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Impacts of Illegal Mining (Galamsey) on the Environment (Water and Soil) At Bontefufuo Area in the Amansie West District

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Abstract
Illegal mining (galamsey) is known to cause significant environmental pollution; the chemical used and the waste heaps are a source of long term contamination of soil and water bodies. The thrust of this study was to assess the impact of illegal mining operations on the soil and water bodies at four (4) selected communities (Esaase-Manhyia, Aboabo, Mpatuam and Tetrem) in Bontefufuo in the Amansie West District of Ghana. Three 100m × 100m plots were demarcated at each galamsey site in each community. The extent of environmental damage was assessed in respect of numbers of pits and heaped laterite per plot, area of pits and heaped laterite identified on plots and amount of ore washed. Level of pollution of streams in the study area were also analysed. Large pits were dug and had all their streams polluted to a certain degree. There was a statistical significant difference *(p = 0.000)* between the mean radii of pits dug in the different communities. Furthermore, many heaps of stockpiles were found at Tetrem as compared to the other mining sites. The radii of the heaped laterite differed statistically *(p = 0.021)* between the communities. Large quantities of ore were washed daily in the communities and were statistically different *(p = 0.001)*. Turbidity was extremely high above the EPA-Ghana recommended limit of 5NTU with corresponding low level of Dissolved Oxygen in the range of 1.43mg/L, and 2.40mg/L, recorded in all the water bodies at the sites. Notwithstanding, the pH, conductivity and Total Dissolve Solids (TDS) were all within the range of EPA Ghana standards. Mercury was identified as the main chemical used for the gold extraction in all the sites which is polluting the soil and water bodies in the area.
Keywords: Illegal mining, water pollution, galamsey operation, soil degradation

1.0 Introduction

The activities of illegal mining (galamsey) operators pose great threat to the environment (Asiedu, 2013) and this has heightened interest from the public and many researchers. Although, it has been a source of employment for some sect of the youth (Amponsah-Tawiah and Dartey-Baah, 2011), and also contributes to the overall gold production annually, its environmental consequences are myriad and very critical.

It involves the exploitation of mineral deposits using rudimentary tools and primitive mining and processing techniques (Owusu-Boateng and Kumi-Aboagye, 2013) and often employs unskilled and stark illiterates who for diverse reasons, have little or no sensitization for the consequences of their actions on the environment (Kessey and Arko, 2013; Mudyazhezha and Kanhukamwe, 2014). They involve in activities that cause varying degrees of environmental degradation including large and dangerous excavations, vegetation destruction, pollution of soil, air and water with remnants of hazardous chemicals and heavy metal.

Pollution of water bodies, vegetative cover and the soil are the most noticeable effect of mining. The large amount of water needed to wash the ore often results in illegal miners working close to water bodies (Fatawu and Allan, 2014; Mudyazhezha and Kanhukamwe, 2014). This results in heavy contamination of the streams/rivers with the debris as tailings are discarded directly into the rivers without any form of treatment (Kessey and Arko, 2013). Not only does it alter the aesthetic feature but also the phyisco-chemical and biological parameters of the river/stream making it unfit for domestic purposes.

Some key rivers and streams, particularly Birim, Densu, Pra, Ankobra have been polluted to the extent that, they are almost losing their self-cleansing ability. These rivers that serve communities along the watersheds are turned into reservoirs for dangerous chemicals disposal and also turned muddy because of heavy siltation

(Appiah and Buaben, 2012; Oduro *et al.*, 2012; Amankwah, 2013; Fatawu and Allan, 2014). Destructions of river banks and river course diversion have led to serious inundations with the slightest downpour (Fatawu and Allan, 2014).

Again, illegal mining is ensued by land degradation with negative consequences on soil. Many pits are dug haphazardly with pit sizes between 400 and 4000sqft with a depth ranging from 6 to 30ft (Kessey and Arko, 2013). Unfortunately these remain uncovered even long after mining operations have ceased (Kpan *et al.*, 2014). Pits become filled with rain water and becoming breeding grounds for mosquitoes, emanating nauseating stench on the environment and also becoming death trap (Awaomim, 2013). Furthermore, the activity results in the destruction of valuable topsoil (Asiedu, 2013) rendering the land unsupportive for crop growth. These consequences are least observed with certified legal miners as they have reclamation plans; however same cannot be said about illegal mining operation. All illegal mining operation centers across the nation including Bontefufuo results in environmental damage.

Bontefufuo is an area comprising about thirteen indigenous towns in the Amansie West District in the Ashanti Region of Ghana. The area is noted as one of Ghana's large scale gold mining operation centers where the Bonte Gold Mines Ltd predominantly operated. Its mineral deposits has proliferated many illegal gold miners ("galamsey") who are operating at the expense of the environment. What is more serious is that the galamsey activities that exploit alluvial gold mainly take place along streams and valleys where farming (cash crop, cocoa and food crops) is predominant. The thrust of this current study is to access the impact of the illegal mining activities on the soil and the various rivers in the catchment.

2.0 Methodology

The research was conducted in Bontefufuo area in the Amansie West District in Ashanti. The district serves as regional boundary between Ashanti Region on one side and central and Western Region on the other side. Specifically, the district is located within latitude 6.05^o West: 6.35^o North: 1.40^o South and 2.05^o East. Data was collected from four communities within Bontefufuo area, namely: Esaase Manhyia, Tetrem, Aboabo and Mpatuam. Visits were made to the various illegal mining sites and various observations were made. At the various illegal mining sites in each of the communities, three plots were marked with each having an area of 100m × 100m. These plots were marked using tape measures, pegs, cutlass, etc. The three $(100m)^2$ plots in each town were named plots A, B and C. The number of illegal mining pits on each site was recorded. The radius of the mined pits, radius of heaped soil and number of heaped soils were also determined. This was mainly done at Esaase-Manhyia, Tetrem and Aboabo. At Esaase-Manhyia, Tetrem and Mpatuam, the following parameters were determined: the amount of soil the "galamsey" operators washed daily, the number of rivers/streams in each community polluted with laterite soil, the type of chemicals used by the galamsey operators and the number of water sources the communities used. In addition, water samples from the washing sites were also collected and analyzed at the laboratory using standard methods for: Conductivity, Total Dissolved Solids (TDS), Salinity, Turbidity, pH. Dissolved Oxygen (DO) and Mercury. The data were analyzed using Statistical Package for Social Science (SPSS V20) and results presented using descriptive statistics.

3.0 Results and Discussion

3.1 Number of Illegal Mining Pits

The average number of illegal mining pits as recorded per $(100m)^2$ is shown in table 1. It was observed that illegal mining activities occurred predominantly at Tetrem community recording an average of 60 pits per $(100m)^2$ with less mining activities occurring at Esaase-Manhyia. The high rate at Tetrem was, perhaps, due to the high occurrence of gold in the area which intensified the surface mining activities. It was, thus, clear that the effect of the illegal mining on the soil would be higher at Tetrem than Esaase-Manhyia and Aboabo (Table 1).

Table 1: Number of Illegal Mining Pits in Every $(100m)^2$ Piece of Land

	Number of Mining Pits per $(100m)^2$			
Community	Site A	Site B	Site C	**Mean**
Esaase-Manhyia	20	30	25	25 ± 5.00
Aboabo	15	29	18	20.67 ± 7.37
Tetrem	53	63	65	60.33 ± 6.42

Mining activities carried out in the communities involved digging to a depth of hundreds of feet using primitive equipment to recover minerals near the earth's surface (Kuma and Yendaw, 2010; Mkpuma *et al.,* 2015). The radii of the various open pits measured at the various sites showed that, Tetrem had wider diameter of mined pits compared to pits at Esaase-Manhyia and Aboabo thus the pits covered a larger surface areas (Table 2).

Table 2: Radius of Illegal mining pits

	Mean Values of the Sites *(m)*		
Community	Site A	Site B	Site C
Esaase-Manhyia	0.60 ± 0.20a	0.60 ± 0.18a	0.40 ± 0.16b
Aboabo	0.80 ± 0.14c*	0.7 ± 0.12c	0.90 ± 0.16d*
Tetrem	1.86 ± 0.38e	2.18± 0.45f*	2.04 ± 0.42e*

Sites with different letters are statistically different from each other at 5% confidence level

The mean area of the pits at Tetrem was approximately 13m^2 which were much larger than means areas for pits at Esaase-Manhyia (0.88m^2) and Aboabo (2.01m^2). This observation especially at Tetrem showed high soil degradation by the illegal mining activities. The mean radii at the different sites in each community were found to be statistically significant (Table 2).

Table 3: One way Anova for the mean radii at the different sites

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	3.806	2	1.903	116.348	.000
Within Groups	.098	6	.016		
Total	3.904	8			

A one way Anova between communities was conducted to compare the mean radii of mine pits among the three (3) communities (Esaase-Manhyia, Aboabo and Tetrem). There was significant difference between the mean radii at $p < 0.05$ level of significance for the three communities ($p = 0.000$). Post hoc comparison using Tukey HSD test revealed that the mean radius at Tetrem (2.03 ± 0.16, $p = 0.00$) was much higher and statistically differed from Esaase-Manhyia and Aboabo. This revealed that large pits were dug at Tetrem compared to Esaase-Manhyia and Aboabo. However, there was no statistical difference between Esaase-Manhyia and Aboabo ($p = 0.095$).

3.3 Heaped Laterite/Gravel at Washing Sites

The galamsey activities involved washing the soil and grinding and washing of gravels presumed to contain gold. These washed materials are often heaped on the topsoil in the operational areas mostly near river banks. The number of heaps found at each site per plot was counted (Table 4). Many heaps were counted at Tetrem because the area was active in illegal mining as compared to the other two communities. The radii of the heaped laterites were subsequently measured in the different communities (Table 5).

Table 4: Number of Laterite/Gravel heaps at washing/grinding sites

	Number of heaps		
Community	Site A	Site B	Site C
Esaase-Manhyia	5	8	6
Aboabo	8	10	15
Tetrem	23	15	29

Tetrem and Aboabo recorded the highest heaped laterite radii (4.22 ± 0.27 and 4.18 ± 0.59 respectively) and thus, averagely covered a wider areas (55.95m^2 and 54.89m^2) as compared to Esaase-Manhyia (2.13 ± 1.09) averagely covering an area of 14.25m^2. The result showed that, Tetrem and Aboabo had large stockpiles in relation to areas covered as a result of illegal mining (galamsey) activities which could have negative ramifications on the soil microorganisms and also could heavily cause siltation into the rivers in which the soils were washed during rainfall.

Table 5: Radius of Heaped Laterite/Gravel

Community	Mean Values of the Sites		
	Site A	Site B	Site C
Esaase-Manhyia	0.90 ± 0.35a	2.5 ± 0.73b	3.0 ± 0.50b
Aboabo	3.50 ± 0.73c	6.0 ± 2.02d	4.50 ± 1.15d
Tetrem	3.98 ± 1.12e	4.16 ± 1.36e	4.51 ± 1.27e

Sites with different letters are statistically different from each other at 5% confidence level

One way Analysis of Variance (Table 6) revealed statistically significant difference between the mean radii of the heaped gravels at $p < 0.05$ level of significance for the three communities ($p = 0.021$). Tukey HSD Post hoc multiple comparison test revealed that the mean radii of heaps at Aboabo (4.18 ± 0.59, $p = 0.033$) and Tetrem (4.22 ± 0.27, $p = 0.031$) differed statistically compared to that of Esaase-Manhyia (2.13 ± 1.09). However, there was no statistical difference between Aboabo and Tetrem ($p = 0.998$). Stockpiles were, therefore, heavy at both Aboabo and Tetrem; this was due to the fact that most of the mining activities were more intensive at these communities and perhaps, they were also the communities where the illegal miners could get enough water to wash the soil.

Table 6: One way Anova for mean radii of heaped laterite among the communities

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	8.558	2	4.279	7.902	.021
Within Groups	3.249	6	.0541		
Total	11.807	8			

3.4 Depth of Topsoil Available

The mean depth of top soil available from the "galamsey" sites at each community was measured to be 0.10±0.015, 0.12±0.010 and 0.08±0.012 for Esaase-Manhia, Aboabo and Tetrem respectively. Because heavy "galamsey" activities occurred at Tetrem, the depth of the top soil available had been reduced drastically to 0.08m. There was a significant difference between the communities ($p = 0.015$). Significant difference was found between Aboabo and Tetrem ($p = 0.013$). However, no difference was found between Esaase-Manhyia and Aboabo ($p = 0.302$) as well as between Esaase-Mahyia and Tetrem ($p = 0.088$). This meant that quiet the same illegal mining activities occured at the communities which affected the topsoil.

Table 7: The depth of top soils available

Community	Depth of topsoil (m)			Mean
	Site A	Site B	Site C	
Esaase-Manhyia	0.12	0.10	0.09	0.10±0.015
Aboabo	0.11	0.13	0.12	0.12±0.010
Tetrem	0.09	0.07	0.06	0.08±0.012

3.5 Quantities of Soil Washed at Sites

Different quantities of soil were washed daily by the illegal miners. At each 'galamsey' site, there were about thirty to forty-five people working as loaders. The groups were able to dig large quantities of soil due to their huge number in each pit. They started their business at dawn and ended around 6.00pm each day. From the mean soil washed, miners at Tetrem washed larger quantities of soil as compared to other mining communities with a mean of 32205.55kg soil. Aboabo miners washed an average of 22825.00kg because they had fewer numbers of miners per hole.

Table 8: Amount of soil being washed daily

Community	**Mean Values of soils washed daily *(kg)***		
	Site A	Site B	Site C
Esaase-Manhyia	32033.3± 5620a	27180.0 ±3345.65a	30500 ±4610.27a
Mpatuam	22800 ± 1641.40b	22925.0±2738.99b	22750 ± 2148.30b
Tetrem	33750 ± 6218.68c	32233.33 ± 4902.57	30633.33 ± 1825.69c

Same letters are not statistically different from each other.

There was a statistical difference between the amount of soil washed daily at $p < 0.05$ level of significance for the three communities ($p = 0.001$) (Table 9). Mean soil washed at Esaase-Manhyia differed statistically from soil washed at Aboabo ($p = 0.005$) which also differed from soil washed at Tetrem ($p = 0.001$) using Tukey HSD post hoc test. However, the study found no difference between mean soil washed at Esaase-Manhyia and Tetrem ($p = 0.292$). This means that, mean soil washed at the Esaase-Manhyia (29904 ± 2480.72) and Tetrem (32205.55 ± 1558.15) were not different though the number of pits might be different. The consequence of this is heavy siltation of rivers and subsequent pollution of the rivers which serve as a source of water for the communities.

Table 9: One way Anova for mean soil washed at the communities

	Sum of Squares	**df**	**Mean Square**	**F**	**Sig.**
Between Groups	143407354.77	2	71703677.38	25.039	.001
Within Groups	17182255.92	6	2863709.32		
Total	160589610.69	8			

3.6 Number of Rivers/Streams polluted

The number of rivers polluted with mud as against the total number of rivers or streams found in the three communities understudy were recorded. Out of the identified rivers and streams, each community had at least two (2) polluted with mud.

Table 9: Total number of rivers/Streams polluted with mud

Communities	**Number of Rivers / Streams**	**Number of Rivers / Streams Polluted with Mud**
Tetrem	4	4
Esaase-Manhyia	3	2
Mpatuam	4	4
Total	11	10

Tetrem and Mpatuam had all their identified rivers/streams polluted with mud. The most unfortunate thing was that the Bonte River which runs through all the Bontefufuo communities was also heavily polluted. The activities of the “galamsey” operators had heavily silted the rivers and polluted with mud and chemicals. This resulted in large number of people croded to fetch water from the few boreholes in the communities as the rivers could not be used for domestic activities.

3.7 Analysis of Water Samples from the Three Communities Understudy

Water samples from rivers or streams at galamsey sites in the three communities understudy were analyzed at the laboratory for Conductivity, Total Dissolved Solids (TDS), salinity, Turbidity, pH, Dissolved Oxygen.

Table 10: Physico-Chemical Parameters of Water Samples from the Communities

Communities	Parameter						
	Conductivity (µs/cm)	TDS (mg/l)	Salinity	Turbidity (NTU)	pH	DO (mg/l)	Mercury µg/kg
Tetrem	495	241	0.6‰	3705	6.60	1.43	35 - 37
Esaase-Manhyia	330	167	0.8‰	7708	6.74	2.40	25 - 32
Mpatuam	83.3	41.9	0.1‰	2531	6.45	1.48	33 - 51
EPA Ghana Limit	750	1000	-	5	6.0 – 9.0	5	0.5 – 0.8

Water samples from the three (3) communities were highly turbid. Turbidity was very high at Tetrem and Esaase-Manhyia compared to Mpatuam. These were found to be extremely above the EPA Ghana recommended limit. This could be due to high quantity of soil washed at the sites which made the water very muddy or perhaps introduction of other substance that could impact on the turbidity of the water which might have negative consequence on aquatic organisms. Likewise the Dissolved Oxygen (DO) was found to be extremely low especially at Tetrem (1.43mg/L). All the recorded values were far below the recommended limit. The extreme low level of DO, perhaps, was partly due to the high sediments from the washed soil which was prevented dissolve oxygen from in the water. Another reason could be due presence of microorganisms to breakdown of debris and other organic matter resulting from the large quantity of soil washed which required large amount of oxygen. Notwithstanding, the pH was slightly acidic for the all samples with Mpatuam, Tetrem and Esaase-Manhyia recording a pH of 6.45, 6.60 and 6.74 respectively; however, they were within the EPA recommended range. Conductivity of the water samples were 495, 330 and 83.3 µs/cm for Tetrem, Esaase-Manhyia and Mpatuam respectively. The salinity was 0.6‰, 0.8‰ and 0.1‰ for Tetrem, Esaase-Manhyia and Mpatuam respectively. The Total Dissolved Solids (TDS) was quiet high at Tetrem (241mg/L) whiles Mpatuam recording the least TDS of 41.9mg/L but all were within EPA Ghana limit.

Discussion

The most noticeable effect of post-mining is, perhaps, the inevitable environmental destruction (Siswanto *et al.*, 2012). Mineral exploitation generally results in some kind of environmental damage (Tom-Dery *et al.*, 2012); however, the activities of surface illegal mining ("galamsey" operators) are noted to pose massive threat to the environment than the certified mining operators (Asiedu, 2013). This is because, illegal miners do not embark on reclamation and lack environmental education (Ontoyin and Agyeman, 2014; Essumang, 2015) and therefore destroy the environment. Some of these include, soil erosion, soil compaction, removal of soil layers, land left with piles of waste tailings, shallow and deep dug out pits, river siltation, encroachment and destruction of farm lands, soil pollution with chemicals, destruction of soil organisms (Ako *et al.*,2014; Rajaee *et al.*,2015).

Results from the study found substantial environmental destruction especially at Tetrem which was an active mining site. Large pits had been excavated; nonetheless, they were not backfilled after the mining activity. This had turned the sites into death traps to both humans and animals (Ofosu-Mensah and Ababio, 2011). Furthermore, the dug holes and pits become filled with rain water which serves as a breeding ground for mosquitoes and supports malaria vector growth (Arthur, *et al.*, 2016). These pits covered larger area and one can envisage the total land mark being lost to illegal surface mining. Similar finding was reported by Schueler *et al.*, (2011) who found farmlands converted to mine pits in the Damang mine.

Surface mining involves removal of the topsoil from an area of operation and accumulating it into heap elsewhere (Asiedu, 2013) which invariably wastes the topsoil. Observation from the various mine sites showed that valuable topsoil at the various sites had been removed and piled over unmined land forming mine spoil. This removal of the topsoil has rendered the land unproductive for plant growth (Mensah *et al.*, 2015; Mishra, 2015).

Stockpiling the topsoil in heaps is noted to have negative repercussions for soil micro-organisms culture, disturbs the biological functionality along with the nutrient cycle, impact on the chemical and physical properties of the soil resulting in non-functional soil system (Sheoran *et al.*,2010; Mensah *et al.*,2015). These conditions were much obvious at the various visited abandoned mine sites in the communities with more damages witnessed at Tetrem. The heaped laterite to be washed and other stockpiles has the tendency of ceasing oxygen and water supply to beneficial soil microorganism reducing their population drastically. According to Rai *et al.,* (2014) valuable topsoil takes longer time to form and should therefore be protected; however, the actions of the illegal miners are not protecting the topsoil which needs attention.

River pollution was one of the visible impacts at the mining site (Amankwah, 2013). This pollution came from indiscriminate use of chemicals for gold extraction, washing of ores in rivers, discharging of untreated tailings into river bodies, heavy metal pollution and other illegal activities which affect the physico-chemical parameters of the river body. The study revealed high level of turbidity in surface water bodies in all the three communities under study which is an indication of the presence of silt, suspended materials, plankton, fine and course organic materials and other inorganic and organic materials (Gyang and Ashano, 2010). This could be due to the washing of soil directly into the river and run offs from the mined lands, which added a lot of soil into the water bodies causing the high turbidity (Cobbina *et al.,* 2013; Mudyazhezha and Kanhukamwe, 2014). According to EPA Ghana standard, turbidity should not exceed 5NTU. Turbidity above this limit is noted to impair fish vision and could also promote breeding of microorganisms with low infective doses such as viruses and protozoa (Cobbina *et al.,* 2013; Nevhulaudzi *et al.,* 2014). Personal communication with indigenes who were involved indicated that the water bodies had a lot of fish which used to be sources of livelihood for the people but the advent of the galamsey has destroyed all the fish to the extent that none could be found in the water as at the time of the study. The study showed that the level of pH of the water samples were though within the recommended range, they were close to acidity. According to Udiba *et al.,* (2013), the pH is an important parameter for water quality determination as it affects solubility and toxicity of metals. The electrical conductivity indicates the presence of dissolved minerals in the water (Cobbina *et al.,* 2013). The high value for conductivity at Tretrem and Esaase-Manhyia is an indication of dissolved minerals. Although, this was within the permissible range, the activities of the illegal miners should be closely monitored and restricted to ensure that the concentration of the EC did not escalate to unacceptable limits. The DO of the water samples were very far below the recommended limit. This could be due to the decomposition of organic matter by microorganisms that used up oxygen in the water bodies (Aris *et al.,* 2014) which can lead to the death of aquatic organisms. The presence of high amount of particulate matter could also affect the dissolution of oxygen in the water and therefore accounting for the low levels of oxygen. The water bodies, therefore, needed particular attention to save them from further deterioration.

Mercury was identified as the main chemical used by the miners (personal communication with the miners) which is known to be the main chemical used in laterite gold mining (Soelistijo and Mili, 2014). This chemical pollutes water bodies and soil as well. The mercury vapor and its converted methyl mercury are noted to bioaccumulate in vital organs of fishes and humans when entered into rivers/streams and the food chain (Idowu, *et al.,* 2013). In as much as the illegal miners are not conscious of the harmful effects of mercury, they predispose themselves and community to the lethal effect of mercury through the inhalation, adsorption through the skin and ingestion.

4.0 Conclusion

The study identified that 'galamsey' has had negative impact on both soil and water bodies in the area understudy. Large mining pits were dug without backfilling. Illegal miners encroached farmlands and valuable topsoil was destroyed making the lands unproductive. Large amounts of stockpiles on the topsoil recorded at all the study sites have the tendency of also abating the supply of oxygen and water to beneficial edaphic organisms which will reduce their population and functionality should these activities continue.

Water bodies especially rivers and streams were polluted with soil or mud washed from the ore which impacted negatively on the physico-chemical parameters of the water. They were highly turbid with extreme low dissolve oxygen. Nonetheless, no attempt has been made to salvage the situation. The conditions of the rivers as observed were degraded to a point that they least serve their intended purpose.

It was therefore, imperative that the Environmental Protection Agency together with the Regional Security Council act immediately to control the activities of the illegal miners. Furthermore, there should be enforcement of laws to make sure that miners do not mine 200 meters close to water bodies. Illegal miners should also be educated on the harmful consequence of their actions and the need to reclaim the lands after mining.

Recommendations for further studies

The high levels of mercury measured in the water bodies must be a cause for concern for farming communities in the lower courses of the rivers and streams and therefore further studies must be conducted to find out the levels in the food crops grown.
Further studies needed to be conducted on the ground water in the communities to identify the mercury levels since they use wells and boreholes as sources of drinking water.

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