Water Quality Appraisal in Selected Rivers at Atiwa Forest in the Eastern Region of Ghana

ABSTRACT

The high spate of illegal mining activities in the Atiwa forest in the Eastern Region of Ghana has caused lots of damage to water bodies and its surrounding environment including soil and air pollution. This anthropogenic activity has resulted in elevated amounts of heavy metals pollution of the affected water bodies and its adjacent environment. This calls for the needs for the investigation into the analysis of the total coliform, E. coli and heavy metals for drinking and irrigation water accessibility is highly recommended. These are dangerous bacterial and pollutants which have health implications. A total of 20 water samples were collected from the five (5) major rivers, namely Ayensu, Birim, Ewusu, Wankobiri and Suhyen in the Anum Apapam, Kyebi Apapam, Kwabeng, Asikam and Kobriso Atiwa forest which serve at irrigation and drinking purposes for these communities. The water samples were analyzed for pH, electrical conductivity (EC), dissolved solids (TDS), turbidity, colour, total calcium (Ca), magnesium (mg), total hardness (TH), sodium (Na), sodium (Na), Bicarbonate (HCO_3^-), Carbonate (CO_3^{2-}), Sulphate (SO_4^{2-}) and Chloride (Cl^-). The results obtained were compared with permissible values of WHO and FAO Guidelines for drinking water and irrigation. The results obtained shows that the water samples from all the rivers; Ayensu, Birim, Ewusu, Wankobir and Suhyen are not suitable for drinking even though all the water quality parameters are within the range of acceptability except the colour and turbidity levels of the water samples which exceeded its acceptable limit thereby making the water unsafe for drinking. Also, all the water quality parameters for irrigation suitability are within the acceptable limit except HCO_3^- and CO_3^{2-}.

Keywords: Water quality, Irrigation, Rivers, Parameters

1. INTRODUCTION

The Atewa landscape is a site of an important forest reserve, mineral deposits and the source of three major rivers in the country: the Densu River, the Ayensu and the Birim. [1] ascertains that, the Atewa Forest Reserve harbours a high diversity of rare and endemic species, particularly of birds, amphibians, butterflies, plants and mammals. [2] also supports that, the forest represents about 33.5 % of the residual closed forest in Ghana's Eastern Region. A research conducted by [3] shows that, the majority of small-scale miners in Ghana operate informally, due to the barriers associated with obtaining land and a licence. This informality has given rise to a host of environmental and social problems in Ghana, such as the degradation of arable farmland, as well as the negative health impacts of working in hazardous conditions and ultimately the pollution and destruction of water bodies and soil for farming. According to [4], the pollution and destruction of water bodies and soils is caused by the clearing of land which results in soil erosion, siltation, soil compaction, destruction of ecosystems and loss of biodiversity. To [5], the quality of water and soils are impaired through the use of mercury in the mining process. Mercury is added to the deposits suspected to contain minerals and mixed to form an amalgam. This mixture is then washed continuously with water to separate the precious minerals from the rocky debris. This process of extraction largely informs the choice of site for small scale mining operations: the nearness of the site to a source of water.

[6] noted in his research that, two major rivers in the Eastern region, Birim and Densu Rivers which serves as source of drinking water for several communities have been affected by small-scale mining activities. This menace obligated the Ghana Water Company Limited which takes its water source from the river to close its water treatment plant momentarily at Kyebi. In the quest of the Government of Ghana to fight against galamsey in the country, a joint Task Force dubbed Operation Vanguard made up of four hundred (400) officers and men from the Ghana Army, Navy, Air Force and the Ghana Police Service has been deployed to combat illegal mining activities in the Eastern, Ashanti and the Western Regions. The Task Force has been tasked to arrest illegal miners and also remain in the affected areas until degraded land and rivers are restored.

However, the contaminated soil and water bodies in the Atewa Landscape as a result of mining activities through dug pits and use of chemicals poses serious threat to the livelihood of the fringe communities and ultimately those who depend on the food crops and water resources from the Atewa landscape for their domestic use. This research focuses on the pollution status of river bodies and their tributaries with respect to water quality characteristics.

2. MATERIAL AND METHODS

The Atewa Landscape can be found in the Akyem-Abuakwa Traditional Area in the Eastern Region of Ghana, near the town of Kyebi, and lying between latitude 06 08 48.5 N and longitude 00 35 56.9 W. The landscape comprises of steep-sided hills with equally flat terrains. Politically, the Atewa Landscape falls under five districts; the Kwaebibirem District, the Atiwa District, the Ayensuano District, the East Akyem District and the West Akyem District.

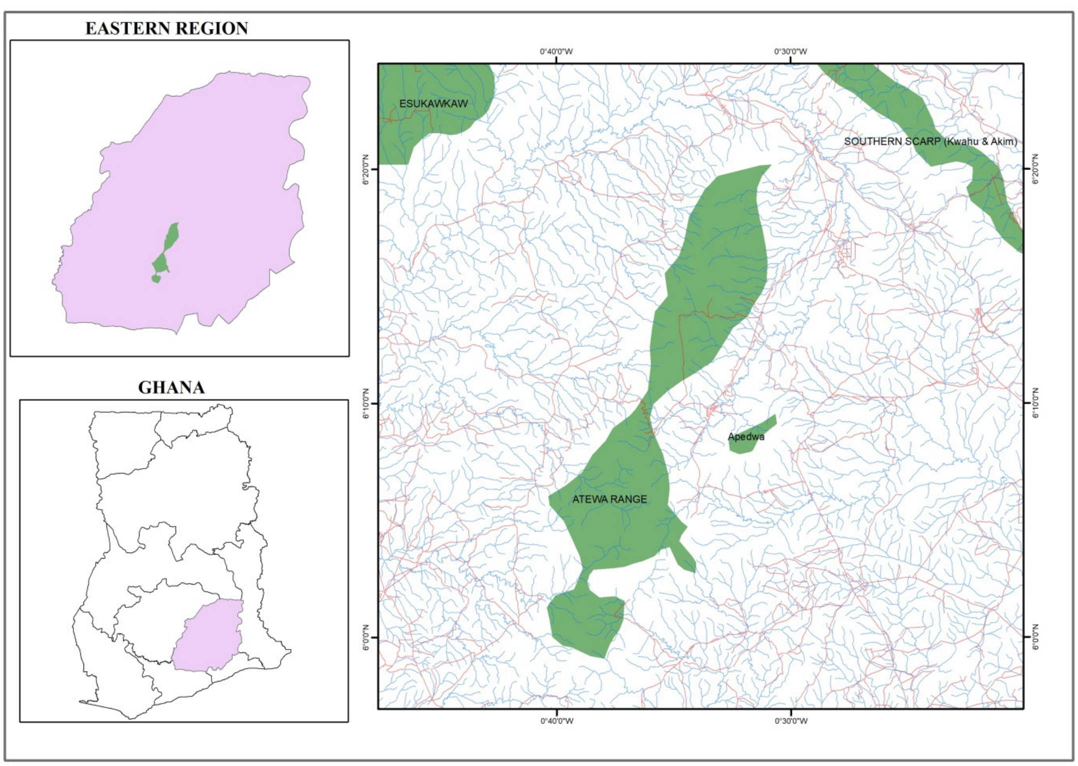

Figure 1 Map showing the Atewa Landscape

The forest has a dual highest rainfall pattern and it is characterized by high temperatures (Figure 2). Its mean periodic temperature is between 24 ℃ and 29 ℃, and experiences a mean yearly rainfall of between 1,200 mm and 1,600 mm.

From May to July, occurs its first topmost rainfall while the second one occurs in September-November. Relative humidity is generally high between 70 % – 80 % in the dry season and 75 % – 80 % in the wet [7].

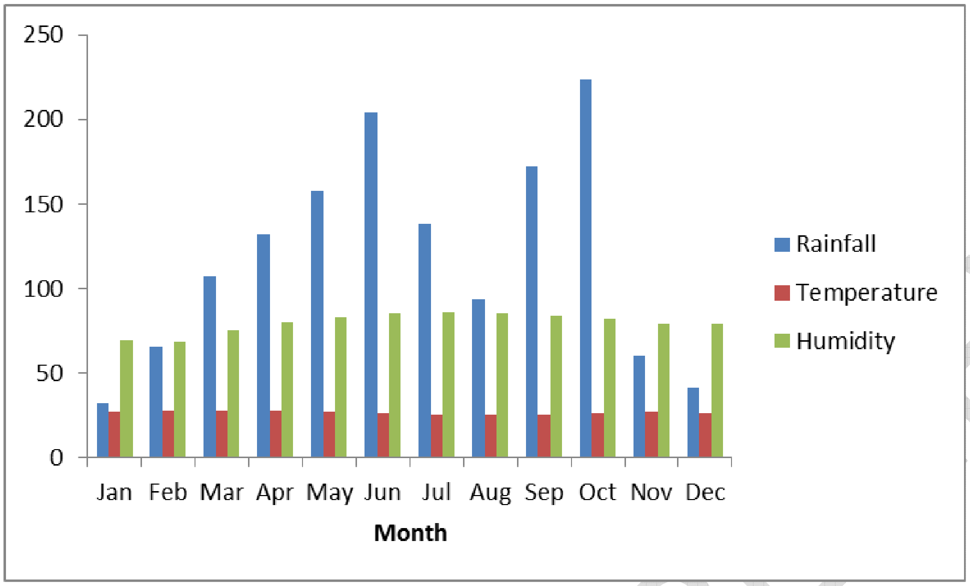

Figure 2: Climatic condition of Atiwa forest over a 30-year period

2.1 Water Sampling and Analysis

A total of 20 water samples were collected from the five (5) major rivers, namely Ayensu, Birim, Ewusu, Wankobiri and Suhyen in the Anum Apapam, Kyebi Apapam, Kwabeng, Asikam and Kobriso Atiwa forest which serve at irrigation and drinking purposes for these communities.

The water samples were analyzed at the Department of Laboratory Analytical Services of CSIR-Soil Research Institute, Ghana. The water samples were analyzed for pH, electrical conductivity (EC), dissolved solids (TDS), turbidity, colour, total calcium (Ca), magnesium (mg), total hardness (TH), sodium (Na), Bicarbonate (HCO_3^-), Carbonate (CO_3^{2-}), Sulphate (SO_4^{2-}) and Chloride (Cl^-). All the reagents used in the analysis were of analytical reagent grade and deionized water was used for experimental purpose. All the precautions were taken as given in [8], for sampling and analysis. In this research the values of the parameters were compared with permissible values of WHO and FAO Guidelines for drinking water and irrigation as below:

Table 1: **shows the maximum acceptable limit of heavy metals concentration and Physiochemical parameters in drinking water according to the WHO and FAO standard**

Parameters	Unit	WHO	FAO
pH		6.5-9.2	6.0-7.0
EC	µs/cm	400	300-700
TDS	mg/l	500	200-500
Total hardness	mg/l	100	-
Colour	Pt.co	0	-
Potassium (K)	mg/l	-	5-20
Calcium (Ca)	mg/l	75	20-60
Magnesium (mg)	mg/l	150	10-25
Bicarbonate (HCO_3^-)	mg/l	150	<120
Carbonate (CO_3^{2-})	mg/l	75	<15

Sulphate (SO_4^{2-})	mg/l	200	-
Chloride (Cl^-)	mg/l	200	100-300
Fluoride (F^-)	mg/l	1	-

2.1.1 Statistical Analysis

Data were analyzed using statistix 10.0 version. Analysis of variance for water quality parameters for water samples collected from each river.

RESULTS AND DISCUSSION

The results on the effect of illegal mining and small-scale mining activities on physicochemical properties of water and water quality parameters for Irrigation assessment are presented in Table 2 and Table 3

Table 2 Physical and chemical properties of water samples from the selected rivers.

River	pH	EC_w	Hardness	Turbidity	Colour	Ca	mg	Na	HCO_3^-	CO_3^{2-}	Cl^-	NO_3^-	SO_4^-
		µs/cm	mg/l	mg/l	PtCo.	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l
Ayensu	**7.48**	**158.53**	**64.02**	**8.68**	**62.17**	**10.69**	**17.34**	**72.99**	**54.80**	**26.67**	**61.98**	**2.77**	**15.00**
Birim	**7.08**	**149.80**	**60.03**	**13.43**	**48.33**	**11.22**	**7.78**	**2.24**	**240.67**	**28.02**	**116.90**	**2.31**	**16.67**
Ewusu	**7.10**	**90.30**	**38.03**	**1923.67**	**9761.00**	**8.02**	**4.38**	**2.35**	**114.00**	**20.02**	**55.38**	**5.74**	**88.67**
Wankobiri	**6.77**	**83.57**	**40.70**	**20.13**	**708.33**	**8.55**	**4.70**	**1.46**	**218.67**	**21.36**	**106.21**	**3.11**	**38.00**
Suhyen	**7.43**	**98.03**	**40.01**	**68.97**	**336.17**	**9.09**	**4.21**	**40.55**	**38.00**	**22.67**	**50.99**	**3.47**	**23.33**

Effect of illegal mining and small-scale mining activities on physicochemical properties of water

Water quality could be described as the physical, chemical, and biological characteristics of water in comparison with the set of standards. These parameters directly related to the safety of the various purposes to human use. Water quality parameters provide important information about the health of a water body. These parameters are used to find out the quality of water for drinking purpose.

From Table 2, The pH of pure water could be described as the measure of hydrogen ions concentration in water. It ranges from 0 to 14. Water with a pH of 7 is considered neutral while lower and higher than 7 are described as acidic and basic. The average pH of the samples ranged from 6.77 to 7.48. This is within the range of the suitability for drinking and irrigation purposes (Table 1). The highest occurred in the Ayensu River in the Anum Apapam community. The pH levels of the rivers (water samples) differed by communities since the p-value of 0.0013 is less than the 5% (or 1%) level of significance. This implies that the pH levels of the rivers in Ayensu, Birim, Ewusu, Wankobir and Suhyen are different from each other. Water with pH outside of this range may not directly influence crop performance, but indicates a need to evaluate other chemical component of the water.

Water with high level of purity is not a good conductor of electric current rather a good insulator. Increase in ions concentration increases the electrical conductivity of water. Generally, the number of dissolved solids in water regulates the electrical conductivity. Electrical conductivity (EC) is actually measures the ionic process of a solution that enables it to transmit current [9]. According to WHO and FAO standards EC value should not exceed 400 and 700µS/cm (Table 1). The EC of the water samples varied from 83.57 to 158.53µs/cm. Ayensu River in Anum Apapam community recorded the highest EC. Primary effect of high ECiw water on crop productivity is the inability of the plant to compete with the ions in the soil solution of water. The higher the ECiw, the less water is available to the plants, even though the soil may appear wet, leading to low productivity [10].

Also, Hard water is considered as high mineral contents that are usually not harmful for humans. It is often measured as calcium carbonate ($CaCO_3$) because it consists mainly calcium and carbonates the most dissolved ions in hard water. According to World Health Organization (WHO) hardness of water should be 500 mg/l. The average hardness of the water samples ranged from 38.03 to 64.02mg/l of which still River Ayensu recorded the highest hardness, but they are all within the range of acceptability.

Moreover, the colour of the water may come from the activities of the small-scale mining in the rivers. Pure water should have virtually no colour according to WHO. The water could be suitable for irrigation but unsuitable for domestic activities in the study area depending on the intensity of the colour of the water. The higher level of colour means water is much dirtier. River Ewusu recorded higher value of colour of 9761ptco implying that the river is much dirtier than others. During the fieldwork it was observed that lots of illegal mining activities go on in River Ewusu and it is no surprised that the river recorded high colour. The colour levels of the rivers (water samples) do no differed by communities since the p-value of 0.1191 is greater than the 5% (or 1%) level of significance. This implies that the colour levels of the rivers in Ayensu, Birim, Ewusu, Wankobir and Suhyen are not different from each other.

The calcium and magnesium are the most abundant elements in the water. Calcium may originate from carbonate rocks and lime stones or from soils as a result of leaching. Dissolved mg concentration is mostly lower than Ca in the water. Other sources may include primarily industrial and municipal discharges. Calcium is an essential nutritional element for human being and helps in maintaining the structure of plant cells and soils. Magnesium is a constituent of bones and is essential for normal metabolism of Calcium. Its deficiency may lead to protein energy malnutrition (Mohsin et al., 2013). The average values of calcium and magnesium ranged from 8.02 to 11.22mg/l and 4.21 to 17.34mg/l which are within the range of suitability for drinking and irrigation. The Ca levels of the rivers (water samples) are not differed by communities since the p-value of 0.1804 is greater than the 5% (or 1%) level of significance. This implies that the Ca levels of the rivers in Ayensu, Birim, Ewusu, Wankobir and Suhyen are not different from each other.

Bicarbonates concentration in water depends on pH and is usually less than 150 mg/l in water for drinking purpose. It is the standard alkaline constituent found almost all surface and ground water bodies and therefore affects alkalinity and hardness of water. The weathering of rocks adds bicarbonate content in water. Mostly bicarbonates are soluble in water i.e. bicarbonate of magnesium and calcium etc. is the main causes of hardness of water. The hard water is not suitable for drinking purpose and causes the gastro diseases (Mohsin et al., 2013). In the study area HCO_3^- and CO_3^{2-} varied from 38.00 and 20.02mg/l to 240.67 and 28.02mg/l indicating higher values of HCO_3^- and CO_3^{2-} , especially in River Birim which had high values of carbonate and bicarbonate (Table 3) for irrigation purpose. Irrigation water rich in HCO_3^- content tend to precipitate insoluble Ca^{2+} and mg^{2+} in the soil which ultimately leaves higher proportion of Na^+ and increases the SAR value [11] as:

$$2HCO_3^- + Ca^{2+} \rightarrow CaCO_3 + H_2O + CO_2 \uparrow$$

Table 3: Water quality parameters for Irrigation assessment

Parameters	Ayensu	Birim	Ewusu	Wonkobiri	Suhyen
SAR	**4.48**	**0.14**	**0.23**	**0.14**	**3.93**
RSC	**-0.23**	**3.57**	**1.72**	**3.38**	**0.55**

Effect of illegal mining and small-scale mining activities on water quality for irrigation assessment

Although sodium in the irrigation water can be toxic to plants, a more common deleterious effect of sodium results from its effect on soil structure. When irrigation water is applied to the soil, the best indicator of sodium effect is water's Sodium Adsorption Ratio (SAR). A high SAR value implies a hazard of sodium (alkali) replacing Ca and mg in the soil through a cation exchange process that damages soil structure, mainly permeability, and which ultimately affects the fertility status of the soil and reduces crop yield [12]. According to table 4 all the water samples from the rivers fall within the range of irrigation suitable from Food and Agricultural Organization (FAO).

Residual sodium carbonate (RSC) is a common means of assessing the sodium permeability hazard, and takes into account the bicarbonate/carbonate "and" calcium/magnesium concentrations in irrigation water. RSC is important because it's not the absolute bicarbonate and carbonate concentrations that are important, but instead, the relative concentrations of bicarbonate and carbonate compared to concentrations of calcium, magnesium, and sodium. A positive RSC value indicated that the contents of dissolved Ca^{2+} and mg^{2+} ions is less that of CO_3^{2+} and HCO_3^- [13]. RSC values were satisfied in the study area. According to [12], satisfactory RSC should be less than 5mg/l (Table 3)

4. CONCLUSION

Water quality from rivers in the Atewa forest is deteriorating as a result of Small Scale and Illegal Mining Activities. From the results above it could be concluded that the water samples from all the rivers; Ayensu, Birim, Ewusu, Wankobir and Suhyen are not suitable for drinking even though all the water quality parameters are within the range of acceptability. The colour and turbidity levels of the water samples are outside the threshold which made the water unfit for drinking. Also, all the water quality parameters for irrigation suitability are within the range except HCO_3^- and CO_3^{2-}. The water could be suitable for irrigation since Na, SAR and RSC, which could have been elevated by HCO_3^- and CO_3^{2-} by forming insoluble salt with Ca and mg are also within the threshold.

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