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Effects of Small-Scale Salt Mining on the Quality of Well Water in the Komenda-Edena-Eguafo-Abrem (KEEA) District in the Central Region, Ghana

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Abstract: The main aim of the research was to investigate how small-scale salt mining has been impacting negatively on the quality of well water in Komenda-Edina-Eguafo-Abrem (KEEA) district of Ghana. Salt mining is a major occupation of inhabitants of the coastal regions of Ghana. A community where salt mining has just begun was used as a control. Well water samples were collected from four wells in the communities. Generally the quality of well water in the three salt mining communities was poor. Many well water quality parameters measured were above WHOs recommended levels for portability. pH levels ranged from 4.1 to 8.3 with a mean value of 6.7, electrical conductivity ranged from 1730 to 9900 and 4628 μS/cm as the mean, turbidity levels recorded ranged from 1.4 to 14 NTU with a mean of 4.7 NTU. Total Dissolved Solids (TDS) ranged from a minimum of 895 mg/L to a maximum of 3790 mg/L with a mean of 1904 mg/L, salininty levels ranged from 0.8 to 6.0 mg/L with a mean of 2.6 mg/L, calcium ranged from 80 to 400 mg/L with a mean of 216 mg/L and Mg ranged from 146 to 534 mg/L with a mean of 224 mg/L. Total and faecal coliforms ranged from 100 to 570 cfu/100 mL with a mean of 250 and 40 to 300 cfu/100 mL with a mean of 134 cfu/100 mL respectively. The results indicated that generally, salt mining has impacted negatively on the quality of well water in the study area. Concentrations of physico-chemical parameters, especially, those of conductivity, salinity and TDS were very high in the three communities with large concentration of saltpans as compared the community with only one saltpan. Again, values recorded for physico-chemical parameters were higher in the dry season when salt mining is at its peak than the wet season. The pollution of the wells may be attributed to the salt mining activities because at Brenu Akyinim where salt mining have just started and there is only one producer in the area, the quality of water in terms of concentrations of physico-chemical parameters was better.

Keywords: Physicochemical coliforms, salinity, salt mining, well water

INTRODUCTION

Traditional minerals like gold, diamond, bauxite and manganese have served as the backbone to the economy of Ghana since pre-colonial era. Mining of these traditional minerals has been identified as one of the major causes of environmental pollution and degradation (IIED, 2002). A good example of this is the cyanide spillage into Rivers Huni and Asuman by Goldfields Ghana Limited (GGL) near Tarkwa in the Western Region. The effect of this spillage was the pollution of the major source of water for domestic use by communities such as Abekoase, Huniso and Huni Valley, as well as the killing of fish and other aquatic organisms in the rivers concerned (Baneseh, 2002).

Salt is one mineral that has the potential to help accelerate economic growth of the country with less environmental and investment problems as compared to the mining of traditional minerals such as gold, diamond and bauxite. It is the most common of all minerals produced in the world.

Its production started with the beginning of human civilization and each person is estimated to consume about twelve (12) pounds of salt a year Braitsch (1971). However, its value as food and food preservation has been overshadowed by the high industrial uses that make it one of the most essential raw materials in the chemical industry (Braitsch, 1971).

Ghana has a comparative advantage in the process of salt mining along the coast of West Africa in view of the wide stretch of coastline, suitable climate and physical conditions (Adjei, 1998). The salt mining industry in Ghana is almost entirely a private sector venture of which there are two main types. These are the joint venture medium-scale industries and the small-scale local producers (Adjei, 1998). The medium-scale industries are concentrated mostly in areas such as Ada, Songhor, Prampram and Weija in the Greater Accra Region; and

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Winneba, Gomoa Fetteh and Abora in the Central Region. The small-scale production occurs between Ada in the Greater Accra Region and Elmina in the Central Region with the KEEA District in the Central Region having a large number of the production pans. This is due to the fact that, the Benya Lagoon, which constitutes an important source of brine for salt production extends inland. This has allowed the production of salt to be extended a little bit further inland than the other producing areas in the Central Region (Gadzekpo, 2002). The production of salt in Ghana is mainly by boiling and solar evaporation of seawater (brine).

Salt is very important to the socio-economic development of Ghana. Apart from being very important in our diets, its increasing demand on the international market is as a result of its importance to the chemical industry and other industrial sectors. This encourages people to increase its exploitation. It therefore serves as a source of employment to a large number of residents along the coast as well as income for the nation as a whole.

Salt mining can, however, have some impacts on the environment, be it physico-chemical, biological or social. Seawater which serves as brine for making salt is, however, known to affect the quality of the environment. For example, sea spray leads to exchangeable base cations of soil being dominated by sea salt inputs rather than mineral inputs, as well as fresh water becoming susceptible to increasing acidification (White *et al*., 1998). One major effect of salt mining is increasing salinisation, which is a process that increases the salinity of many inland waters. Salinisation has significant economic, social and environmental impact. According to Williams and Aladdin (1991), the increase in salinity content of the Aral Sea located between Uzbekistan and Kazakhstan has led to a marked change in the biota and biological condition of the lake. A decrease in agricultural productivity around the lake, the demise of the economically and socially important fishes as well as an increase in respiratory and other human illness also occurred. Increase in salinity in an area leads to an increase in Total Dissolved Solids (TDS) in underground aquifers. When salt droplets get into the soil, they build up. This is due to the fact that they are not transpired by crops or evaporated from the soil. They therefore leach into the underground aquifers, increasing both TDS and salinity content of the water (Bedient *et al*., 1998; Allersma and Tilmans, 1993). Bitterns, a waste product from salt mining, contain some amount of calcium and magnesium salts and their discharge into the environment cause negative changes in the hydro-geochemistry of the area. Both underground and surface may water be affected both physically and chemically.

Currently, very little research work has been done in this area. The negative influence of salt production on the quality of underground water in the communities has not been assessed. It is for this reason that this research sought to identify the effects of small-scale salt mining on the quality of underground water in the KEEA District.

Study area: The study area lies within the coastal zone of Ghana, which stretches from Half Assini in the west to Aflao in the east and is about 550 km long. The coastal zone contains several wetlands, including over a hundred lagoons. It is the area within which interactions between physical and biological, social, cultural and economic processes take place. The offshore zone with an area of about 26000 km^2 extends to about 10 km inland (Varley and White, 1958; Agyepong *et al*., 1995; Gordon *et al.*, 1998). It is the most densely populated part of the country with high concentration of over 1000 persons/sq km in the urban industrial centres. The coastal zone covers about 6.5% of the total land area of the country and yet accommodates over 25% of the total population of the country (World Health Organisation, 1987; Mensah, 1997).

The KEEA District is underlain by sedimentary rocks known as the Elmina sandstone and Sekondian series. The rocks that are dark-brown colour reach depths of over 100 m. The rocks were formed from a thick layer of marine deposits due to the sinking of the outer edges of what was once known as Gondwanaland beneath the sea. These marine deposits hardened and formed rocks like sandstone, shale and limestone (Dickson and Benneh, 1990).

Along the coast of the KEEA District, the major type of soil found is the coastal sandy soil (De Vrees, 1996). It is made up of pale-yellow grains of quartz with considerable air space between them. This soil allows water to rapidly drain through, suggesting deficiency in organic matter content (Monkhouse, 1999). The soil therefore supports mainly coconuts (Buchanan, 1983). However, when it is treated with manure, it supports crops like shallot, maize and, to some extent, cassava.

Along the banks of lagoons where salt production takes place, the soil is made up of clay which consists of very fine mineral particles with individual grains of less than 0.02 mm in diameter (Monkhouse, 1999). The clay contains very little air and holds much water. This makes it form a tenacious sticky mass. Colour ranges from reddish brown to black. It contains a lot of decomposing plant and animal remains and thus very rich in organic matter.

Selection of sampling sites: The selection of sampling sites began with a reconnaissance survey of the coastal areas of the KEEA District where salt mining is actively undertaken. This was based on the existing zones demarcated by the Elmina Salt Producers Association.

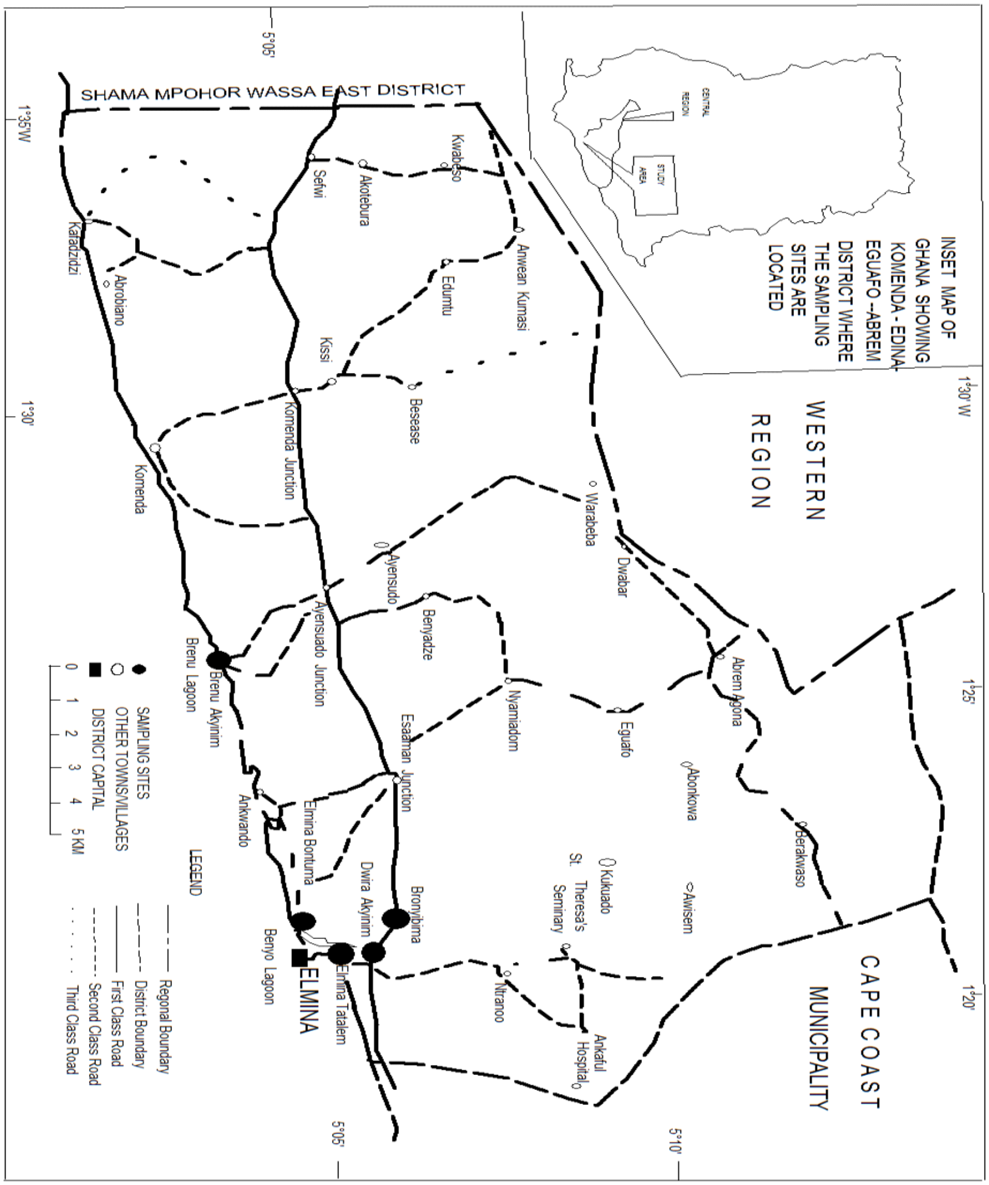

Fig. 1: Map of the study area with sampling sites

The three (3) major areas identified as shown in Fig. 1 were; Dwira Akyinim/Bantuma, Elmina Tatalem/Nyanta and Bronyibima/Brenu Akyinim. However, for the purpose of this study, Brenu Akyinim was considered as a single zone. This is due to the fact that, the brine for the salt mining in this area is from a different (Brenu) lagoon. Also, salt-mining activities had just started in the area and, as a result, its impact on the environment is likely to be limited. Wells (W) selected for the study were quite some distance away from the saltpans and lagoons. The wells were either located in or near communities where people could get easy access to the well water. There was only one producer at Brenu Akyinim where salt mining had just begun. Based on the above factors, Brenu Akyinim (BRA), Bronyibima (BRB), Dwira Akyinim (DWA) and Elmina Tatalem (ELT) were selected as sampling sites (Fig. 1).

Salt mining activities take place in two major lagoons that drain the area. These are the Benya and the Brenu lagoons. The Benya lagoon is an open lagoon located at Elmina. It covers an area of about 4.5 km^2 and is of great economic importance to the people of Elmina and its surrounding towns and villages. Whereas the southern and western portions of the lagoon serve as fishing harbour, the northern and eastern sections are used for commercial salt production (Biney, 1993). The Benya lagoon is the source of saline water (brine) for salt production in Elmina Tatalem, Bronyibima and Dwira Akyinim. The Brenu Lagoon, which is located at Brenu Akyinim, covers an estimated area of about 2.5 km^2. Whereas salt production takes place on the north-eastern section of the lagoon, the entire stretch of the lagoon serves as fishing grounds for the local residents.

Brenu Akyinim (BRA) is a community located on longitude N 05º 04′ 10.8″ and latitude W 01º 25′ 42.2″ is about 18 km from Elmina. Salt mining activities had just started and as a result very few saltpans were located in the area. The distance between the well and the lagoon sampled for analysis in this community is 0.34 km. The depth of the well is 5.0 m

Bronyibima (BRB) which is a village located on longitude N 05º 06′ 06.2″ and latitude W 01º 21′ 17.4″ and found at the base of a hill is about 4 km from Elmina. Information gathered indicated that salt mining activity had been going on for a long time and the village had the largest number of saltpans in the District. The distance between the well and the lagoon sampled for analysis in this community is 0.57 km. The depth of the well is 4.4 m

Dwira Akyinim (DWA) is a community located on longitude N 05º 05′ 18.9″ and latitude W 01º 21′ 32.7″ is about 2 km from Elmina. Information gathered indicated that salt mining activity had been going on for a long time and the village had the largest single salt mining company (Edinaman Salt Industries) in the District. The distance between the well and the lagoon sampled for analysis in this community is 1.28 km. The depth of the well is 3.5 m

Elmina Tatalem (ELT) is a suburb of Elmina township and is located on longitude N 05º 05′ 32.6″ and W 01º 20′ 26.4″. It is densely populated and this has led to the creation of sanitation problems in the area. Information gathered suggested that salt mining activities have been going on for a long time and there were relatively many saltpans in the village. The distance between the well the lagoon sampled for analysis in this community is 0.48 km. The depth of the well is 4.2 m.

METHODOLOGY

Water sampling and analysis: Water samples for physico-chemical and bacteriological analysis were taken from wells from each of the sampling sites. Six samples were taken at a month's interval from November 2002 to April 2003. In all, seventeen (17) parameters were analyzed to check the effect of salt mining on well water quality. Parameters analyzed were;

Physical parameters: Temperature, pH, Total Dissolved Solids (TDS), Turbidity and Suspended Solids (SS)

Chemical parameters: Iron (Fe), Copper (Cu), Nitrate (NO_3), Salinity, Calcium (Ca) Phosphate (PO_4), Dissolved Oxygen (DO), Magnesium (Mg) and Biochemical Oxygen Demand (BOD).

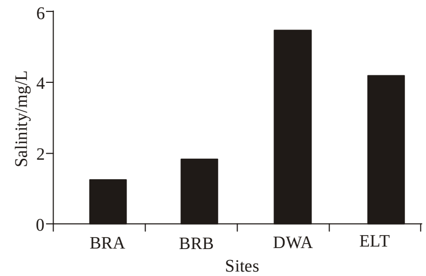

Fig. 2: Mean salinity for the various sites

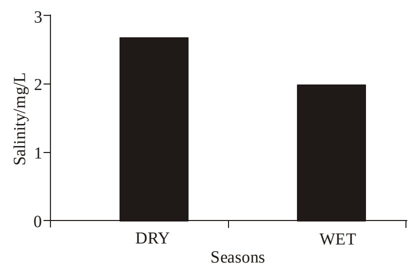

Fig. 3: Seasonal means for salinity

Bacteriological parameters: Total Coliform and Faecal Coliform

At each sampling site, a clean plastic bucket with a rope attached to it was used to fetch the water manually. The water was taken at depths between eight to ten centimetres below the surface for *in-situ* measurements of some parameters. A 1.5 L plastic bottle was used to sample well water meant for physico-chemical analyses. Water samples were immediately placed in ice chests with ice cubes at a temperature of about 4ºC (De Zuane, 1997) and transported to the laboratory for analysis. All water quality analyses were carried out in the laboratory within three days of collection with the exception of BOD which was analysed after 5 days.

Temperature, pH, conductivity, salinity and total dissolved solids were measured *in-situ*, using a Horiba Digital Water Quality Checker (Model V.10). Suspended solids, Iron, Copper, Nitrate and Phosphate were measured with the photometric method using the HACH DR/2000 Direct Reading Spectrophotometer. The Absorptometric method using the HACH DR/2000 Direct Reading Spectrophotometer was used to measure turbidity. The Winkler method was used in measuring Dissolved Oxygen Biochemical Oxygen Demand.

RESULTS AND DISCUSSION

Salinity: Salinity values range from 0.8 mg/L recorded at Brenu Akyinim in April to 7.4 mg/L recorded at Dwira Akyinim in November. Figure 2 indicates that mean values for the various sites also ranged from 1.2 mg/L recorded at Brenu Akyinim to 7.4 mg/L recorded at Dwira

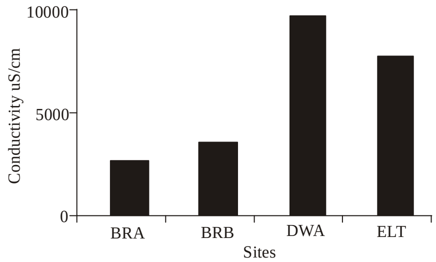

Fig. 4: Mean conductivity for the various

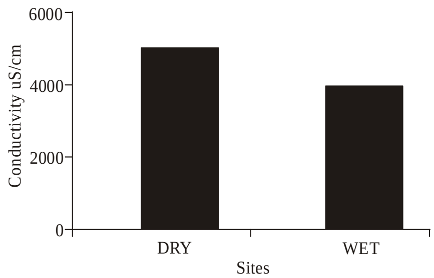

Fig. 5: Seasonal means for conductivity sites

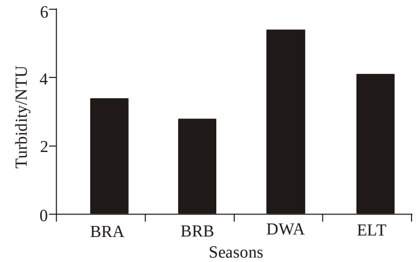

Fig. 6: Mean turbidity for the various sites

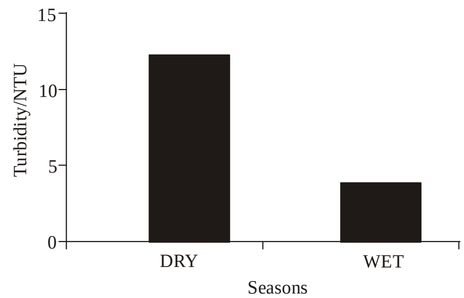

Fig. 7: Seasonal means for turbidity

Akyinim. As shown in Fig. 3, 2.7 and 2.0 mg/L were also recorded as seasonal means for the wells. As expected, higher values were recorded in the dry season than the wet season.

There were no significant differences between values for the wells during the dry and wet seasons (ANOVA. p>0.05), though all the values recorded were above the acceptable range. Generally, salinity of the wells declined from the dry season to the wet season. The only difference is that December had lower values than January and this may be attributed to the heavy down pour that occurred 2 days before sampling day in December. It must be noted that the well at Brenu Akyinim is closer to the lagoon and the salt pans than the other wells and yet the lowest salinity value was recorded there. This may be attributed to the fact that there is only one salt mine at Brenu Akyinim and it is relatively new as compared to the other sites. Seepages into the soil and eventually into the wells may have not been going on for long. This may have reduced the salt content in the soil in the area. The highest salinity values were obtained at Dwira Akyinim, though the well in this community is the one located farthest away from a salt pan. This may be attributed to the fact that the well is very shallow and open leading to excess evaporation. Another reason could be that there are so many pans scattered over the area which may have resulted in increased seepage into the soil. The dry season values were slightly higher than the wet season. Run offs enter the wells to produce dilution effects.

Conductivity/Total Dissolved Solids (TDS)/turbidity: Conductivity values for the wells range from 1730 μS/cm recorded at Brenu Akyinim in December to 9600 μS/cm recorded at Elmina Tatalem in November. Figure 4 and 5 indicates that the mean values for the sites were between 2500 and 9400 μS/cm for Brenu Akyinim and Dwira Akyinim respectively while 4964 μS/cm was recorded for the dry season and 3961 μS/cm for the wet season. There was no specific pattern in the values recorded. However the lowest values for all the sites were recorded in April, probably due to the fact that there was a heavy down pour a day before sampling. The variability between the values was significant. There was some seasonal variability. On the average, higher values were recorded for the dry season than the wet season. The seasonal values showed no significant difference (ANOVA. p>0.05).

Turbidity levels for the wells range from 1.4 NTU recorded in March at Brenu Akyinim to 14.0 NTU recorded at Elmina Tatalem. As shown in Fig. 6, mean values range from 2.8 NTU recorded at Brenu Akyinim to 7.7 NTU recorded at Elmina Tatalem. 5.6 NTU and 3.8 NTU were also recorded for dry and wet respectively as seasonal mean (Fig. 7). Values recorded for turbidity did not show any specific pattern. Differences between the seasonal means were not significant (ANOVA. p>0.05), even though values recorded in the dry season were a bit high than that of the wet season.

Total Dissolved Solids (TDS) values range from 895 mg/L recorded at Brenu Akyinim in March to 3790 mg/L recorded at Elmina Tatalem in January. Figure 8 and 9 indicates that mean values for the various sites also ranged from 11048 mg/L recorded at Brenu Akyinim to 3120 mg/L recorded at Dwira Akyinim and 2014 and 1705 mg/L were also recorded as seasonal means for the wells. Generally values recorded in the dry season were slightly higher than in the wet season, even though

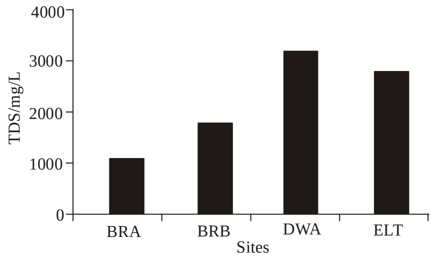

Fig. 8: Mean TDS for the various sites

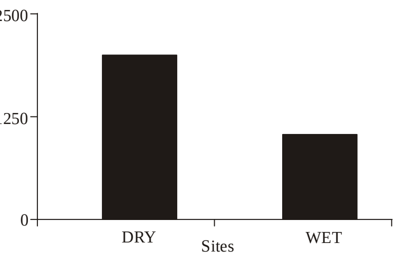

Fig. 9: Seasonal means for TDS

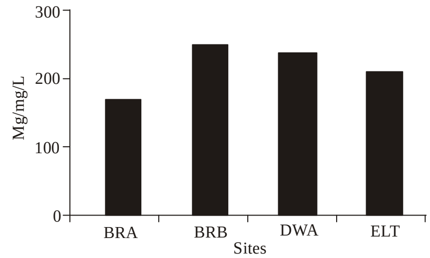

Fig. 10: Mean Mg for the various sites

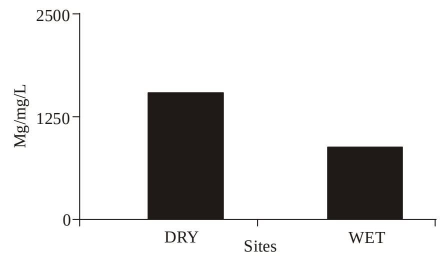

Fig. 11: Seasonal means for Mg

differences between the seasonal values were insignificant (ANOVA. p>0.05). Differences were also minimal among the values obtained at the various sites Conductivity for the wells was far above the natural background level of 700 µS/cm for domestic use (UNESCO, 1987). Though that of Brenu Akyinim was slightly lower than the other sites, it was still far above the acceptable limit. There were some seasonal variations with the dry season recording higher values. This can be attributed to excessive evaporation of the water during the dry season. The clayey nature of soils found in the area could, among others be responsible for the high values (Davies and Day, 1998). The presence of dissolved salts from the salt pans can also increase the conductivity level of the water. This is because conductivity is affected by the presence of inorganic dissolved solids of anions and cations (Chapman, 1992).

As reported by Biney (1993), the occurrence of high Suspended Solids concentration usually coincides with high turbidity values. Generally, higher values were recorded in the dry season than the wet season and this may be due to excessive evaporation, leading to high concentration of particles in the waterWith the exception of two in the dry season, all the monthly means of turbidity for the wells fell below the acceptable background limit of 5 NTU. One of the monthly recordings at Elmina Tatalem was however, above the natural background level. This may be due to the fact that the well at that site was not covered and so particles could easily blow into it. One major effect of high conductivity, turbidity, TDS/SS is that it increases the hardness of the water, thus making it unsuitable for domestic purposes such as washing (Spellman and Drinan, 2000).

Magnesium (Mg): Mg values recorded ranged from 146 mg/L recorded at Brenu Akyinim in April to 316 mg/L recorded at Elmina Tatalem. The mean values as shown in Fig. 10 indicated that means for the various sites ranged from 164.6 mg/L recorded at Brenu Akyinim to 256.0 mg/L recorded at Bronyibima. Values of 211 and 186 mg/L were recorded for the dry and wet seasons respectively. Generally higher Mg values were recorded in the dry season than that of the wet season as shown in Fig. 11 The differences were however not significant (ANOVA. p>0.05). Values less than the natural background level of 150 mg/L were recorded at Brenu Akyinim for two months. Values recorded in March for both Bronyibima and Elmina Tatalem were below the natural background level. The values recorded did not follow any specific pattern and the variations between the values in both the dry and wet seasons were high.

All the Mg values were above the WHO permissible limit with the exception of March and April when values lower than the WHO permissible limit were recorded at Brenu Akyinim and Elmina Tatalem. All of them were however above the natural background range of between 1.0 and 99.0 mg/L (Akpabli and Drah, 2001). The lowest value, recorded in April was likely due to the dilution effect of the run-off of rainfall a day before sampling. The highest, recorded in March may be due to the fact that the mining activity had gone on for about six month and, as a result salinity may have been high.

Calcium: Generally, the wells had most of their values falling below the natural background level of 200 mg/L. Values higher than the natural background levels were recorded in December, January and March for Elmina

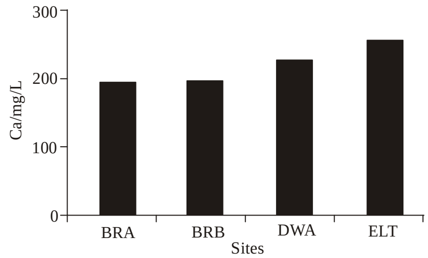

Fig. 12: Mean Ca for the various sites

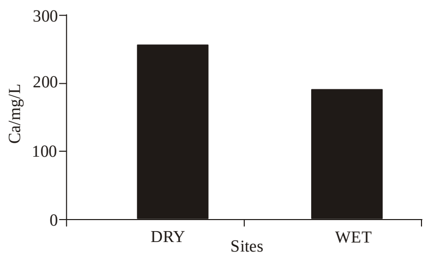

Fig. 13: Seasonal means for Ca

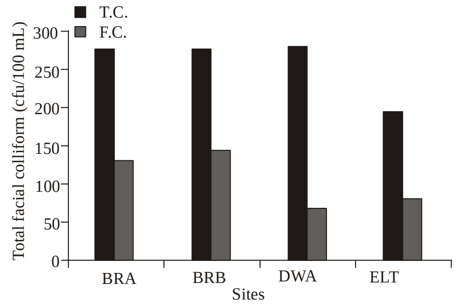

Fig. 14: Mean total and faecal coliform for the various site

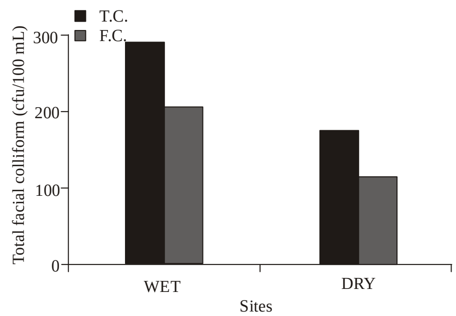

Fig. 15: Seasonal means for total and faecal coliform

Tatalem and December and April for Brenu Akyinim and Bronyibima respectively. There were some variations between the values of the dry and wet seasons.

Higher values were generally recorded in the dry season than the wet season. The variations between the values of the wells for the dry and wet seasons were insignificant (ANOVA. $p>0.05$). The values range from 80 mg/L recorded in April at both Brenu Akyinim and Edina Tatalem to 400 mg/L recorded in January at Elmina Tatalem. Figure 12 and 13 shows that means for the various sites ranges from 183 mg/L recorded at Brenu Akyinim to 258 mg/L recorded to Elmina Tatalem whiles 254 and 186 mg/L were recorded as means for dry and wet seasons respectively.

Only four of the monthly values recorded for Ca on the other hand, were higher than WHO permissible limit of 200 mg/L. Lowest mean concentrations of Ca and Mg were recorded at Brenu Akyinim and this may be due to the fact that salt mining activities has not gone on for a long time in the area and there was only one production site in the area. Though calcium ion is readily dissolved from rocks rich in calcium minerals, particularly as carbonate and Sulphate (Akpabli and Drah, 2001) the geology of the site is almost the same, so the geology may not be reason for the differences recorded between the various sites. The hardness of natural waters depends mainly on the presence of dissolved calcium and magnesium salts.

Coliform bacteria: The highest values for the wells were recorded at Bronyibima, in December. The lowest, on the other hand, were recorded in January at Elmina Tatalem. The monthly mean ranged from 83 cfu/100 mL in February to 172 cfu/100 mL in April. The high values for April may be attributed to the heavy rainfall a day before sampling. It may have drained faecal matter along the banks of the lagoon into the wells As shown in Fig. 15, mean for the sites ranged from 83 cfu/100 mL at Elmina Tatalem to 147 cfu/100 mL at Bronyibima for the wells. Seasonal values for the wells were 119 and 125 cfu/100 mL, respectively, for the dry and the wet seasons (Fig. 14).

Generally, higher values were recorded in the wet season than the dry season as indicated in Fig. 15. The difference between the dry and wet seasons was insignificant (ANOVA. $p>0.05$). Values recorded on days when there has been a rainfall prior to sampling were relatively high than other days.

CONCLUSION

Generally, the quality of well water have been affected by the salt mining and other anthropogenic activities and this in turn has affected socio-economic activities in the study area. The well waters that serve as the source of water for domestic purposes are polluted. Concentrations of physico-chemical parameters, especially, those of conductivity, salinity and TDS were very high. Nutrient levels as well as the presence of bacterial were also high. The values for physico-chemical parameters were higher in the dry season when salt mining is at its peak than the wet season. Lower values were, however, recorded for the chemical parameters during the dry season. All these, especially, the high levels of the physico-chemical parameters which can be attributed to the salt mining activities has rendered the water unwholesome for consumption. The pollution of the wells can be attributed to the salt mining activities because at Brenu Akyinim where salt mining have just started and there is only one producer in the area, the quality of water in terms of concentrations of physico-chemical parameters and bacterial were better.

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