9).

$$MH = \frac{Mg^{2+} \times 100}{Ca^{2+} + Mg^{2+}} \qquad (9)$$

2.5 Human health risks of the groundwater

Hazard quotient (HQ), used to describe the non-carcinogenic risk of an individual experiencing a detrimental effect for using the water, was computed as part of the health risk assessment. The HQ of a specific metal is defined as the ratio of exposure to the toxicity threshold value, also known as chronic reference dose (R_fD), in mg/kg/day and was computed using Equations (10) to (12) developed by (USEPA, 2005). **Table 3** presents input parameters for average daily dose and **Table 4** presents oral ingestion dose and dermal permeability coefficient for various metals.

$$A_{av,ing} = \frac{C_w \times ED \times IR \times EF}{AT \times BW} \qquad (10)$$

$$A_{av,derm} = \frac{K_p \times SA \times ET \times EF \times ED \times CF \times C_w}{AT \times BW} \qquad (11)$$

$$HQ = \frac{A_{av,ing}}{R_fD} \qquad (12)$$

Where $A_{av,ing}$ is ingestion exposure, C_w is the concentration of metal in groundwater, ED is exposure duration, IR is the metal's rate of ingestion in groundwater, EF is the frequency of exposure, AT is averaging time, BW is average body weight, K_P is dermal permeability coefficient in water, SA is exposed skin area, ET is the time of exposure, CF is a unit conversion factor, $A_{av,\,derm}$ is exposure dose via dermal absorption, and R_fD is the toxicity reference dose.

Table 3: Input parameters for oral ingestion or dermal Aav dose assessment **(USPA, 2004)**

Exposure Parameters	**Symbols**	**Unit**	**Value**	
			Adult	**Child**
Concentration	C_w	Mg/L		
Rate of ingestion	IR	L/day	2.2	1.8
Frequency of Exposure	EF	Days/year	365	365
Duration of Exposure	ED	Years	70	6
Body Weight	BW	kg	70	15
Average Time	AT	Years	25550	2190
Exposed Area of Skin	SA	cm^2	18000	6600
Exposure Time	ET	Hrs/day	0.58	1
Unit Conversion Factor	CF	L/cm^3	0.001	0.001
Permeability Coefficient	K_p	cm/hr	0.001	0.0s01

Table 4: Oral reference dose and dermal permeability coefficient of metals **(USEPA, 1989)**

Metal	**R_fD**	**Dermal Permeability Coefficient(K_p)**
Fe	7.0×10^{-1}	1.0×10^{-3}
Cu	4.0×10^{-2}	1.0×10^{-3}
Mn	1.4×10^{-2}	1.0×10^{-3}
Pb	3.5×10^{-3}	4.0×10^{-3}
Hg	3.0×10^{-4}	1
As	3.0×10^{-4}	1.0×10^{-3}

R_fD in mg kg^{-1} day^{-1}; K_p in cm/hr

According to the USEPA (2005), it is impossible to be exposed to non-carcinogenic risk via the dermal and oral routes when the value of the HQ is less than 1, implying the water is considered safe. However, a possible health concern is considered if the value of HQ for both pathways become greater than 1. Furthermore, there can be possible associated health risks if the HQ for metals evaluated in both routes (HQ_{ing} + HQ_{dermal}) is more than 1.

The cancer risks (CR_{ing} and CR_{derm}) of consuming the contaminants in the groundwater via intake by dermal and ingestion routes was computed using Equation (13) by USEPA (2005) given as:

$$CR = (\text{cancer slope factor (CSF) in mgL}^{-1}\ \text{day}^{-1}) \times (\text{Exposure dose}) \qquad (13)$$

When the calculated CR is within the region (10^{-6}–10^{-4}), it is acceptable. However, cancer risk outside the extremes, calls for attention.

3 Results and discussion

3.1 Groundwater quality analyses

Table 5 shows the summary statistical results for all the groundwater quality parameters measured in the study area in both wet and dry seasons. Generally, most of the parameters were within the acceptable WHO (2017) guidelines for drinking water in both seasons except for pH and EC in the significant number of communities and then Fe, Mn, F, As, Ca, TA, TDS, Turb, and TC in few isolated communities. The groundwater pH values for the area in the wet season varied from 5.43 to 7.39 with about 55 % within the WHO guideline values whereas it varied from 3.73 to 7.99 with about 29 % within the WHO (2017) guideline value in the dry season. These results for both seasons show that the groundwater in the area is largely acidic, and the pH slightly increased during the wet season **(Fig. 2).** The acidic nature of the groundwater could be due to human-induced activities such as the excessive use of agrochemicals (fertilizers) as suggested by Sarath *et al.* (2012) and/or weathering of the basement rock (i.e., the Granitoids) in the area.

Table 5: Parameters for the wet (and dry season) summary statistical results

Parameter	**Min**	**Max**	**Mean**	**Std dev**	**WHO GV**	**% Within WHO GV**
pH	5.43 (3.73)	7.39 (7.99)	6.40 (5.69)	0.58 (1.09)	6.5 - 8.5	55 (29)
Turbidity	0.62 (0.78)	20.50 (7.80)	3.26 (2.01)	5.56 (1.84)	5	90 (90)
EC	80.10 (73.40)	1254.00 (1263.00)	354.91 (375.80)	267.20 (371.76)	500	90 (67)
Temperature	27.4 (27.7)	27.6 (28.6)	27.51 (28.39)	0.04 (0.25)	-	-
TDS	40.50 (36.70)	627.00 (631.50)	177.26 (188.51)	133.27 (186.73)	600	95 (95)
TA	30.0 (14.0)	138.0 (300.0)	84.55 (66.14)	44.08 (71.01)	200	100 (95)
TH	31.0 (14.0)	111.0 (352.0)	63.70 (82.10)	21.78 (87.00)	500	100 (100)
Ca Hardness	13.0 (8.0)	51.0 (294.0)	31.1 (58.0)	12.73 (71.54)	-	-
Mg Hardness	16.0 (4.0)	60.0 (88.0)	32.6 (24.1)	12.54 (19.13)	-	-
Calcium	5.2 (7.2)	20.4 (138.4)	12.44 (32.75)	5.09 (33.27)	75	100 (90)
Magnesium	3.9 (4.4)	14.6 (30.6)	7.93 (10.93)	3.05 (6.44)	150	100 (100)
Iron (Total)	-	2.08 (0.14)	0.23 (0.03)	0.55 (0.04)	0.3	90 (100)
Manganese	-	0.18 (0.02)	0.03 (0.01)	0.04 (0.00)	0.1	95 (100)
Phosphate	0.56 (0.28)	2.68 (2.90)	1.08 (1.16)	0.44 (0.79)	30	100 (100)
Chloride	12.0 (10.0)	56.0 (98.0)	19.05 (32.57)	10.23 (23.08)	250	100 (100)
Fluoride	0.21 (0.00)	0.76 (1.54)	0.49 (0.43)	0.15 (0.48)	1.5	100 (95)
Sulphate	2.0 (0.0)	35.0 (35.0)	8.45 (8.73)	8.43 (9.40)	250	100 (100)
Nitrate	0.32 (0.50)	1.58 (5.85)	0.66 (1.86)	0.29 (1.84)	50	100 (100)
Nitrite	-	0.01 (0.01)	-	-	3	100 (100)
Ammonia	0.04 (0.00)	0.34 (0.57)	0.16 (0.05)	0.08 (0.13)	1.5	100 (100)
Arsenic	-	0.10 (0.01)	0.01 (0.00)	0.02 (0.00)	0.01	95 (100)
Bicarbonate	18.3 (8.54)	84.2 (183.0)	51.58 (40.35)	26.89 (43.32)	-	-
Carbonate	18.0 (8.4)	82.8 (180.0)	50.73 (39.69)	26.45 (42.61)	-	-
Sodium	4.68 (3.90)	21.84 (38.22)	7.43 (12.70)	3.99 (9.00)	200	-
Potassium	0.98 (1.11)	4.98 (3.66)	2.6 (2.37)	1.24 (0.71)	30	-
TC	-	14.0 (0.0)	1.11 (0.00)	3.34 (0.00)	0	90 (100)

Note: pH (pH units), Turbidity (NTU), EC (S/cm), Temp (°C) and TC (cfu/ml); rest are all in mg/L

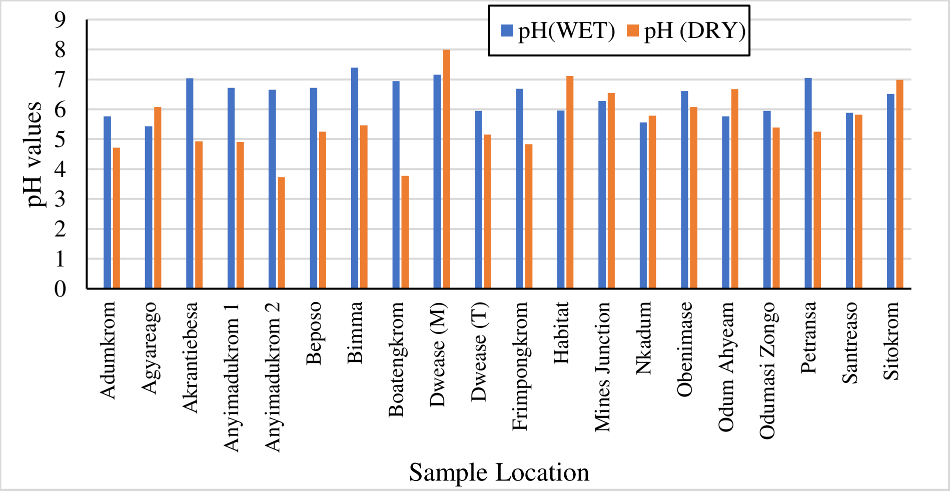

Fig. 2 Comparison of the pH concentrations for both wet and dry seasons

The turbidity in the groundwater of the area ranged between 0.62-20.50 NTU in the wet season and 0.78-7.80 in the dry season; the high values in the wet season could be linked to an increase in silt and clay carried into groundwater by rainfall runoff on the landscape (Yashoda *et al.* 2014), which led to surface runoffs with lots of suspended matter into water bodies. High turbidity values above recommended WHO guidelines only occurred from the sources at Adumkrom and Mines Junction. The continuous use of such turbid groundwater in the affected areas may constitute health risks such as cramps, diarrhoea, nausea, and associated headaches since it could stimulate the growth of bacteria and pathogenic microorganisms (Qadir *et al.* 2008).

TDS in the wet season water samples ranged from 40.50 to 627.00 mg/L, with an average of 177.26 mg/L and nearly 95 % of the groundwater samples were within the WHO permitted limit. The groundwater within the Mines Junction had a TDS value of 627 mg/L, which exceeded the WHO limit and may have been caused by the leaching of surface pollutants from the mining activities and agricultural waste along with recharging rainwater (Wagh *et al.,* 2016). TDS values in the dry season ranged between 36.70–631.50 mg/L with a mean of 189; 95 % of the samples had TDS values within the WHO's permissible limit with the Mines Junction exceeding the guideline by 30 mg/L. The high values of TDS observed during the wet and dry seasons at the Mines Junction may be due to the high concentration of dissolved minerals from the rock units and/or anthropogenic activities (Mandafiya *et al.,* 2014). Higher TDS levels in water can create significant scaling in water pipelines, boilers, and residential appliances (Ganiyu *et al.,* 2017; WHO, 2017).

The EC of the groundwater in the wet season ranged from 80.10 to 1254.00 S/cm with 20 % of the groundwater samples showing EC values outside the WHO (2017) limit while the values for the dry season ranged from 73.40–1263.00 S/cm with 25 % outside the WHO (2017). The high EC values (**Fig. 3**) were recorded in Anyimadukrom, Bimma, Dwease Market, Boatengkrom, and Obenimase, which are all predominantly farming communities, and then the Mines Junction close to the mining area. The high EC values in the groundwater suggest salt enrichment and the existence of anthropogenic influences in the study area due to household and agricultural activities. Based on the classification of EC by Sarath *et al.* (2012), all the groundwater samples for both seasons have low salt enrichment since they all fall within the Type I class (i.e., EC < 1500 S/cm).

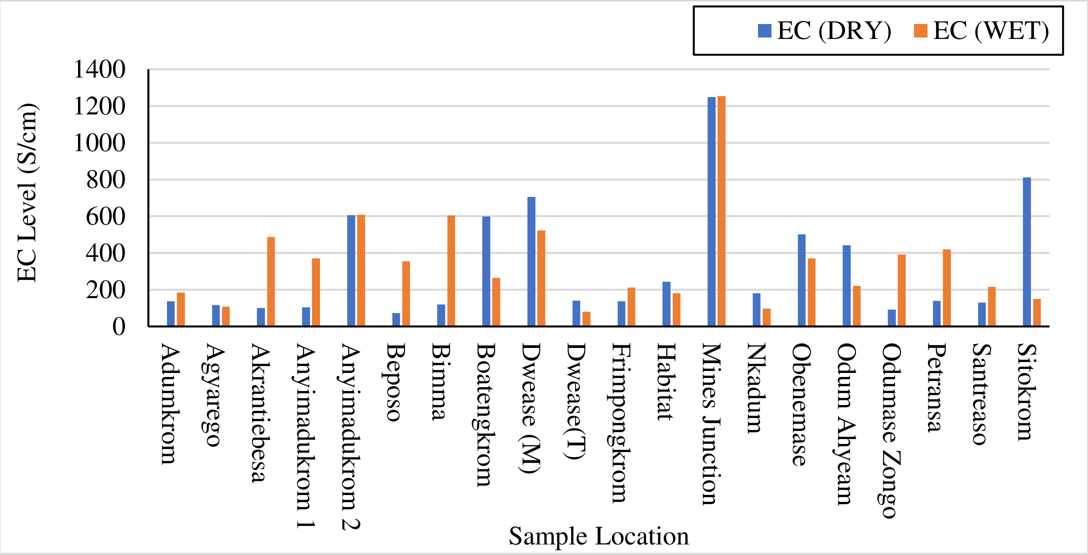

Fig. 3 Variation of EC in the samples for wet and dry seasons

The major cations in the groundwater are Ca, Mg, Na, and K and their order of abundance are Ca > Mg > Na > K in the wet season while the order of abundance in the dry season is Ca > Na > Mg > K. The order of abundance of the ions did not alter much as a result of the seasonal change; however, there were some substantial differences in the ionic concentrations between the dry and wet seasons, with higher cationic concentrations reported in the dry season (see Table 5). Among all the major ions measured in the groundwater samples, Ca is the only one that exceeded the WHO (2017) guideline in isolated areas in the dry season while all the others were within acceptable limits in both seasons. The high levels of Ca during this period could be the result of the dissolution of carbonate minerals and the decomposition of the sulfate, phosphate, and silicate minerals, which may lead to the formation of solid scales in pipes, kitchen utensils and increased soap consumption (Mensah, 2011).

The order of abundance of the main anions in the groundwater for each season is HCO_3 > Cl > SO_4 > F. Their concentrations in the groundwater of the area were largely within the acceptable WHO (2017) guidelines in both seasons except for one sampling source in a farming community where the F^- concentration was 1.54 mg/L in the dry season. The presence of the high F^- concentration in this community could be a result of the application of phosphatic fertilizers on the farmlands (Ali *et al.,* 2016). The presence of F^- beyond the suggested limit for drinking water may expose residents to dental cavities, weak bones, and dental fluorosis throughout their lives (Sezgin *et al.,* 2018)

The faecal coliform count in the groundwater of the area in the wet season ranges from 0.0 to 14.0 (cfu/ml) with water sources at Mines Junction and Adumkrom recording values exceeding the WHO acceptable limits of 0.00 cfu/ml; hence, rendering those sources unsafe for drinking. In the dry season, all the samples showed zero coliforms which could be because of no recharge to carry contaminants from runoffs to the groundwater systems. The source of the coliforms in the two observed areas could be due to leaky effluents from a septic tank and wastewater disposals observed in those environs. These findings agree with a study by Singh *et al.* (2019). Drinking water contaminated with total coliform and faecal coliform may lead to the incidence of typhoid fever, hepatitis, cholera, intestinal infections and diarrhoea (Yang & Wang, 2018).

3.2 Correlation matrix for water parameters

Pearson's correlation coefficients were generated as a basis for establishing links between parameters as well as to a significant part, predicting the values of other parameters at different locations without any measurement (Trivedi *et al.*, 2017). Pearson's correlation coefficient (r) is a value that varies between -1 and 1, with -1 representing perfect inverse correlations and 1 showing perfect direct correlations. Tables 6 and Table 7 show the correlations between the groundwater quality parameters in the wet and dry seasons. Generally, there are considerable positive associations between total hardness (TH) and Ca^{2+}, pH, EC, Mg^{2+}, TDS, K^+, and HCO_3^- for both seasons. The main contributions to TH appear to be calcium and magnesium, which arise from limestone dissolution by carbon dioxide-charged precipitation. The high positive association of the other parameters with TH, on the other hand, shows that these variables may contribute to the total hardness of the groundwater in the municipality. Hard water is known to leave scaly deposits in pipes, impair soap and detergent cleaning capacity, and degrade materials (Nas, 2009). Extremely low TH levels are also likely to induce nutrient deficiencies, particularly in calcium and magnesium. The Mg^{2+},HCO_3^-, TDS and Ca^{2+} all demonstrated a substantial positive relationship with pH.

Table 6: Pearson correlation matrix for wet season water quality parameters.

	Turb	**EC**	**TDS**	**pH**	**TH**	**Ca**	**Mg**	**Fe**	**PO$_4$**	**Cl**	**F**	**SO$_4$**	**NO$_3$**	**HCO$_3$**	**CO$_3$**	**Na**	**K**	**TC**
Turb	1																	
EC	**0.547***	1																
TDS	**0.548***	**1.000***	1															
pH	-0.247	0.230	0.230	1														
TH	0.437	**0.848***	**0.847***	**0.502***	1													
Ca	0.154	**0.723***	**0.728***	**0.561***	**0.860***	1												
Mg	**0.614***	**0.725***	**0.719***	0.274	**0.845***	**0.456***	1											
Iron	**0.991***	**0.466***	**0.468***	-0.282	0.374	0.107	**0.552***	1										
PO4	**0.954***	**0.655***	**0.657***	-0.266	**0.469***	0.228	**0.589***	**0.943***	1									
Cl	-0.128	-0.209	-0.224	**-0.445***	-0.313	**-0.458***	-0.065	-0.119	-0.117	1								
F	0.308	0.123	0.116	-0.255	-0.070	-0.372	0.264	0.302	0.284	0.257	1							
SO4	**0.952***	**0.549***	**0.552***	-0.314	0.410	0.161	**0.569***	**0.936***	**0.927***	-0.132	0.209	1						
NO3	**0.466***	0.394	0.389	0.000	**0.462***	0.260	**0.536***	**0.479***	**0.546***	0.129	-0.126	0.412	1					
HCO3	0.011	**0.620***	**0.621***	**0.777***	**0.858***	**0.875***	**0.567***	-0.044	0.054	**-0.492***	-0.258	-0.041	0.242	1				
CO3	0.014	**0.621***	**0.623***	**0.774***	**0.860***	**0.874***	**0.571***	-0.042	0.056	**-0.489***	-0.258	-0.038	0.245	**1.000***	1			
Na	-0.123	-0.188	-0.203	**-0.453***	-0.306	**-0.452***	-0.059	-0.119	-0.112	**0.997***	0.272	-0.124	0.101	**-0.486***	**-0.483***	1		
K	0.165	**0.601***	**0.593***	0.211	**0.659***	**0.596***	**0.530***	0.111	0.192	0.110	0.034	0.176	0.120	**0.535***	**0.541***	0.151	1	
TC	**0.936***	**0.682***	**0.684***	-0.260	**0.480***	0.247	**0.588***	**0.921***	**0.998***	-0.116	0.278	**0.914***	**0.552***	0.071	0.073	-0.110	0.205	1

*Correlation is significant at the 0.5 level.

Table 7: Pearson correlation matrix of dry season water quality parameters

	Turb	**EC**	**TDS**	**pH**	**TH**	**Ca**	**Mg**	**PO_4**	**Cl**	**F**	**SO_4**	**NO_3**	**HCO_3**	**CO_3**	**Na**	**K**
Turb	1															
EC	**0.419***	1														
TDS	**0.422***	**1.000***	1													
pH	**0.387***	**0.515***	**0.518***	1												
TH	**0.589***	**0.874***	**0.876***	**0.679***	1											
Ca	**0.553***	**0.829***	**0.832***	**0.627***	**0.964***	1										
Mg	**0.484***	**0.702***	**0.704***	0.289	**0.728***	**0.813***	1									
PO_4	0.204	**0.410***	**0.412***	**0.527***	**0.523***	**0.510***	**0.439***	1								
Cl	-0.224	0.121	0.118	**-0.658***	-0.177	-0.170	0.028	**-0.395***	1							
F	**0.427***	0.194	0.194	0.022	0.206	0.260	**0.420***	0.046	0.097	1						
SO_4	-0.024	**0.419***	**0.417***	0.133	0.312	0.262	0.162	0.061	0.101	0.315	1					
NO_3	-0.241	0.093	0.090	-0.172	-0.168	-0.212	-0.348	-0.311	0.321	-0.368	-0.092	1				
HCO_3	**0.579***	**0.755***	**0.759***	**0.616***	**0.913***	**0.974***	**0.879***	**0.541***	-0.263	0.282	0.151	-0.299	1			
CO_3	**0.579***	**0.753***	**0.757***	**0.616***	**0.912***	**0.974***	**0.879***	**0.543***	-0.265	0.283	0.152	-0.303	**1.000***	1		
Na	-0.219	0.124	0.121	**-0.651***	-0.173	-0.167	0.029	**-0.389***	**1.000***	0.101	0.099	0.313	-0.261	-0.263	1	
K	0.270	0.138	0.138	0.253	0.145	0.260	**0.391***	0.194	-0.350	0.172	0.047	-0.032	0.364	0.364	-0.358	1

*Correlation is significant at the 0.5 level.

The highest correlation coefficients of r = 0.777 and r = 0.616 respectively for wet and dry seasons were found between pH and HCO_3^-, with HCO_3^-increasing significantly as pH increased. The release or dissolution of these ions in solutions can be triggered by changes in pH levels as evidenced by the positive correlation. For the rainy season, HCO_3^- had high correlation with TDS (r = 0.621), Ca^{2+} (r = 0.875), EC (r = 0.620), and Mg^{2+} (r = 0.567). The dry season HCO_3^- also had strong correlation with TDS (r = 0.759), Ca^{2+} (r = 0.974), EC (r = 0.755) and Mg^{2+} (r = 0.879). The high association between Ca^{2+} and HCO_3^- supports a Ca-HCO_3 water type, arising from likely dissolution of carbonate minerals and decomposition of silicate minerals like quartz and feldspar. The Pearson's correlation matrix also showed positive relationships between the ions of NO_3, K, PO_4, F, and SO_4 during the wet season. This means that agriculture input fertilizers and other anthropogenic activities are the most likely sources of infiltrating precipitation. Chemical fertilizers, such as NKP, have an impact on groundwater potassium, nitrate and phosphate levels because they are mostly made up of these compounds. The weathering of K-rich feldspars is linked to the release of potassium and other associated ions in the solution.

3.3 Assessment of groundwater type and origin

Groundwater is always in contact with the rock minerals that form the aquifer. This contact has a significant influence on water quality. Gibbs (1970) produced diagrams in which dominant cation and anion ratios are displayed against TDS values to understand the mechanisms governing groundwater chemistry. The Gibbs diagram is a method for determining the source of ions in groundwater by identifying the relationship between cation (Na^+, Ca^{2+}) and anion (Cl^-, HCO_3^-) concentrations and TDS. Precipitation, rock, and evaporation dominance are all examples of functional sources of dissolved chemical constituents that are commonly used.

Fig 4 is the Gibbs diagram showing the hydrochemistry of the groundwater in the wet season and indicates that 75 % of the groundwater samples are in the rock dominance zone while the rest fell in the rainfall dominance zone. This implies that chemical weathering is the dominant mechanism governing the groundwater chemistry in the area through the dissolution of rock-forming minerals. It is also a sign that rock–water interaction has influenced the quality of groundwater in the area. In the dry season **(Fig 5)**, the majority of the samples (55 %) in the study area fell into the rainfall dominance portion while the rest were in the rock dominance section**.**

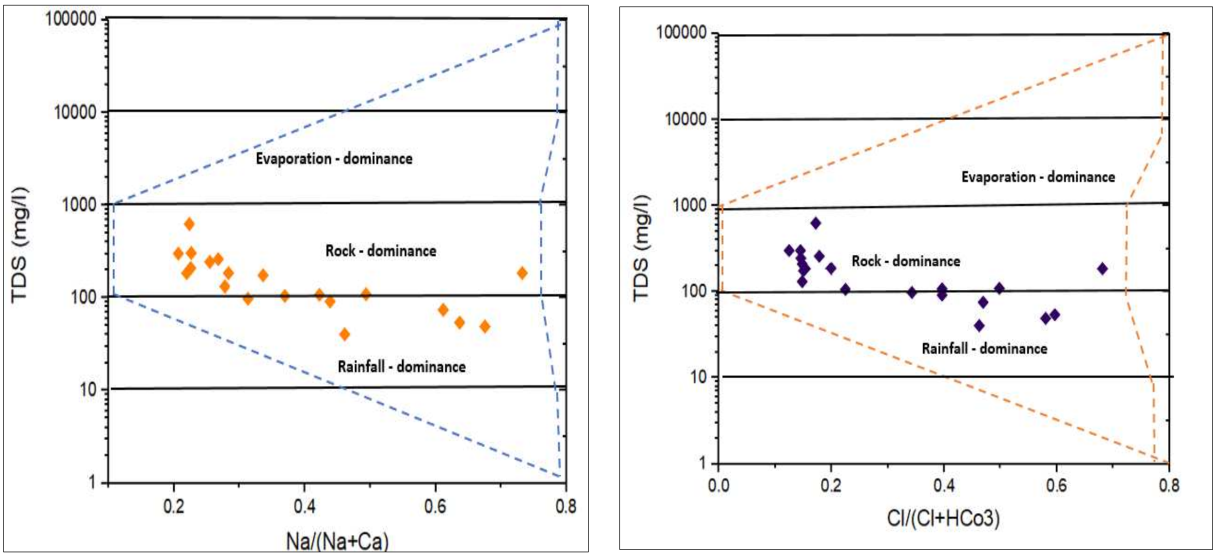

Fig 4 Gibb's diagram for wet season hydrochemistry mechanisms

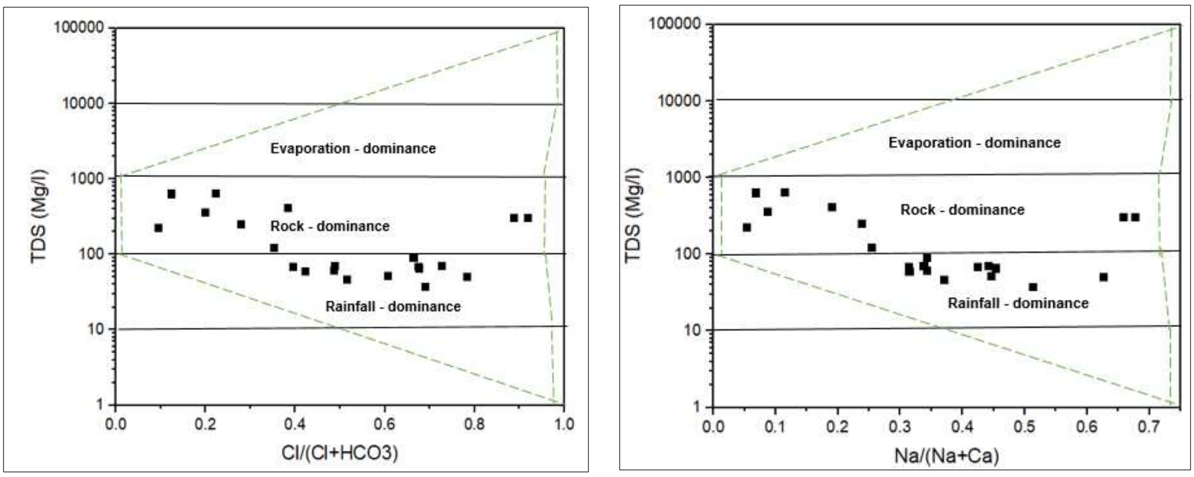

Fig 5 Gibbs diagram for dry season hydrochemistry mechanisms

Fig 6 shows the plots of groundwater samples using the piper triplot (Piper, 1944) in the wet and dry seasons. Two hydrochemical facies were dominant in the wet season (Fig 6(a)) and were identified as Ca–HCO_3 and Mixed Ca–Mg-Cl, which were made up of 95 % and 5 % respectively of the groundwater samples. The Ca–HCO_3 was identified to be from a freshwater source while Ca–Mg–Cl was identified as a mixed water type**.**

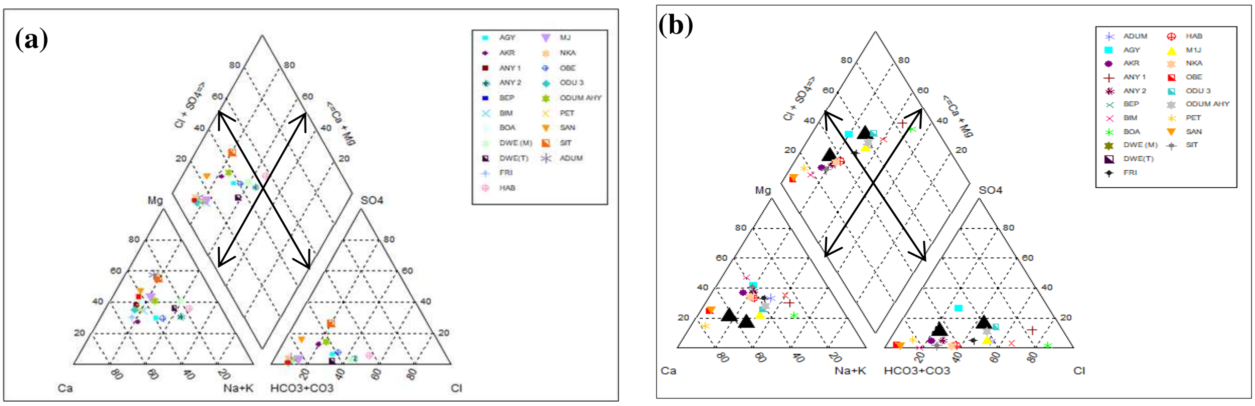

Fig 6 Piper plot of the water samples in the (a) wet season and (b) dry season

The dry season groundwater samples also recorded 45 % as Ca–HCO_3 water type with the remaining 55 % identified as mixed Ca–Mg–Cl type of water **(Fig 6(b))**. The lack of $NaHCO_3$ water in the samples could be explained by cation exchange mechanisms during which Ca^{2+} from freshwater $CaHCO_3$ replaces Na^{+}, resulting in the mixed CaMgCl water type prevailing. Low salinity groundwater, according to Clark, (2015), is dominated by Ca^{2+} and HCO_3 as a result of carbonic acid mineral weathering, which suggests that precipitation or rainfall affects water quality in the area by dissolving gases in the atmosphere.

3.4 Groundwater quality assessment for drinking purposes

Table 8 summarizes the estimated WQI for both seasons to determine the overall quality of groundwater in the area for drinking purposes. Generally, the computed WQI for most of the samples in both seasons were less than 50 and were, therefore, classified to be of excellent quality (Sahu & Sikdar, 2008; Tiwari *et al.,* 2014). However, one sample in the wet season was classed as poor while another one in the dry season was also classed as very poor. These poor water quality categories were from high As and Fe contents in the groundwater at the Mines Junction, which were above the recommended WHO guideline values.

Table 8: Estimated WQI classification for the wet (and dry season) after (Sahu & Sikdar, 2008; Tiwari *et al.,* 2014)

WQI Range	Classification of Water	Percentage
≤ 50	Excellent	90 (95)
Between 50-100	Good	5 (0)
Between 100-200	Poor	0 (5)
Between 200-300	Very Poor	5 (0)
Above 300	Unsuitable	0 (0)

3.5 Groundwater quality assessment for irrigation

The computed values of the various indices for irrigation suitability assessment in the wet and dry seasons are shown in **Table 9**. The calculated values of RSC of the groundwater in the area ranged from 0.94–2.93 with an overall average of 1.90 for all water samples analysed during the rainy season while the dry season RSC values ranged from 0.26–1.01 with an average value of 0.69. Based on the RSC classification of water for irrigation purposes by Singh *et al.* (2013), 10 % of the groundwater points are good for irrigation with 85 % and 5 % classed as doubt and unfit, respectively, for irrigation in the wet season. On the other hand, all groundwater points were classed as good for irrigation in the dry season.

Table 9: Calculated irrigational water indices for wet (and dry seasons) results

Sampling Sites	RSC	MH	SAR	Na%	PI
Beposo	2.31 (0.61)	68.02 (49.13)	0.25 (0.78)	11.89 (31.48)	70.94 (58.16)
Dwease (T)	1.43 (0.65)	43.04 (51.74)	0.55 (0.39)	29.08 (17.25)	80.69 (47.56)
Habitat	1.44 (0.89)	34.89 (43.85)	0.35 (0.34)	20.08 (13.92)	76.14 (47.08)
Anyimadukrom 2	2.39 (0.28)	45.19 (54.18)	0.24 (1.60)	11.70 (42.86)	73.60 (55.24)
Agyareago	1.36 (0.82)	54.73 (48.43)	0.80 (0.35)	38.61 (16.36)	84.78 (53.80)
Akrantiebesa	2.48 (0.49)	50.75 (58.28)	0.26 (0.80)	12.48 (37.10)	73.32 (64.88)
Obenimase	2.24 (0.93)	43.98 (54.10)	0.33 (0.29)	15.08 (10.92)	70.41 (41.22)
Boatengkrom	2.93 (0.26)	47.69 (44.36)	0.28 (1.84)	14.42 (50.03)	86.92 (61.81)
Nkadum	1.27 (0.50)	66.73 (25.15)	0.81 (0.58)	36.86 (24.77)	78.71 (50.82)
Sitokrom	1.88 (0.70)	58.25 (26.60)	0.64 (0.29)	35.52 (12.67)	97.79 (44.50)
Anyimadukrom 1	2.50 (0.70)	36.59 (46.94)	0.26 (0.66)	12.84 (26.31)	76.09 (55.52)
Odumasi Zongo	1.08 (0.79)	66.66 (43.81)	1.23 (0.62)	42.18 (21.87)	71.30 (48.63)
Frimpongkrom	2.33 (0.60)	54.45 (33.39)	0.38 (0.64)	18.24 (28.87)	78.54 (59.60)
Bimma	2.27 (0.79	50.64 (43.28)	0.21 (0.56)	9.57 (20.16)	64.77 (47.09)
Odumasi Ahyeam	1.36 (1.01)	45.18 (26.05)	0.60 (0.11)	30.16 (3.47)	77.80 (29.47)
Petransa	2.44 (0.46)	42.12 (38.21)	0.26 (0.61)	12.22 (28.73)	71.30 (57.03)
Santreaso	1.29 (0.59)	54.23 (41.26)	0.34 (0.58)	21.94 (28.63)	80.95 (62.28)
Dwease (M)	2.38 (0.82)	44.13 (15.79)	0.33 (0.20)	14.41 (6.58)	69.40 (30.82)
Mines Junction	1.59 (0.95)	54.13 (26.72)	0.24 (0.20)	9.87 (4.44)	51.99 (22.03)
Adumkrom	0.94 (0.88)	68.80 (50.46)	0.34 (0.40)	16.94 (15.93)	56.41 (47.99)

Calculated values of Na % in the groundwater of the area ranged from 9.57–42.18 with a mean of 20.70 for the rainy season while it ranged from 3.47–50.03 with an average of 22.12 in the dry season. Following from the classification of Na% by Hussain *et al.* (2012) and Yıldız & Karakuş (2020) for irrigation water, 60 % of the point sources in the area had excellent groundwater for irrigation while 35 % and 5 % were good and permissible, respectively, for irrigation in the wet season. Likewise, in the dry season, 85 % of the points sources had excellent groundwater for irrigation while the remaining points were of good and permissible groundwater quality for irrigation.

The SAR values in the groundwater of the area for the wet season ranged from 0.21 to 1.23 with an average of 0.44 while the values ranged between 0.11–1.84 with an average of 0.59 for the dry season. Based on the classification of irrigation water by Bian *et al.* (2018), groundwater from all the sources in the area is categorised as excellent for irrigation.

The average value of MH in the groundwater of the area during the wet season was 51.51 and ranged from 34.89 to 68.80 whereas the dry season values ranged from 15.79–58.28 with an average of 41.09. Thus, based on the classification of MH values for irrigation water (Szabolcs & Darab, 1964; Gautam *et al.* 2015), groundwater from 45 % and 75 % of the points sources are classed as suitable for irrigation in the wet and dry seasons respectively.

The PI for the groundwater in the area for the wet season ranged from 51.99-97.79 with a mean of 74.59 while in the dry, it ranged from 22.03–64.88 with an average of 49.28. This, according to the classification of PI (Doneen, 1964 and Rawat *et al.* 2018) indicates that groundwater from 85 % of the point sources are excellent for irrigation in the wet season while 95 % of the point sources in the dry season are suitable for irrigation with the remaining in both seasons unsuitable for irrigation.

Fig 7 shows the evaluation of the suitability of the groundwater in the area for irrigation using the USSL diagram (Richards 1954), and indicates that groundwater from all points sources in the wet season have low sodicity based on the (S1) classification **(Fig 7(a))**. On the salinity hazard axis for the same season, 50 %, 35 %, and 15 % of the groundwater points plotted in C1, C2, and C3 respectively **(Fig 7(a)),** indicating the groundwater from all the sources is of good quality for irrigation and may be used without endangering the land or crops.

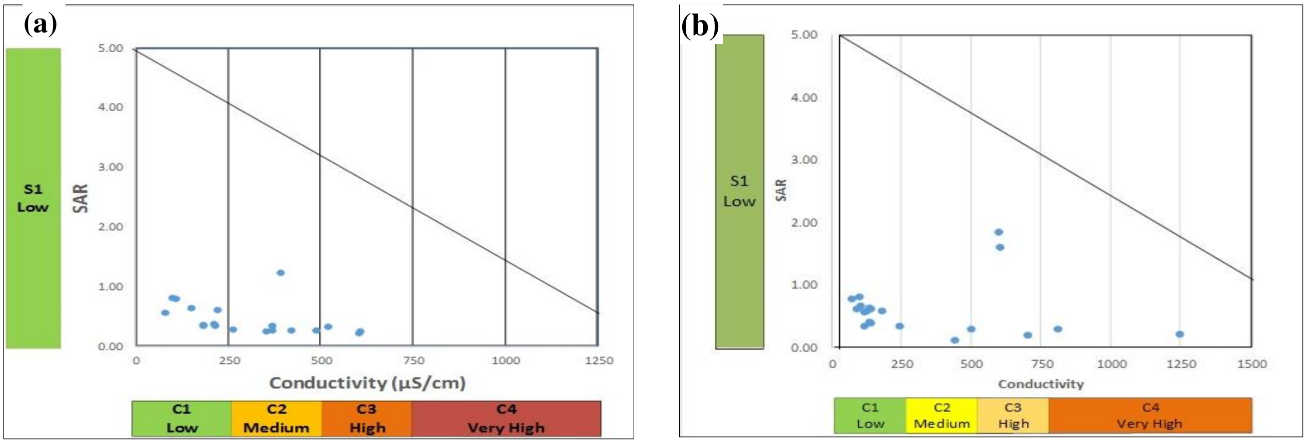

Fig 7 Groundwater salinity diagrams for the (a) wet season and (b) dry season (after Richards, 1954)

Likewise, groundwater from all the points in the dry season is plotted in the low sodicity category (S1). On the salinity hazard axis, however, 65 %, 10 %, 15 % and 10 % of the points plotted in C1, C2, C3 and C4 respectively **(Fig 7).** This indicates that groundwater from 90 % of source points had good irrigation quality and could be utilized as such without any problems whereas 10 % had very high salinity content and, hence, unsuitable for irrigational purposes. Both seasonal results were comparable to those of Yidana *et al.* (2011) who found that 90 % of their samples plotted in the low class of the USSL diagram, probably due to the low concentration of physicochemical parameters collected. The groundwater at Dwease and Santreaso communities had high salt concentrations and were, therefore, not suitable as irrigation water.

3.6 Estimation of health risk of excess arsenic intakes

Groundwater samples from a single water source Mines Junction had arsenic values of 0.1 mg/L and 0.01 mg/L, respectively, throughout the wet and dry seasons. Since the concentration of arsenic (As) during the wet season exceeded the WHO (2017) 0.01 mg/L recommended value, the human health risk linked with excessive As intake was assessed for various age groups in the study area. To do so, the hazard quotient (HQ) is a useful tool for calculating non-carcinogenic health risks.

In the wet season, HQ values ranged from 0.0 to 0.1 mg/L with an average of 0.01 mg/L while the dry season values ranged from 0.0 to 0.01 mg/L with a mean of 0.006 mg/L. One possible reason for the high As concentrations during the rainy season was due to groundwater recharge to the aquifer being able to dissolve minerals more easily. Another cause, according to Leung & Jiao (2006), is that during the wet season, some metals may be leached out of the vadose zone into groundwater due to the normally higher water table. Also, the chemicals used in the numerous illegal mining and other anthropogenic activities at the Mines Junction could have contributed to the high As content.

According to the USEPA (2004), if the estimated HQ is less than 1, non-carcinogenic risk exposure through oral ingestion and skin channels is impossible, meaning that water is safe for use. However, if the HQ value for the dermal and/or oral pathway(s) is greater than 1, the pollutants in the water being swallowed may pose a health risk. Both adults and children estimated HQs via oral and dermal exposures were greater than 1 (**Table 10**); hence, the non-carcinogenic risk will be high when the groundwater from that water source is consumed. Dermal pathways for adults were greater than 1 while for children, it did not present any significant non-carcinogenic risk since their computed HQs were less than 1.

Table 10: Estimated non-carcinogenic risk for adults and children

Category	**Daily Average Exposure**		**Non-cancer Risk**		
	$\mathbf{Aav_{(ing)}}$	$\mathbf{Aav_{(derm)}}$	$\mathbf{R_fD}$	$\mathbf{HQ_{ing}}$	$\mathbf{HQ_{derm}}$
Adult	3.14×10^{-3}	1.49×10^{-2}	3×10^{-4}	10.47	4.97×10^{1}
Children	1.20×10^{-2}	4.40×10^{-5}	3×10^{-4}	40.00	1.47×10^{-1}

Carcinogenic or cancer risks (CR) are defined by Rice & Ncea (2019) as "the chance of developing cancer for a person's lifetime as a result of exposure to a possible carcinogen." Arsenic (As) was used to calculate the carcinogenic risk for oral consumption and dermal absorption since it was discovered to be the sole cause of cancer risk. For regulatory purposes, the USEPA considers a cancer risk in the range of 10^{-6} to 10^{-4} acceptable (USEPA, 2004). The estimated cancer risk in water samples for oral consumption and dermal absorption are presented in **Table 11**. Adult CR oral ingestion for As was 4.71×10^{-3} when oral ingestion exposure paths were considered. In addition, the estimated adult CR dermal for As was 2.24×10^{-5}. This means that the risk of adults getting cancer from drinking the water was 4.71 in 1000, while the risk of adult cancer from dermal contact was 2.24 in 100,000.

Table 11: Carcinogenic risk calculations of adults and children

Category	Pathway	Daily Average Exposure	Cancer Risk
Adult	Ingestion	3.14×10^{-3}	4.71×10^{-3}
	Dermal	1.49×10^{-5}	2.24×10^{-5}
	Total	3.16×10^{-3}	4.73×10^{-3}
Child	Ingestion	1.2×10^{-2}	1.8×10^{-2}
	Dermal	4.4×10^{-5}	6.6×10^{-5}
	Total	1.2×10^{-2}	1.8×10^{-2}

The estimated CR for As was 1.8×10^{-2} through oral ingestion for children while their computed CR_{dermal} for As was 6.6×10^{-5}. This means that the risk of cancer in children from drinking water was 1.8 in 100, while the risk of cancer in children from dermal contact was 6.6 in 100,000. The results revealed a possible cancer risk for both adults and children via oral ingestion; however, young people are the most vulnerable to carcinogenic As through oral ingestion. Additionally, the TCR of the children is higher than the adults, implying that children were more vulnerable to CR from As. Adult and child cancers of the bladder, kidney, liver, and skin are among the probable carcinogenic diseases that may impact inhabitants for the rest of their life overexposure to the groundwater with high As levels.

4 Conclusions

The suitability of groundwater for drinking and irrigation purposes has been comprehensively assessed in this study employing a combination of WHO guideline values, WQI and indices such as MH, PI, RSC, SAR, Na % and PI as well as ascertain the health implications of consuming the water. The results indicate that Ca-HCO_3 and mixed Ca-Mg-Cl water types dominate in the study area with chemical weathering and precipitation as the main processes controlling the water chemistry. Also, most of the analysed water quality parameters were within the acceptable WHO guidelines for drinking water in both dry and rainy seasons except for pH and EC, which were outside the guidelines in the significant number of communities while Fe, Mn, F, As, Ca, TA, TDS, Turb, and TC were outside the guidelines in few isolated communities. Additionally, the calculated WQI classified 95 % of the groundwater sources in the area as being excellent and good for domestic use in both the dry and rainy seasons while the remaining 5 % was classified as very poor due mainly to the presence of high arsenic (As) levels.

The analyses of the computed RSC, %Na, SAR, MH, and PI indices revealed that 10 %, 95%, 100%, 45% and 85%, respectively, of the groundwater sources in the area, are suitable for irrigation in the rainy season whereas 100%, 100%, 100%, 75% and 95% of the sources are suitable for irrigation in the dry season per the computed RSC, %Na, SAR, MH, and PI respectively. Additionally, the USSL diagram revealed that groundwater from all the sources in the area in the wet season was suitable for irrigation while groundwater was suitable for irrigation in 90% of the sources in the dry season. Thus, based on the classification and the computed irrigational indices, the groundwater was generally found to be suitable for irrigation in both seasons.

The computed non-carcinogenic and carcinogenic risks of the As, found in the groundwater from an isolated community in the area, via oral exposures showed children were more vulnerable to potential cancer risk than adults. Thus, the water in the community needs to be treated before usage. Also, the source of the high As in the groundwater of that community is possibly from the gold mining activities since arsenopyrites are known to be associated minerals in the gold ores of the area; thus, the mining needs to be controlled to protect the groundwater. Overall, the study has provided detailed information on groundwater quality in the area to aid in the usage, awareness creation, and protection of the resource from pollution.

Declarations

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Conflicts of interest/Competing interests
The authors have declared that they have no conflicts of interest that are relevant to the content of this paper.

Availability of data and material
On reasonable request, the corresponding author will provide the datasets created and/or analyzed in the current study.

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