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Heavy Metal Pollution in Soil and Water in Some Selected Towns in Dunkwa-on-Offin District in the Central Region of Ghana as a Result of Small Scale Gold Mining

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Abstract

Illegal small scale gold mining popularly called "Galamsey" in our local communities is on the increase. This has led to concerns about the level of environmental pollution resulting from these mining activities. This work was conducted to determine the level of heavy metal contamination in the environment due to the activities of the small scale miners. This paper discusses the concentrations of some selected heavy metals—Hg, Pb, and Cu which were measured in 14 sampling sites in Dunkwa-on-Offin in the Central Region of Ghana, known for these activities. The heavy metal concentrations have been investigated for soil and water samples in the selected towns and compared with the relevant guidelines of the Environmental Protection Agency. The concentration of heavy metals was measured by using AAS. In most locations, the concentration for the investigated heavy metals far exceeded the concentration admitted by the guidelines. The mean concentration of Lead was 95.13 mg/Kg for soil and 190.27 mg/L in water; Copper was 63.26 mg/Kg in soil and 75.92 mg/L in water while Mercury was 140.87 ug/Kg in soil and 211.31 mg/L in water. The mean recorded concentrations in the sensitive areas exceeded greatly. Hence the levels of heavy metal contamination have spread beyond control.

Keywords

Small-Scale Gold Mining, Mercury Pollution, Heavy Metal, Dunkwa-on-Offin, Ghana

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1. Introduction

Small scale gold mining, popularly called "galamsy" in Ghana and other developing countries, is seen as a source of subsistence and a determinant of the environmental degradation [1]. In Ghana, small scale gold mining is set to be responsible for about 5% of the annual gold production. However, this gold mining of late has become unpopular as it is seen as the source of significant heavy metal contamination of the environment [2]. Some of the impacts associated with this small scale gold mining include the destruction of vegetation, land degradation and the pollution of water bodies. The rate at which mercury is discharged into the environment and water bodies is very alarming [3]-[5]. In small scale gold mining, simple tools are used in the recovery of gold from the land. Pits are dug haphazardly and these remain uncovered long after their operations. It's reported that in a prospecting work in a field, a pit that was dug revealed the presence of mercury in the soil [6]. Tetteh, *et al*. (2010) [7] reported high levels of mercury and zinc content in the top soil of towns in Wassa West. The levels of the concentration, however, decreased with distance from the main mining centers and extended beyond most probably due to aerial dispersion of the metal from mining areas.

Amalgamation is the preferred method used for the extraction of this free gold from its ores. The gold amalgam is usually roasted to release the mercury and to concentrate the gold. The excess mercury which is discarded into the environment finds its way into the water bodies [8]. Methylmercury in water and mercury oxides in the air as a result of the gold amalgam finds its way in humans through the food chain as in ingestion of mercury contaminated food or fish and through inhalation [2] [9].

The main goal of this paper is to determine the levels/concentration of trace metals introduced into the environment as a result of the small scale mining activities and to compare the values with that of the Romanian guideline which are being used by the Ghana Environmental Protection Agency as a standard to determine if it has reached pollution levels. It will also provide evidences whether the mining activities actually introduced the trace metals into the environment. Lastly, this will help to determine situation and suggest appropriate environmental strategies to contain the problem coupled with recommendations to control the problem.

2. Materials and Methods

2.1. Study Area and Location of Sampling Sites

The study was conducted in Dunkwa-on-Offin in the Dunkwa District in the Central Region of Ghana. The District shares boarders with the Eastern and Ashanti Regions of Ghana. The samples investigated were soil and water collected from various parts of the study area. Fourteen (14) sampling sites were located (**Tables 1-4**). Sites 1 to 12 were located in farms within the vicinity of Dunkwa-on-Offin in various directions and distances from the centre of the town while site 13 was located in Nkronya, the main site of the small scale mining activities. Site 14 was located in the botanical gardens of the University of Cape Coast.

Table 1. Name and shortest distance of the sites 1 to 3 from the centre of the town (In South Direction of Nkronya).

Name of Village	Distance (Km)
Akyempem	3.00
Aduman	10.00
Kyekyewere	12.50

Table 2. Name and shortest distance of the sites 4 to 6 from the centre of the town (In North-Western Drection of Nkronya).

Name of Village	Distance (Km)
Atekyem	1.50
Kwameprakrom	6.40
Ayemfori	12.75

Table 3. Name and shortest distance of the sites 7 to 9 from the centre of the town (In South-Western Direction of Nkronya).

Name of Village	Distance (Km)
Mfuom	2.50
Babiaraneha	4.25
Asikuma	9.25

Table 4. Name and shortest distance of the sites 10 to 12 from the centre of the town (In North-Western Direction of Nkronya).

Name of Village	Distance (Km)
Acquakrom	1.00
Tikyakrom	2.25
Manukrom	5.50

Ghana Environmental Protection Agency has adopted Romanian guideline on levels of trace metals in water and in soil as a standard to determine if the determined levels have reached pollution stage [10].

2.2. Sample Collection and Analysis

The water and soil samples were randomly collected from 14 sampling sites in 14 different areas within Dunkwa and the University of Cape Coast in the Central Region of Ghana. The sampling sites were located in various directions and distances from the centre of the town.

At each soil sample collection site, the samples were collected to cover the plough zone. The samples were collected by removing the top litter first and with a Teflon-coated soil auger; the sample was collected into an already well washed plastic containers and sealed. They were then conveyed to the laboratory for analysis.

For the water, samples were collected at each site from the river which runs through all the towns selected in the Dunkwa District. The sample bottles were rinsed with deionised water twice before samples were collected. Collected samples were then preserved with 0.5 ml of concentrated nitric acid and stored in an ice chest with a temperature of 4˚C.

The samples were then analysed for the various trace metals. Atomic absorption spectrophotometer was employed in the analysis of the selected metals, Hg, Pb and Cu. The cold vapour technique was used for Hg determination while in the determination of Pb and Cu, the flame-AAS technique was used [11] [12].

3. Results and Discussions

Although there are clear guidelines of limit values for maximum metal concentrations in drinking water, air and food, there is still no equivalent consensus of permissible levels of metals in rivers, sediments and soils by the Ghana Environmental Protection Agency. This is as a result of uncertainties of metal does-relationships in soil and sediments and hence some contradictory values.

The results were compared with similar studies conducted in Romani with similar characteristics. The WHO guideline values for drinking water and that of US for soil and sediments were also used for comparison [13].

The total metal concentrations recorded in this study clearly indicate that the situation of metal pollution within the study area where this small scale gold mining is taking place has reached intervention levels. The concentrations of Mercury in particular were identified and discussed because of its immediate implications on human health.

3.1. Heavy Metal Pollution in Soil

The 3 metals were detected in the soil sample at varying concentrations in all the selected towns. **Table 5** shows the mean concentrations of the trace metals that were found in the soil sample. The pollutant concentration of Cu and Pb were measured in mg/Kg while that of Hg was in µg/Kg.

Table 5. Distribution of heavy metal concentrations in the soil sample.

Town	Distance from Nkronya (Km)	mg Pb/Kg		mg Cu/Kg		µg Hg/Kg	
		Mean	Std. D	Mean	Std. D	Mean	Std. D
Kyekyewere	3.00	99.80	9.30	51.60	0.10	261.50	13.05
Aduman	10.00	63.40	0.70	64.30	0.10	137.50	5.15
Akyempem	12.50	86.20	0.60	45.70	0.15	248.20	11.90
Atekyem	1.50	30.40	0.25	85.40	0.20	148.20	0.60
Kwameprakrom	6.40	89.40	8.85	49.90	0.10	133.70	9.85
Ayamfori	12.75	132.00	0.45	71.40	0.15	146.90	5.15
Mfuom	2.50	58.10	10.15	72.80	0.05	83.30	5.85
Babiaraneha	4.25	82.40	3.10	59.90	0.20	74.00	13.85
Asikuma	9.50	76.46	2.20	66.10	0.55	69.80	1.25
Acquahkrom	1.00	25.00	2.35	66.10	0.44	116.90	10.00
Tikyakrom	2.25	86.20	2.70	52.10	0.07	110.50	9.35
Manukrom	5.50	46.10	3.65	38.10	0.06	136.20	6.15
Nkronya	0.00	154.00	0.25	90.40	0.05	265.70	3.80
UCC	275.00	6.20	0.00	3.10	0.00	1.10	0.00
Standard		80.00		50.00		40.00	

From **Figure 1**, the lead concentrations in the various towns depicted a varying trend. About 50% of the towns showed values less than the standard. The towns which showed the higher value concentration were towns where there has been extensive cultivation of cocoa and other similar food crops. Here, there has been profilic use of various pesticides, herbicides and artificial fertizers to boost crop yeilds. This could cause the increase of the metal in the soil.

The concentration of copper as seen in **Figure 2** demonstrated the higher concentration of the metal. This could have come about as a reuslt of the area ever housing a copper mine dating back to 1493 - 1600 [14].

The total mercury concentrations were higher in all the towns as shown in **Figure 3**. There has been increased illegal mining activities across the entire district and with corresponding increase in mercury in the environment. This really suggests that the small scale gold mining and recovery activities contribute to the level of mercury. Comparing this results to that obtained on the sample from the botanical garden of the University of Cape Coast and that of an organized gold mine in Obuasi [15], the illegal mining indeed caused the pollution of the environment with the trace metals.

3.2. Heavy Metal Pollution in Water Sample

The heavy metals were detected in the water sample at varying concentrations in all the towns. **Table 6** shows the mean concentrations of the trace metals in the water sample. The pollutant concentration of Cu and Pb were measured in mg/L while that of Hg was in µg/L.

From **Figures 4-6**, the mean trace metal concentrations depicted a varying trend from the different towns. However, one thing has been observed that the concentrations were well above the standard level. The highest levels were recorded in towns that are located upstream of the river Offin which run through all the towns under study. Most of the concentrations reduced with stretch of the water flow down the stream. The river Offin which runs through Dunkwa district is up stream of its source in Tarkwa in the Western Region of Ghana which is well known for its gold mining activities as far back as 1471 [14]. The trace metal concentration however, confirmed the idea that heavy metal pollutants and others in water turn to reduce along the distance of travel for the moving surface of a water body [8] [16] [17].

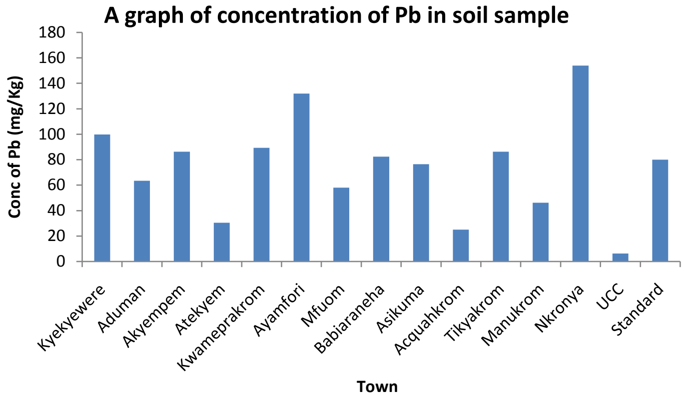

Figure 1. A graph showing the distribution of Pb concentrations in the soil sample at the various towns.

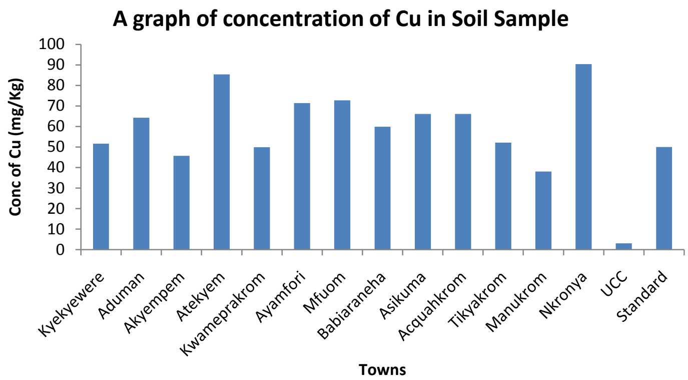

Figure 2. A graph showing the distribution of Cu concentrations in the soil sample at the various towns.

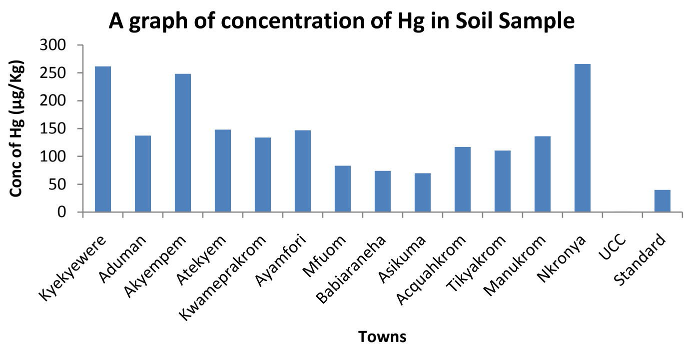

Figure 3. A graph showing the distribution of Hg concentrations in the soil sample at the various towns.

The results obtained from the sample taken from the botanical garden of the University of Cape Coast were expected because there is no mining activity taking place in the garden or even within the environs of the University. The presence of some trace metals as seen could be due largely to background levels in the soil and water as a result of the use of fertilizers and also carried by wind from elsewhere.

4. Strategies and Recommendation

4.1. Strategies for Environmental Control

The government, the civil society and nongovernmental organizations in Ghana have formed a joint public initi-

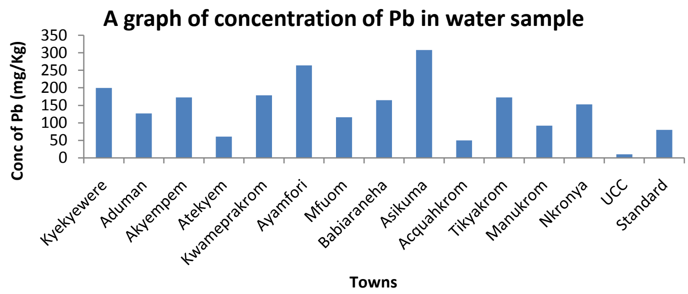

Figure 4. A graph showing the distribution of Pb concentrations in the water sample at the various towns.

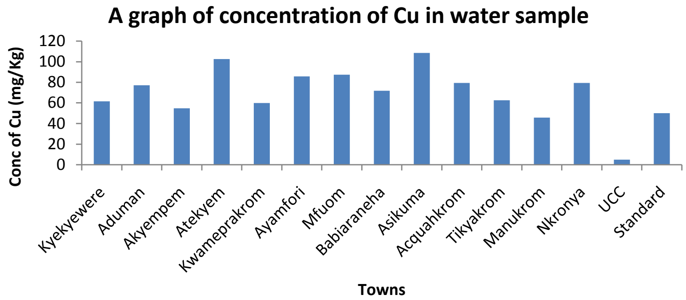

Figure 5. A graph showing the distribution of Cu concentrations in the water sample at the various towns.

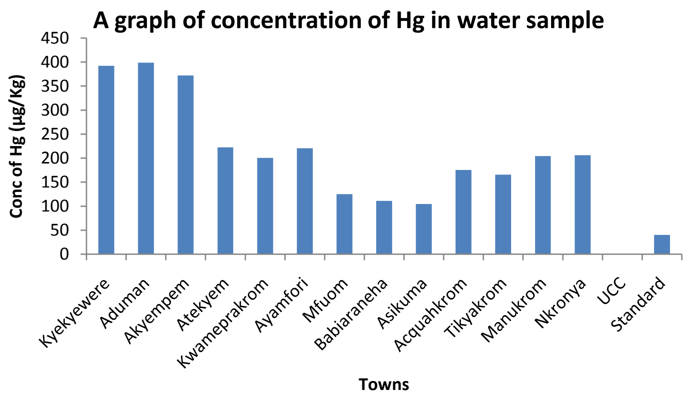

Figure 6. A graph showing the distribution of Hg concentrations in the water sample at the various towns.

ative to control the environmental pollution caused by small scale mining. These strategies should entail a joint initiative of the small scale miners, the government, civil societies, non-governmental organizations, and finally environmental entities and experts.

Revising environmental laws to ensure that they are relevant to the situation at hand, the laws should recognize and prescribe the best mining practices that promote environmental conservation.

Implementation of strong rules and regulations that are aimed at controlling the activities of the small scale gold miners; the regulations should provide for punishment and penalties for those who are found culpable.

Small scale miners should be encouraged to avoid sluicing of gold in the open air, rivers beds and streams. The small scale miners should avoid burning the gold amalgam in the open air as this releases dangerous fumes of mercury and carbon dioxide.

The government should implement land reclamation program. The initiative should entail planting of more trees on the areas that have undergone deforestation. Planting of more trees ensures that the soil regains its fertility and also reduces soil erosion.

Table 6. Distribution of heavy metal concentrations in the water sample.

Town	Distance from Nkronya (Km)	mg Pb/L		mg Cu/L		μg Hg/L	
		Mean	Std. D	Mean	Std. D	Mean	Std. D
Kyekyewere	3.00	199.60	9.30	61.60	0.10	392.25	10.44
Aduman	10.00	126.80	0.70	77.16	0.10	398.55	4.12
Akyempem	12.50	172.40	0.60	54.84	0.15	372.30	9.52
Atekyem	1.50	60.80	0.25	102.48	0.20	222.30	0.48
Kwameprakrom	6.40	178.80	8.85	59.88	0.10	200.55	7.88
Ayamfori	12.75	264.00	0.45	85.68	0.15	220.35	4.12
Mfuom	2.50	116.20	10.15	87.36	0.05	124.95	4.68
Babiaraneha	4.25	164.80	3.10	71.88	0.20	111.00	11.08
Asikuma	9.50	308.00	2.20	108.48	0.55	104.70	1.00
Acquahkrom	1.00	50.00	2.35	79.32	0.44	175.35	8.00
Tikyakrom	2.25	172.40	2.70	62.52	0.07	165.75	7.48
Manukrom	5.50	92.20	3.65	45.72	0.06	204.30	4.92
Nkronya	0.00	152.92	0.25	79.32	0.05	206.25	3.04
UCC	275.00	10.00	0.01	5.00	0.00	0.02	0.00
Standard		80.00		50.00		40.00	

The miners should be encouraged to avoid land excavation by using modern techniques and tools in mining.

4.2. Recommendations

To control environmental pollution caused by the activities of the small scale gold miners, this research therefore proposes the following recommendations.

The government should empower the Minerals commission to exercise its mandate through adequate funding and support.

The commission should enact legislations to control the small scale mining in the country.

The Minerals commission should conduct a proper and comprehensive research to determine the level of environmental degradation caused by the activities of the small scale miners.

The players in the industry both small scale and large scale operators should adopt proper environmental management tools.

The commission should control illegal mining activities practiced by the small scale miners. The government should enable the licensed small scale operators in the mining sector access funding from financial institutions in the economy. Funding of their operations will enable them to adopt modern mining techniques and abandon traditional techniques such as shallow alluvial mining which leads to the massive deforestation and excavation of the earth surface. Funding will also enable the miners to procure modern mining tools which can enable them crush hard rocks containing gold without causing noise and dust.

The government, the Minerals Commission, the civil society, and non-governmental organizations should conduct proper campaigns to enhance awareness on the impacts of environmental pollution. The initiative should aim at educating the small scale miners on the impacts of their activities.

5. Conclusion

The study revealed that small scale mining activities indeed introduce mercury and other trace metal pollutants into the environment. The concentrations of these trace metals determined in this study showed that it has reached pollution levels in the environment and therefore need urgent attention. This is because the results as compared to the standards and other areas where organized gold mining has taken place indicated much higher concentrations of the selected trace metals.

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