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Mapping Ankobra and Manse Rivers That Have Been Impacted by Illegal Small-Scale Mining (Galamsey) Operators in the Prestea Huni-Valley Municipality of Ghana

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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 analyzed for a period of six months with the aim of assessing the effects of illegal small-scale mining on the water quality. Levels of physicochemical parameters such as 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.

Keywords: Mapping, impacted, illegal small scale mining (Galamsey), physicochemical parameters, heavy metals, model or map

1. Introduction

In Ghana, there is no clear-cut definition for small-scale mining. The definition for small-scale gold mining is given in the Small Scale Gold Mining Law (SSGML), 1989, PNDCL 218, Part III, Section 21, as: "The mining of gold by any method not involving substantial expenditure by an individual or group of persons not exceeding nine in number or by a cooperative society made up of ten or more persons". Small scale mining mostly of diamond and gold has expanded dramatically in recent years in Ghana. Although gold deposits from small scale mining activities in Ghana over the past ten decades has risen tenfold and doubled since 1998 and accounting for an estimated contribution of \$461.1 million to the national economy since 1989 (Yakubu, 2000), the activities of illegal small scale gold mining (locally referred to as "galamsey") are causing serious environmental havoc and destruction. Galamsey affects many facets of life but one area in which its impact is being felt most is the pollution of rivers and water bodies (Davis et al., 1994). The extent to which rivers have been polluted by these galamsey operators exerts significant pressure on individuals who live near and depend on these river bodies as source of drinking water and other domestic purposes. Water, a vital necessity of life is affected both in quality and quantity by activities of the galamsey operators.

Contaminations of surface and ground water bodies have particularly been experienced in gold mining communities (Davis et al., 1994) in Ghana, however, gold mining in recent times has become unpopular as it is regarded as a significant source of heavy metals such as mercury, lead, iron, copper, cadmium etc. contamination to rivers and water bodies owing to activities such as mineral exploitation, ore transportation, smelting and refining, disposal of the tailings and waste waters around mines (Hilson, 2001; Hilson, 2002; Aryee et al., 2003; Essumang et al., 2007; Paruchuri et al., 2010). The major problem associated with small scale gold mining is the technique used to extract gold from ores called amalgamation (Ntibery et al., 2003) which involves the use of mercury. Almost all small-scale gold miners use the method of amalgamation to recover gold from ore because it is a simple technique used in gold extraction but it is well known that the process is devastating to health (Lombe, 2003). Moreover, the processes of amalgamation are commonly done along rivers and water bodies resulting in water pollution with communities downstream seriously affected most.

With the discovery and eventual extraction of gold in the Prestea Huni-Valey Municipality by Golden Star Bogoso/Prestea Limited, the activities of galamsey operators have increased in the area. It is their activities on the quality of surface water including the Manse and Ankobra rivers in the Municipality that serves as the basis of this study.

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 (Fig. 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

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 (Fig. 1). Water samples were collected from the two rivers in plastic bottles that have been pre-washed with detergent and tap water and later rinsed with 1:1 concentrated nitric acid (HNO₃) and distilled water. The sampling bottles were rinsed three times with the water samples from the rivers after which the water samples were collected from the four sampling sites. Two samples were collected from each sampling sites. The samples were labeled with the sampling point codes (Table 1) and then transported in an ice chest containing ice to the laboratory for analysis. The analysis was done to test for Physicochemical parameters such as 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; Minczewski and Marczenko 2011) 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

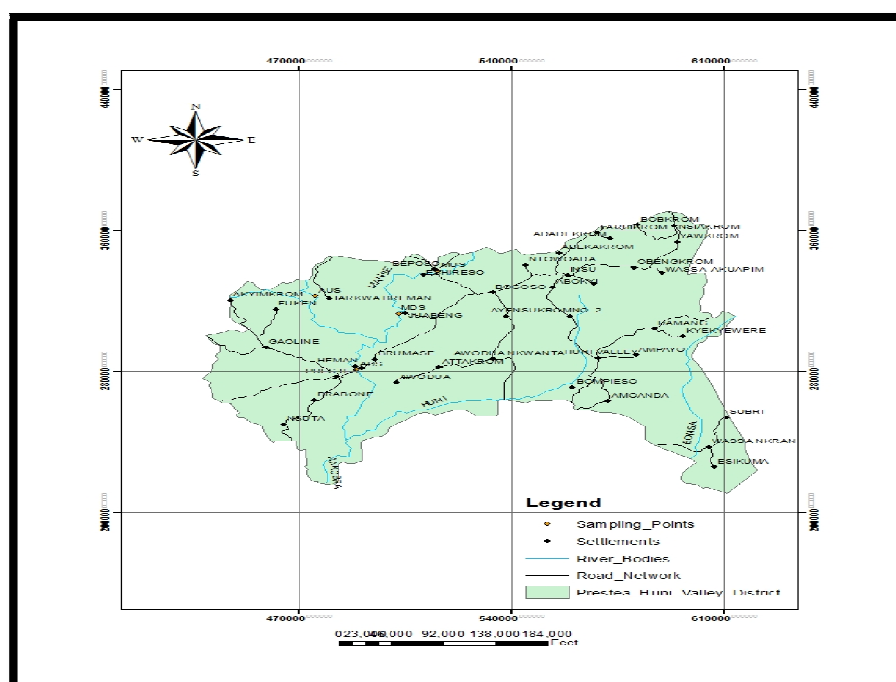


Figure 1: Map of the Study Area Showing the Sampling Points

| 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 Wassa Juabeng where the ferry is. |
| AUS | Ankobra Upstream located at Tarkwa Breman 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 Points codes and Locations

Using HACH 5000™ UV-VIS SPECTROPHOTOMETER. The positions of the sampling points were taken using a portable hand held GPS device called Juno 3D 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 HNO₃. 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 HNO₃ was added. Heating continued with the addition of concentrated HNO₃ 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.

2.5. Model or Map Generation

The river data was extracted using ArcMap 10.4 from a Landsat 8 image downloaded from United States Geological Survey (USGS) website and the data of the galamsey sites in and along the banks of the two rivers were also extracted from scanned image of galamsey distribution map from the Prestea Huni-Valley Municipal Assembly using ArcMap 10.4. The boundary of the Municipality, settlements and roads were also extracted from paper map from the Lands Commission of Ghana which was scanned, georeferenced and digitized using ArcMap 10.4. These layers were then overlaid (Appendix A to Appendix F) to form the model or map.

2.6. 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 zone is frequently used to mitigate environmental hazards. A buffer of 100m (Appendix G) was created for the galamsey sites along the banks of the two rivers.

2.7. Data Analysis

Microsoft Excel was used for the statistical analysis of the results and comparisons were made with the World Health Organization (WHO) standards for drinking water (WHO, 2004).

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 µS/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 (mg/L) |
|--------------------|------------------|-----------------------------------|---------------|---------------------------------------|--------------------|------------------|------------------------|-----------------|
| AUS | 6.13 \pm 0.65 | 99 \pm 4.34 | 48 \pm 6.36 | 26.3 \pm 1.26 | 9908 \pm 282.84 | 2732 \pm 93.91 | 36 \pm 2.76 | 2.89 \pm 0.07 |
| ADS | 6.41 \pm 0.90 | 79 \pm 4.47 | 40 \pm 2.83 | 26.3 \pm 1.26 | 8338 \pm 64.84 | 1447 \pm 63.58 | 112 \pm 6.23 | 2.64 \pm 0.03 |
| MUS | 6.59 \pm 0.63 | 82 \pm 2.61 | 41 \pm 5.33 | 26.3 \pm 1.26 | 4734 \pm 55.19 | 660 \pm 46.04 | 68 \pm 4.24 | 3.28 \pm 0.16 |
| MDS | 6.08 \pm 0.64 | 66 \pm 3.85 | 33 \pm 5.55 | 26.1 \pm 0.62 | 1724 \pm 12.98 | 356 \pm 4.77 | 94 \pm 4.34 | 2.95 \pm 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 \pm 5.55 to 48 \pm 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 $^{\circ}\text{C}$ - 29 $^{\circ}\text{C}$ 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). The turbid nature of the rivers at the four sampling sites could be attributed to algae blooms produce by nitrogen and phosphorous from fertilizer source (lawn, golf course, animal or vegetable) when there is an abundance of nutrients present and runoff resulting from small-scale gold mining activities in and along the banks of the two rivers (<https://www.quora.com/what-is-the-effect-of-turbidity-on-quality-of-water>).

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 may be attributed to runoff resulting from small-scale gold mining activities in and along the banks of the two rivers, algae, zooplankton, bacteria and detritus that are carried along by water as it runs off the land (www.state.ky.us/nrepc/water/ramp/rmtss.htm).

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). This high colour values recorded could be attributed to the high turbid nature of the water values recorded at the four sampling sites due to the activities of small-scale gold mining activities in and along the banks of the two rivers.

The mean dissolved oxygen values recorded at the four sampling sites ranged between 2.64 \pm 0.03 to 3.28 \pm 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 levels of iron in the water samples may be attributed to the existence of iron in the earth's crust and the abundance of iron-rich rocks such as arsenopyrite and pyrite in the study area through which the rivers flow (Agyapong et al. 2012).

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 (https://ww2.health.wa.gov.au/Articles/A_E/Copper-in-drinking-water). The low levels could be

| 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

Attributed to the weathering of the rocks in the study area.

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

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).

4. Conclusion and Recommendations

Results from the study show that illegal small scale 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 and that the use of water from the two rivers for drinking and other domestic activities could pose a serious health risk to consumers. It is therefore recommended that the findings of this research should be brought to the notice of the people of the study area by the regulatory agencies so as to discourage them from using these contaminated water bodies as a source of drinking water and the regulatory agencies should educate illegal Small scale gold miners about the impacts their activities have on river bodies.

5. References

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Appendix I

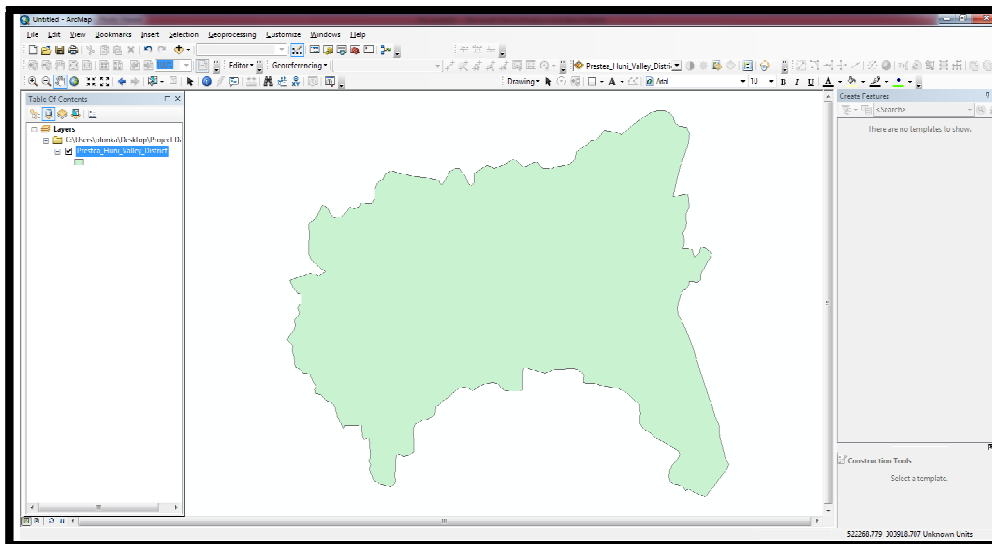


Figure 2: Digitized Thematic Layer of the Study Area

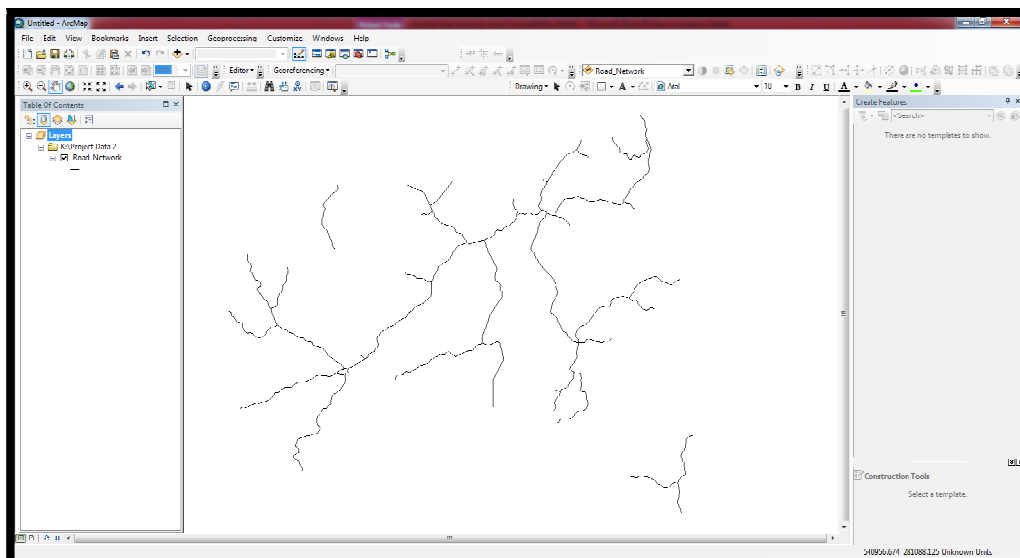


Figure 3: Digitized Thematic Layer of Roads in the Study Area

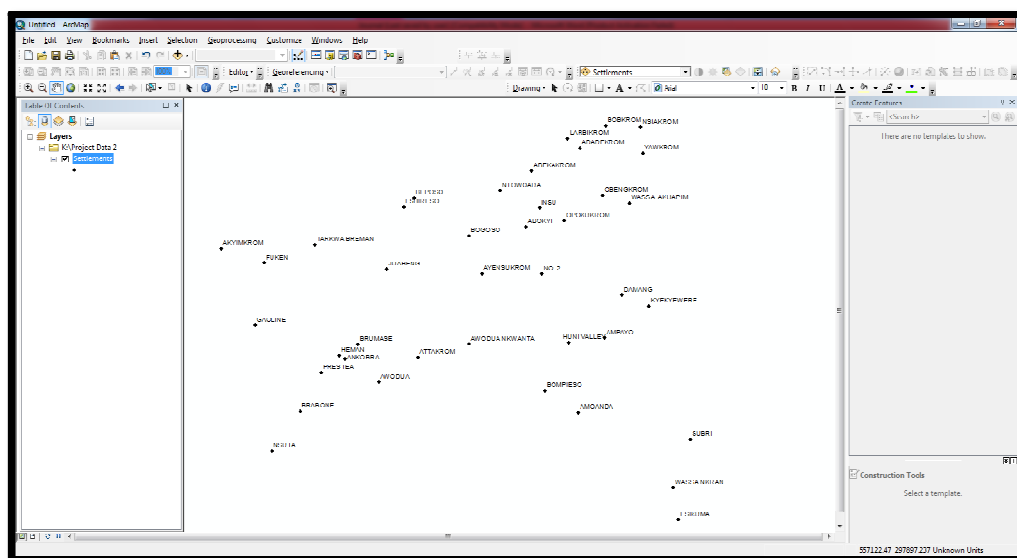


Figure 4: Digitized Thematic Layer of Settlements in the Study Area

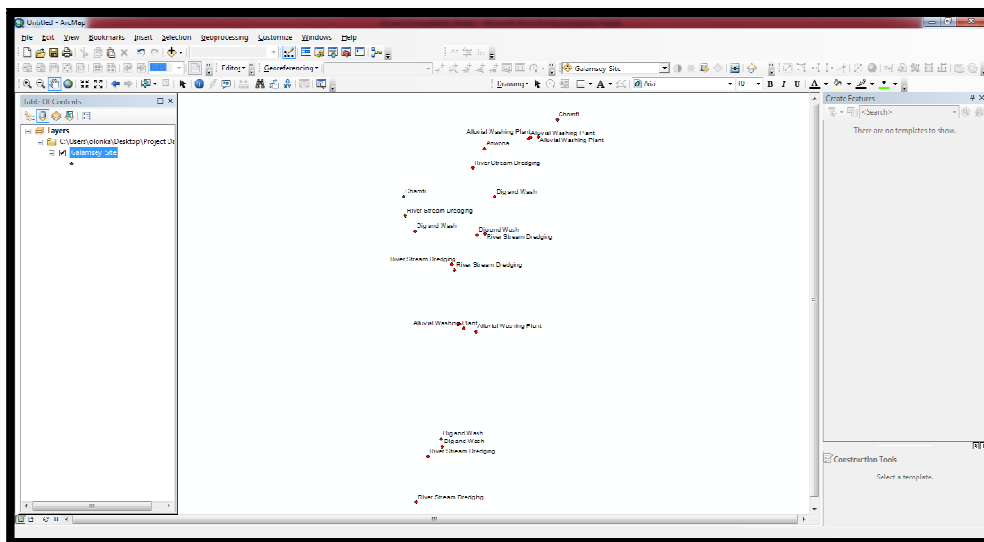


Figure 5: Digitized Thematic Layer of Galamsey Sites Along the Banks of Ankobra and Manse Rivers

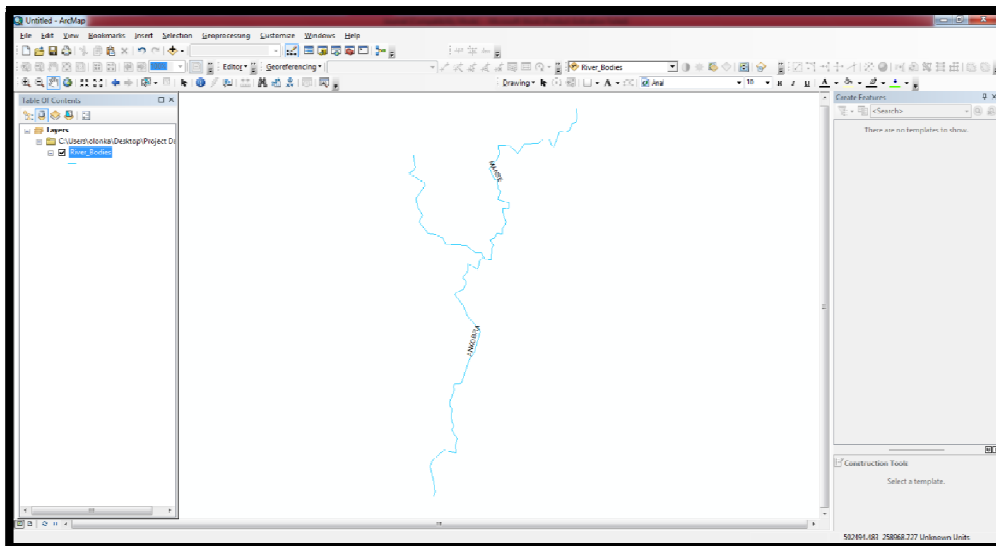


Figure 6: Thematic Layer of Ankobra and Manse Rivers

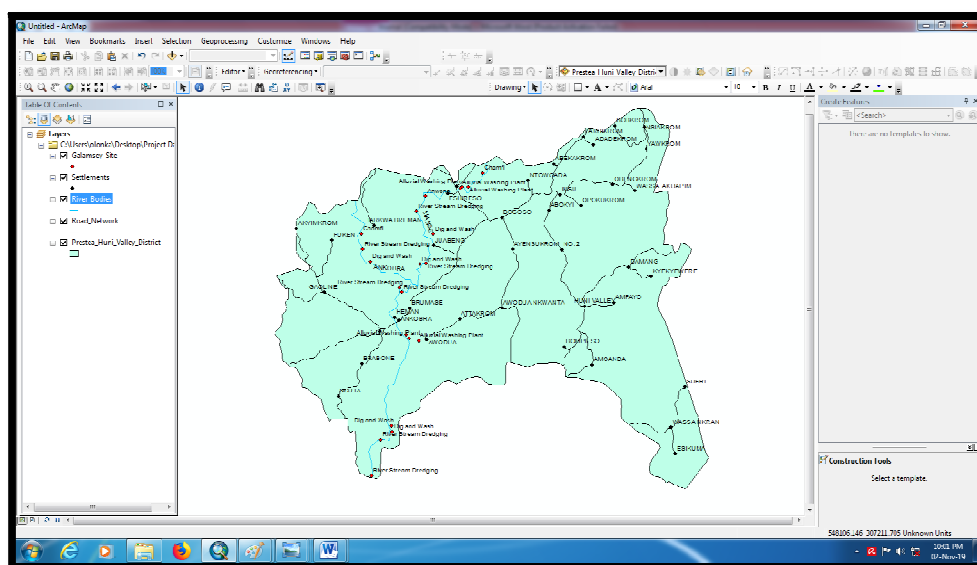


Figure 7: Overlay of All Thematic Layers

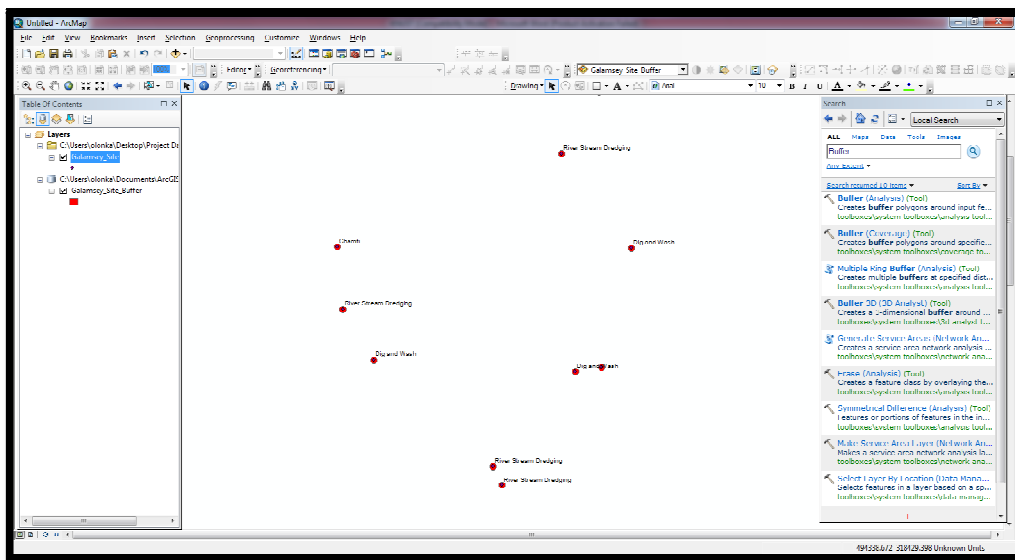


Figure 8: Buffer of 100m Created for the Galamsey Sites Along the Banks of Ankobra and Manse Rivers