THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Impacts of Illegal Small-Scale Mining (Galamsey) on Manse and Ankobra Rivers in the Prestea Huni-valley Municipality of Ghana

Stephen Boadi Adjei

Senior Cartography Officer Department of Cartography,
Cocoa Health and Extension Division (COCOBOD), Accra, Ghana

Dr. Anthony Arko-Adjei

Senior Lecturer, Department of Geomatic Engineering,
Kwame Nkrumah University of Science and Technology, Kumasi, Ghana

Abstract:

Water samples from four sampling sites (Ankobra upstream (AUS), Ankobra downstream (ADS), Manse upstream (MUS) and Manse downstream (MDS) along the profile of Ankobra and Manse rivers in Prestea Huni-Valley Municipality in the Western Region of Ghana were collected and analysed for a period of six months with the aim of assessing the effects of illegal small-scale mining (galamsey) on the water quality. Levels of physicochemical parameters such as Potential of Hydrogen (pH), Temperature, Dissolved Oxygen (DO), Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), True Colour and heavy metals such as Iron (Fe), Lead (Pb), Copper (Cu), Arsenic (As), Cadmium (Cd) and Mercury (Hg) were determined. The levels of the parameters studied suggest that illegal small-scale gold mining operations have impacted negatively on the water quality of the Ankobra and Manse rivers looking at the high levels of true colour, turbidity, total suspended solids, iron and mercury which exceeded the WHO recommended guideline values, the clayey undrinkable water from the two rivers, the fishes and other aquatic creatures that have died and the pits that have been dug along the banks of the rivers which now serve as breeding places for mosquitoes.

Keywords: *Impacts, illegal small-scale mining (Galamsey), physicochemical parameters, heavy metals, model or map*

1. Introduction

In Ghana, the nearby speech utilized to depict illegal small-scale gold mining is called galamsey. Galamsey operations have been a national migraine for the nation Ghana since 1970 because of its impacts on our environment (McQuilken and Hilson, 2016). Small-scale mining in general contributes to wealth creation, work and the economy which makes it the country's most vital vocation exercises. It is reported that about one million individuals are locked in this exercise and accounted for 35% of Ghana's add up to gold generation in 2014 (McQuilken and Hilson, 2016). The activities of illegal small-scale gold miners are causing more harm than good because of its impacts on the pollution of rivers and water bodies (Davis et al., 1994). The rate at which rivers have been polluted by these galamsey operators makes it difficult for the individuals who live near to use these river bodies as source of drinking water and other domestic activities.

Contaminations of water bodies both ground and surface have been experienced for the most part of gold mining communities in Ghana (Davis et al., 1994) be that as it may. Gold mining in later times has ended up disagreeable because it is respected as a source of overwhelming metals like mercury, lead, iron, copper, cadmium etc. defilement to rivers and water bodies. These metals get into the rivers and water bodies through exercises such as refining, metal transportation, mineral misuse, transfer of the tailings and squander waters around mines (Hilson, 2002; Aryee et al., 2003; Essumang et al., 2007; Paruchuri et al., 2010). The major issue related to both legal and illegal small-scale gold mining is the method utilized when extricating gold from minerals called amalgamation (Ntibery et al., 2003) which includes the utilization of mercury. Nearly all small-scale gold miners utilize the strategy of amalgamation to recuperate gold from ore because it may be a basic technique used in gold extraction but it is well known that the method is harmful to health (Lombe, 2003). In addition, the forms of amalgamation are commonly done along rivers and water bodies coming resulting in water contamination with communities downstream truly influenced most. Mineral misuse causes harm to the environment on a scale as against other few human exercises. Mineral misuse is dependable for soil disintegration, deforestation and water contamination. The ecological effects related with it are especially exceptionally extreme in countries that are developing, which is known to create an expansive parcel of the world's minerals. Surface mining scars huge ranges and makes colossal amounts of squander that disintegrate into streams and lakes (Charis, 1994). Exercises including mining affect the environment and the seriousness of the effect depends on the strategies utilized and whether the mine is large or small (Chime et al., 2001). The activities of illegal small-scale gold mining operators have expanded within the Municipality due to the presence of Golden Star Bogoso/Prestea Limited, a Canadian large-scale gold mining company. This study analyses

the procedure of galamsey operations and their impacts on the surface water quality of Manse and Ankobra Rivers within the Prestea Huni-Valley Municipality.

2. Materials and Methods

2.1. Study Area

The study was carried out at the Prestea-Huni-Valley Municipality in the Western Region of Ghana located between Latitude 5°N and 5°40'N and Longitudes 1° 45'W and 2° 10'W (Figure 1) and lies within the south-western Equatorial zone (Oduro, 2011). The relief of the study area is characterized by series of undulating landscape with prominent ridges that are above 60 to 80 meters above mean sea level. These hills are aligned with the main gold bearing ores, and therefore accommodate majority of ore extraction operations. The climatic condition of the study area is hot and humid, and it is characterized by two wet seasons. The main raining season is from April to July with the peak in May and June. The minor raining season which is between September and October to November peaks by the end of September. Temperatures are usually high with the highest daily temperature recorded in March which is 26°C and the lowest in September which is 20°C. The research area is devoid of mature forest due to large scale agriculture-, lumbering-, large- and small-scale gold mining and other land use. The existing forests are either in reserved areas or areas unsuitable for agriculture. The nature of the original ecology has resulted in thin riparian 22 strips of vegetation along muddy streams which have had their courses diverted or dammed in several places to enhance small scale gold mining activities (GSBPL EMP, 2008). The study area is drained by the Manse River and its tributaries. These include: Asesere (which is used for domestic purposes by the Bondaye village), Worawora, Bogo, Subri (which drains the Bondaye area, and flows into Ankasa), Kokodabo and Pram. The Manse River ultimately flows into the Ankobra River, which is the major drainage in the Bogoso/Prestea mining area (GSBPL EMP, 2008).

2.2. Data Collection, Preparation and Analysis

Landsat 7 ETM+ SLC OFF satellite image of the study area was downloaded from the United States Geological Survey (USGS) website. The image was enhanced to increase or improve the image quality, value, or extent in QGIS. Operations involving line correction was then applied to the satellite image because the Scan Line Corrector (SLC), which compensates for the forward motion of Landsat 7, failed On May 31, 2003. A radiometric correction was again performed on the satellite image. The other operation performed on the Landsat image was image subsetting which was done to select the part of the image needed for the project work. The next operation performed on the Landsat image was layer or image stacking that is joining the subset images together using bands 1-5 and 7. This is done so that remotely sensed images can be analysed properly and also allow for different combinations of RGB to be shown in the view. A supervised classification was then performed on the Landsat image. The river bodies (Manse and Ankobra) were then extracted from the Landsat image using Spatial Analyst Tools from Arc Toolbox of ArcMap 10.4.

The X and Y coordinates of the paper maps containing galamsey distribution from the Municipal Assembly and that from the Lands Commission containing the study area boundary, settlements and road networks were scaled out using the intersection of the grid lines. The paper map from the Lands Commission was then scanned and added to the table of content of ArcMap 10.4. This scanned image was then georeferenced and saved in a folder called Georeferenced. The same process was done for the scanned galamsey distribution map from the Municipal Assembly. The boundary, settlements and road networks of the study area were then digitized from the georeferenced image which was stored in the Georeferenced folder. The same process was performed on the galamsey distribution map to digitize the various galamsey sites along the banks of the two rivers.

Water samples from the Manse and Ankobra rivers were collected for a six-month period from March, 2019 to August, 2019 at one-month interval from four sampling sites (Figure 1). The water samples from the two rivers were collected in plastic bottles which have been sterilized. Two samples were collected from each sampling site which the samples were named with the inspecting site codes (Table 1) and afterward shipped in an ice chest containing ice to the research facility for investigation. The analysis was done to test for Physicochemical parameters such as Potential of Hydrogen (pH), Temperature, Dissolved Oxygen (DO), Electrical Conductivity (EC), Turbidity, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), True Colour and heavy metals such as Iron, Lead, Copper, Arsenic, Cadmium and Mercury in the water samples.

2.3. Determination of Physicochemical Parameters (pH, Electrical Conductivity, Total Dissolved Solids, Temperature, Turbidity, Total Suspended Solids, True Colour and Dissolved Oxygen)

The pH and temperature of each water sample were determined in situ at the time of data collection using a Rozway Digital pH meter and a laboratory thermometer respectively. The Dissolved Oxygen of each water sample was determined using the Winkler titration or iodometric method (Winkler, 1888) and true colour was determined using HI 96727 portable photometer. Turbidity, Electrical Conductivity, Total Dissolved Solids and Total Suspended Solids of each water sample were determined using

Figure 1: Map of the Study Area Showing the Sampling Sites

Sampling Sites Codes	Location
MUS	Manse Upstream located under the right-hand side of the Bepo township bridge when coming from Bogoso.
MDS	Manse Downstream located at Wassajuabeng where the ferry is.
AUS	Ankobra Upstream located at TarkwaBreman near the M/A Basic School.
ADS	Ankobra Downstream located under the left-hand side of the Ankobra Township Bridge when coming from Bogoso.

Table 1: Sampling Sites Codes and Locations

HACH 5000™ UV-VIS SPECTROPHOTOMETER

The Positions of the Sampling Points Were Taken Using a Portable Juno 3D Hand Held GPS Device from Trimble

2.4. Determination of Heavy Metals (Iron, Copper, Cadmium, Arsenic, Lead and Mercury)

Hundred (100ml) of each of the water samples collected were transferred into Pyrex beakers containing 10ml of concentrated HNO_3 . The samples were boiled slowly and then evaporated on a hot plate to the lowest possible volume (about 20ml). The beakers were allowed to cool and another 5ml of concentrated HNO_3 was added. Heating continued with the addition of concentrated HNO_3 as necessary until digestion was completed. The samples were evaporated again to dryness (but not baked) and the beakers were cooled, followed by the addition of 5ml of HCl solution (1:1 v/v). The solutions were then warmed and 5ml of 5M NaOH was added, then filtered. The filtrates were transferred to 100ml volumetric flasks and diluted to the mark with distilled water (Gregg, 1989). The levels of individual metals in the water samples were then analyzed using an Atomic Absorption Spectrometer (AAS) Varian 220 Spectra AA model.

3. Results and Discussions

3.1. Physicochemical Parameters

Mean pH values recorded at the four sampling sites ranged between 6.08 ± 0.64 to 6.59 ± 0.63 and were below the World Health Organization (WHO) standard values of 6.5 - 8.5 (Table 2) with the exception of the value recorded at MUS. This means that the River water at these sites is slightly acidic and can be attributed to the initial stages of Acid Mining Drainage (AMD) which occurs when sulfur-bearing rock, especially one type of mineral called pyrite, is routinely fractured or crushed during coal or metal mining operations and accumulated in piles of mine tailings. Pyrite contains iron sulfide which, when in contact with water, dissociates into sulfuric acid and iron. The sulfuric acid dramatically lowers the pH and the iron can precipitate and form an orange or red deposit of iron oxide that smothers the bottom of the stream or river (Reclamation Research Group, 2008).

The mean EC values recorded at the four sampling sites were below the WHO standard value of $1500 \mu\text{S}/\text{cm}$ (Table 2).

SAMPLE SITES CODES	pH (pH units)	EC ($\mu\text{S}/\text{cm}$)	TDS (mg/L)	Temperature ($^{\circ}\text{C}$)	Turbidity (NTU)	TSS (mg/L)	True Colour (Pt_Co)	DO
AUS	6.13 ± 0.65	99 ± 4.34	48 ± 6.36	26.3 ± 1.26	9908 ± 282.84	2732 ± 93.91	36 ± 2.76	2.89 ± 0.07
ADS	6.41 ± 0.90	79 ± 4.47	40 ± 2.83	26.3 ± 1.26	8338 ± 64.84	1447 ± 63.58	112 ± 6.23	2.64 ± 0.03
MUS	6.59 ± 0.63	82 ± 2.61	41 ± 5.33	26.3 ± 1.26	4734 ± 55.19	660 ± 46.04	68 ± 4.24	3.28 ± 0.16
MDS	6.08 ± 0.64	66 ± 3.85	33 ± 5.55	26.1 ± 0.62	1724 ± 12.98	356 ± 4.77	94 ± 4.34	2.95 ± 0.04
WHO LIMIT	6.5-8.5	1500	500	22-29	5	50	15	-

Table 2: The Physicochemical Parameters at the Four Sampling Sites of Ankobra and Manse Rivers

The low EC mean values indicate that contamination due to ions were low at these sampling sites and the geology of the area through which the rivers flow. Rivers that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, rivers that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water (U.S. Environmental Protection Agency, 2012).

The mean TDS values recorded at the four sampling sites were below the WHO standard value of 500 mg/L (Table 2). Range values of 33 ± 5.55 to 48 ± 6.36 mg/l of TDS were recorded during the study which is within the WHO permissible limit and therefore water samples from the two rivers appear to be good for consumption in terms of TDS.

The mean temperature values recorded at the four sampling sites were within the WHO recommended guideline range values of 22°C - 29°C for drinking water (Table 2). The low temperature values observed at the sampling sites could be attributed to the rainy season during the time of investigation. Water temperature could be affected by the prevailing weather conditions (Fritz, 2001).

The mean turbidity values recorded at AUS, ADS, MUS and MDS were high at the upstream than the downstream and far above the WHO recommended guideline value of 5 NTU for drinking water (Table 2). These high values could be attributed to green growth blossoms produce by nitrogen and phosphorous from compost source (yard, fairway, creature or vegetable) when there is a plenitude of supplements present and spillover coming about due to exercises in and along the banks of the two rivers from small-scale gold mining. Turbid waters are not typically useful for things living in the water and permit less light to go through the water which is not useful for plants developing in the water. Fine suspended solids can cover creatures in the river base and cause problems for fish. Poisonous delivering green growth can slaughter of natural life, are hazardous for individuals who eat fish in these areas and can inevitably execute about everything in the water when they pass on and consume all the oxygen in the water (Bryan, 2017).

The mean values of total suspended solids recorded at the four sampling sites were far above the WHO recommended value of 50mg/l (Table 2). These high mean values of TSS might be ascribed to overflow coming about due to exercises in and along the banks of the two rivers from small-scale gold mining, green growth, zooplankton, microbes and garbage that are conveyed along by water as it runs off the land. At the point when these suspended particles settle to the base of a water body, they become sediments. The expressions "residue" and "sediment" are frequently used to allude to suspended solids. Suspended solids comprise of an inorganic portion (silts, mud and so on.) and an organic division (green growth, zooplankton, microscopic organisms and garbage). The inorganic portion is generally extensively higher than the organic. Both add to turbidity, or darkness of the water. Waters with high sediment loads are clear a result due to their "muddy" appearance. This is particularly apparent in rivers, where the power of moving water keeps the sediment particles suspended (Kentucky Water Watch, 2019).

The mean values for true colour recorded at the four sampling sites were all above the WHO permissible value of 15 Plat_{Co} (Table 2). These high true colour values recorded could be attributed to the high turbid nature of the water values recorded at the four sampling sites due to the exercises in and along the banks of the two rivers from illegal small-scale gold mining.

The mean dissolved oxygen values recorded at the four sampling sites ranged between 2.64±0.03 to 3.28±0.16 (Table 2). The mean dissolved oxygen value recorded at MUS which was greater than 3 mg/L could be attributed to natural processes such as diffusion and photosynthesis where as those recorded at ADS, AUS and MDS which were less than 3 mg/L could also be as a result of acid rock drainage from small-scale mining activities which could reduce dissolved oxygen in surface water. When dissolved oxygen concentrations are less than 2 mg/L, the water is defined as hypoxic (CENR, 2000). The hypoxia kills many organisms that cannot escape, and thus the hypoxic zone is informally known as the "dead zone."

3.2. Metal Concentrations in the Water Samples from Ankobra and Manse Rivers

The heavy metals content which includes Fe, Cu, Cd, As, Pb and Hg in the water samples from Ankobra and Manse Rivers are given in Table 3. The mean iron concentrations in the water samples from the four sampling sites were found in the range of 0.366 – 1.836 mg/l (Table 3) and above the WHO permissible limit of 0.3 mg/l of iron in drinking water. These high values might be ascribed to the presence of iron in the outer layer of the earth and the rock arrangement of the study area through which the rivers flow been the Birimian Super group, (Sefwi and Kumasi Groups) and the Tarkwa Group (Perrouy et al., 2012). The Birimian rock framework contains high measures of iron and the high values of dissolved iron at the four sampling sites might be from the enduring of these rocks. These high qualities may likewise be attributed to Acid Mining Drainage which builds the iron levels in surface water.

The elevated concentrations of iron in the water samples at the four sampling sites will leave rosy earthy colored stains on installations, flatware and clothing that are difficult to expel, gives water a repulsive metallic taste and vegetables cooked in water containing excessive iron turn dark and look unappealing (Illinois Department of Public Health, 2010). Iron is a basic supplement for good health. It is a significant part of hemoglobin, which is utilized to move oxygen and carbon dioxide in the blood. Iron insufficiency can improve lead ingestion and toxicity; anybody with expanded blood lead levels ought to be tried for iron inadequacy. The ingestion of enormous amounts of iron can harm veins, cause grisly vomitus/stool, and harm the liver and kidneys, and even cause death. Be that as it may, in light of the fact that ingestion is directed, body tissues are commonly not presented to elevated level fixations (Association for the Advancement of Restorative Medicine, 2020).

The mean copper concentrations in the water samples from the four sampling sites were found in the range of 0.004 – 0.013 mg/l (Table 3) and below the WHO permissible limit of 1.0 mg/l of copper in drinking water. Copper is a metal that exists in the environment as a mineral in rocks and soil and it is commonly found at low levels in natural water bodies (Government of Western Australia Department of Health, 2016). The low levels could be attributed to the enduring of rocks in the investigation area. A low degree of copper as a rule leaves a green/blue stain on taps, pipes, hand bowls, showers or toilets yet there is no harsh or metallic taste. This water is as yet safe to drink. An elevated level of copper typically leaves a metallic or disagreeable severe preference for the drinking water and this water may not be safe to drink. Utilization of elevated levels of copper can cause queasiness, spewing, looseness of the bowels, gastric (stomach) protests and cerebral pains. Long haul introduction over numerous months and years can cause liver harm and demise copper (Government of Western Australia Department of Health, 2016).

The mean cadmium, arsenic and lead concentrations in the water samples from the four sampling sites (Table 3) were below detection limit.

SAMPLE SITES CODES	Fe (mg/L)	Cu (mg/L)	Cd (mg/L)	As (mg/L)	Pb (mg/L)	Hg (mg/L)
AUS	1.836 ± 0.029	0.013 ± 0.002	<0.002	<0.001	<0.002	<0.002
ADS	0.673 ± 0.018	0.008 ± 0.002	<0.002	<0.001	<0.002	0.384 ± 0.003
MUS	0.366 ± 0.012	0.004 ± 0.001	<0.002	<0.001	<0.002	<0.002
MDS	0.799 ± 0.027	0.011 ± 0.002	<0.002	<0.001	<0.002	<0.002
WHO LIMIT	0.3	1.0	0.003	0.01	0.01	0.001

Table 3: Metal Concentrations at the Four Sampling Sites of Ankobra and Manse Rivers

Cadmium can be found in pesticides and manures and can get into the environment when these pesticides and manures are utilized on the ground. About 30,000 tons of cadmium is released into the earth every year of which part is released into rivers, part into the air and human activities like assembling and mining account for the remainder of the cadmium released. The world production is around 15,000 tons consistently; the key conveying country is Canada, with the USA, Australia, Mexico, Japan and Peru furthermore being the noteworthy suppliers (Lenntech, 1998-2019).

Arsenic is an element that occurs naturally in rocks and soil and is utilized for an assortment of purposes inside industry and agriculture. It is likewise a by-product of copper refining, mining and coal burning. Arsenic can consolidate with different components to make synthetic compounds used to safeguard wood and to murder creepy crawlies on cotton and other agrarian harvests.

Through natural deposits in the earth, agricultural and industrial sully arsenic can enter a water supply. It is believed that every year a large quantity of arsenic is released into the environment by some industries in the United States of America and once this arsenic is released, it remains in the earth for a period of time. Through gradual settling, snow and downpour arsenic can be removed from the air (Centers for Disease Control and Prevention, 2015).

Lead is a poisonous metal that is destructive to human health; there is no safe level for lead exposure. The level of presentation relies upon the grouping of lead, course of introduction (air, water and food), current medical condition and age. It has been assessed that up to 20 % of the total lead exposure in youngsters can be ascribed to a waterborne course, i.e., drinking polluted water. Also, infants, hatch-lings, and small kids are especially helpless against lead harming. This is on the grounds that they typically drink more water and their bodies are actively developing, which encourages the bio-accumulation of lead.

Elevated levels of lead pollution in a kid can bring about spasms, major neurological harm, organ disappointment, unconsciousness and at last demise (Water Research Center, 2014).

The mean mercury concentrations in the water samples from the four sampling sites were found in the range of <0.002 – 0.384 mg/L (Table 3). Mean mercury concentrations obtained from AUS, MUS and MDS were below detection limit with the exception of ADS whose value was far above the WHO recommended guideline value of 0.001 for mercury in drinking water. This high value could be attributed to the method used by small-scale miners to recover gold from ore minerals called amalgamation (Ntibery et al., 2003).

3.3. GIS Map Generation

3.3.1. Digitizing

This is the process of converting data from analog to digital format. This is done to get features from the paper map (analog) into ArcGIS. This can also be used to create new set of themes for an area for which no digital data is available or it can be used to update an existing theme.

Themes created were;

- Boundary of the Municipality
- Rivers
- Roads
- Settlements
- Galamsey Sites

The different thematic layers including the river buffer created were then overlaid (Figure 3) to form the model or GIS map.

3.3.2. Creating Buffer

Buffer is a Geographic Information System operation in which areas that are within a specified distance of selected map features are separated from areas that are beyond. The areas that are within the specified distance are called buffer zones. A buffer (figure 2) zone is frequently used to mitigate environmental hazards. A river buffer of 100m was created.

Figure 2: River Buffer

Figure 3: Overlay of All Thematic Layers (GIS Map)

3.4. Overlay

Overlay is a GIS operation that superimposes multiple data sets (representing different themes) together (Figure 3) for the purpose of identifying relationships between them. An overlay creates a composite map by combining the geometry and attributes of the input data sets. Map overlay combines information from point, line, and polygon vector layers, just as raster layers.

A few essential overlay measures are accessible in a GIS for vector datasets: point-in-polygon, polygon-on-point, line-on-line, line-in-polygon, polygon-on-line, and polygon-on-polygon. As you might have the option to divine from the names, one of the overlay datasets should consistently be a line or polygon layer, while the second might be point, line, or polygon. The new layer delivered following the overlay activity is named the "yield" layer.

The overlay tasks talked about already expect that the client wants the overlain layers to be joined. This isn't generally the situation. Overlay strategies can be more intricate than that and accordingly utilize the essential Boolean operators: AND, OR, and XOR. Depending on which operator(s) are used, the overlay strategy utilized will bring about an intersection, union, symmetrical difference, or identity.

Notwithstanding the previously mentioned vector overlay strategies, other basic various layer geoprocessing choices are accessible to the client. These incorporated the clip, erase, and split tools.

Galamsey activities quicken the rate and level of changes in the indigenous habitat. These activities adjust scenes and can have long haul contamination impacts on communities and water resources because of their physical corrupting nature, just as their utilization of synthetic compounds and other hurtful substances (Adjei, 2012). From figure 2, it can be said that activities involving galamsey have impacted negatively on the Manse and Ankobra Rivers because water from these two rivers which serves as drinking water for the people around have now turned into clayey undrinkable water and

are gradually drying out. The fishes and other aquatic creatures in these rivers have died due to the use of mercury and other harmful chemicals used in these rivers to recover gold from ore. Pits have been dug along the banks of these two rivers which serve as breeding places of abode for mosquitoes and other harmful insects. The values from true colour, turbidity, total suspended solids, mercury and iron were all above the WHO recommended guideline values for drinking water so we can say that galamsey activities have impacted negatively on Manse and Ankobra rivers due to the high values of those parameters.

4. Conclusion

Results from the study show that illegal small scale mining operations have impacted negatively on the water quality of the Manse and Ankobra rivers looking at the high levels of true colour, turbidity, total suspended solids, iron and mercury which exceeded the WHO recommended guideline values and that the use of water from the two rivers for drinking and other domestic activities could pose a serious health risk to consumers. Also, the inhabitants who rely on water from the Manse and Ankobra Rivers for drinking and other domestic activities are no more doing that due to clayey nature of the water. Fishing which used to be the hobby of some of the inhabitants has stopped abruptly because all the fishes have died due to the use of mercury and other toxic substances in these rivers. The pits that have dug along the banks of the two rivers serve as a death trap to the people leaving around and they also serve as breeding places for mosquitoes and other harmful insects.

5. References

- i. Agyapong, E.A., Besseah, M.A. and Fei-Baffoe, B. (2012): Effects of Small-Scale Gold Mining on Surface water and Groundwater Quality in the Bogoso / Prestea Mining Area. *J. Ghana Sci. Asso.* 14(2): 11-19.
- ii. Centers for Disease Control and Prevention (2015). Arsenic and Drinking Water from Private Wells, from <https://www.cdc.gov/healthywater/drinking/private/wells/disease/arsenic.html>
- iii. Fondriest Environmental Learning Centre: Turbidity, Total Suspended Solids and Water Clarity, from <https://www.quora.com/what-is-the-effect-of-turbidity-on-quality-of-water>.
- iv. Fritz, C. (2001): Watershed Information Network: A Watershed Report and Suggested Framework for Integrating Water Quality Monitoring Efforts, 1: 24.
- v. Government of Western Australia Department of Health (2016): Copper in Drinking Water, from https://ww2.health.wa.gov.au/Articles/A_E/Copper-in-drinking-water.
- vi. Gregg, L.W. (1989): Water analysis Handbook. H.A.C.H Company, USA. Pp. 41 – 42.
- vii. Hillier, A. (2011): Manual for working with ArcGIS 10.
- viii. Kentucky Water Watch: Total Suspended Solids and Water Quality, from www.state.ky.us/nrepc/water/ramp/rmtss.htm.
- ix. Lenntech, B.V. (1998-2019). Cadmium, from <https://www.lenntech.com/periodic/elements/cd.htm>.
- x. Murphy, S. (2007). BASIN: General Information on Total Suspended Solid.
- xi. Ntibery, B.K., Atorkui, E. and Aryee, B.N.A. (2003): Trends in small-scale mining of precious minerals in Ghana: a perspective on its environmental impact' *J. Clean. Prod.* 11(2): 131-140.
- xii. Reclamation Research Group, (2008): Acid Mine Drainage and Effects on Fish Health and Ecology: A Review.
- xiii. Stanisław, F., Mateusz, M., Beata, B., and Jacek, S. (2015): Present used Methods for Measuring Dissolved Oxygen Concentration at Wastewater Treatment Plants. Page 432.
- xiv. Tom-Dery, D., Dagben, Z.J. and Cobbina, S.J. (2012): Effect of Illegal Small-Scale Mining Operations on Vegetation Cover of Arid Northern Ghana. *J. Ghana Sci. Asso.* 4(26): 674-679.
- xv. U.S. Environmental Protection Agency (2012): Water: Monitoring and Assessment, from <https://archive.epa.gov/water/archive/web/html/vms59.html>.
- xvi. Water Research Center (2014). Lead in Drinking Water - Is There Lead in My City Drinking Water? From <https://water-research.net/index.php/lead>
- xvii. World Health Organization (2004): WHO guidelines for drinking water quality 3rd edition, vol. 1 Geneva, Switzerland, 89: 214-220.