e-palli

AMERICAN JOURNAL OF ENERGY AND NATURAL RESOURCES (AJENR)

ISSN: 2835-9186 (ONLINE)

VOLUME 2 ISSUE 1 (2023)

American Journal of Energy and Natural Resources (AJENR)

Volume 2 Issue 1, Year 2023
ISSN: 2835-9186 (Online)
DOI: https://doi.org/10.54536/ajenr.v2i1.1978
https://journals.e-palli.com/home/index.php/ajenr

Heavy Metals (Hg and As) Concentration in Mining Endowed Enclaves in Ghana

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Article Information

Received: November 27, 2023

Accepted: December 22, 2023

Published: December 25, 2023

Keywords

Levels, Mercury, Arsenic, Water, Sediments, Ghana

ABSTRACT

Levels of heavy metals in mining areas differ from region to region depending on the level of operations and activities engaged at the mining site. The study assessed the extent of heavy metals contamination in the available water and sediments in mining endowed enclaves in Ghana. A total of forty-eight (48) samples, 24 each of water and sediments samples were taken. At each mining site, 4 samples each of water and sediments samples were taken and studied. Water and sediment samples were taken to the laboratory to determine level of mercury and arsenic. For the sediments, the average levels of Hg ranged from 0.057-0.145ppm and that of As levels in the soil sediments ranged from 0.084-0.087ppm. The average levels of Hg in water samples ranged from 0.010-0.086ppm and that of As levels in the water samples ranged from 0.004-0.008ppm. There were significance differences ($p<0.05$) in the levels of Hg and As of the various mining sites for the water and the sediments. All the samples (water and sediments) taken from the various mining sites had Hg above the recommended levels whereas As for samples were below the recommended levels. There should be enforcement of more stringent water and land monitoring and pollution scheme through Environmental Protection Agency (EPA) and the Minerals Commission.

INTRODUCTION

In the past two decades, there has been a continual demand for gold in the international market, resulting in an astronomical increase in gold prices (Wiafe *et al.*, 2022) thereby increasing in gold production across the globe. There are two kinds of mining; surface and underground mining (Bagah *et al.*, 2016, Ofosu *et al.*, 2020). Surface mining, also called open-pit mining or strip mining is undertaken if the mineral deposit lies on the surface of the earth. This method is usually more cost-effective and requires fewer workers to produce the same quantity of more than the underground mining does. Underground mining on the other hand is used when the mineral deposit lies deep below the surface of the earth. Surface mining is the dominant method of mining practiced by Artisanal Small Scale Gold Miners (ASGM) due to its cost effectiveness, low capital intensity and minimal technical skill requirement (Boakye, 2020).

In most parts of the world, ASGM is as important as Large-Scale Mining (LSM), particularly due to the number of people employed (Wiafe *et al.*, 2022). The mining industry improves the quality of human life by creating jobs, lifespan, skills and knowledge, proper distribution of income, infrastructure, public health services and education (Koushik *et al.*, 2012). The Global Report (2002) on Artisanal & Small-Scale Mining noted that about 13 million people across the world are directly engaged in small-scale mining (Hentschel *et al.*, 2002). In Ghana, mining industry creates economic growth at the national and regional levels. The Ghana Statistical Service (2015) reported that about 300,000 people in Ghana are engaged in small-scale mining. Over the years, small-scale mining has played a very significant role in the socio-economic development of Ghana. It generates both direct and indirect employment, contributing about 40% of the country's gross foreign exchange earnings (an equivalent of about 5.7% of GDP (Aryee, 2001).

Despite the benefits of small scale mining, several researchers (Darko & Ansa-Asare, 2014; Duncan *et al.*, 2018; Sun *et al.*, 2019) have reported that the small scale mining is marked with huge negative environmental impact, both on land and in water bodies. Their operations have caused significant damages to the environment, mainly manifested in land degradation and water contaminations (Hilson, 2002). Mining industry is a human activity with negative impacts on the environment (Mahdi *et al.*, 2020. Some negative impacts are habitat destruction, loss of resources and biodiversity, deterioration of land and accumulation of pollutants in various ecosystems (Tehna *et al.*, 2015). The environmental impacts of mining are widespread especially in rural communities in developing countries (Antoci *et al.*, 2019). Antwi-Boasiako (2003) notes that environmental damage resulting from a mining operation, or left behind after mine closure, ranging from water pollution or restrained water quantity to tailings and subsidence, can seriously limit people's current and future income opportunities, in particular when dependent on agriculture, fishery, forestry or hunting.

The adverse environmental impact of mining activities on the environment is well documented. Particular attention has been directed towards the impacts of large scale and small scale gold mining activities on environmental contamination. While the land degradation caused by the gold mining is pronounced, chemical contamination from the gold extraction process imposes a double burden on the environment, with harmful health implications

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for mining communities and people residing in close proximity to such activities (Yelpaala, 2004). For instance, due to the informal nature of gold-mining in the South (Africa and Latin America), most studies concentrate on mercury exposure and intoxication incurred in the extraction and processing stage of mining (Tirado *et al*., 2000). Results of several studies indicate patterns of mercury intoxication during the gold amalgamation process (Van Straaten, 2000).

According to Akabzaa and Darimani (2001), extensive areas of land and vegetation in Tarkwa have been cleared to make way for surface mining activities. Currently, open pit mining concessions have taken over 70% of the total land area of Tarkwa. It is estimated that at the close of mining a company would have utilized 40-60% of its total concession space for activities such as siting of mines, heap leach facilities, tailings dump and open pits, mine camps, roads, and resettlement for displaced communities (Akabzaa and Darimani, 2001). Large-scale mining activities generally continue to diminish the vegetation of the area to levels that are vicious to biological diversity (Akabzaa and Darimani, 2001). The relative absence of legislation and government controls in Africa makes the environmental impacts of ASGM possibly larger than large scale mining (Wiafe *et al*., 2022). A recent survey by (UNEP, 2013) suggested that "ASGM sector is the largest source of Hg into the environment, accounting for about 37% (727 tones) of all global emissions.

There exist several researches of heavy metal pollution in mining areas. Recent studies outside Ghana such as (Hefni *et al.* 2016; Rajkumar *et al.* 2018; Redwan and Bamousa, 2019; Radomirović *et al.* 2020) in the areas of mining have focused on levels of heavy metals pollution in mining areas (within and around). Hefni *et al.* (2016) carried out pollution risk assessment of the surface sediments of Mahakam Delta, East of Kalimantan on four heavy metals (Zn, Cr, Cd and Ni). Their results showed that all the heavy metals were in elevated level (i.e. above WHO permissible threshold). They also concluded that the ecological potential risk of the heavy metals was in the order of Cd>Ni>Zn>Cr. Rajkumar *et al.* (2018) conducted an appraisal on the soil regime pollution by heavy metals in the hilly tracts of Nalagarh valley, Himachal Pradesh, India, using geochemical indexing approaches and chemometric techniques. They conducted their studies using nine heavy metals (As, Cd, Cr, Cu, Fe, Mn, Ni, Pb and Zn). Their results on geochemical indices (Pollution Load Index, Enrichment Factor and ecological risk showed that Cd, Pb and Cu were gradually polluting the valley soil. Redwan and Bamousa (2019) evaluated the environment quality of the Barramiya gold mine area in the eastern desert of Egypt and found that there are 318–500 t tailings in the area, which cause serious heavy metal pollution to the surrounding environment due to erosion, weathering, and surface runoff. Radomirović *et al.* (2020) found that only Pb and Zn exhibited moderate level of pollution in the study sites out of the rest of heavy metals analysed in Yugoslavia. The above studies support the notion of Zhao *et al*., (2020) who stated that in recent years, studies have shown that mining activities cause soil heavy metal pollution.

Furthermore, concerns and research surrounding heavy metal polluted soil caused by mining are increasing all over the world. In Ghana, Akoto and Anning (2020) analyzed the heavy metals of different solid mine wastes in Ghana mining area and found that the degree of ecological risk varies with the type of wastes: tailings > sulfide > oxide. Darko *et al.* (2021) conducted ecological risk of seven heavy metals on surface soils within auto mechanic enclave in Sunyani, Ghana (As, Cr, Cu, Mn, Pb, Ti and Zn). Their analysis was based on Pollution Load Index and Contamination Factor of the heavy metals in the study area. Their results showed moderate Contamination factor of Pb with the rest of the metals exhibiting lower contamination factors. Wiafe *et al*., (2022) conducted a study on the environmental risk assessment of heavy metals contamination in the catchment of small-scale mining enclave in Prestea Huni-Valley District, Ghana and found out that the concentration of metals in water were below WHO permissible limits, except Ni and Co. Their mean concentrations of Hg and Cd in the soils of the study area were 2.02 mg/kg and 13.2 mg/kg respectively, which exceeded the WHO permissible limits. Their study revealed that the soil and water samples were polluted with heavy metals, particularly Hg and Cd. The above literature indicates various research works carried out at different locations prone to heavy metal contamination. Most early studies evaluated single or limited numbers of mining areas (Zhang *et al*., 2019; Zhou *et al*., 2022) and this is not different for the literatures related to Ghana on levels of heavy metal in mining areas.

Gold deposits discovered in Wassa Amenfi (West, East and Central) enclave in the Western Region of Ghana have attracted a lot of small-scale mining ventures to the area over the years. This has led to illegal small-scale gold mining activities in the area with improper mine waste disposal. Water bodies in the Wassa Amenfi (West, East and Central) enclave have been seriously been polluted by the activities of these small scale mining. This was seen in the recent ban of small scale mining activities in Ghana. From the ongoing, an overall evaluation of heavy metal pollution in several mine areas including water and water sediments on a national scale is severely lacking and urgently needed for environmental management. The present study systematically investigated heavy metal pollution in three municipalities that are well-mined areas among six mining companies. The heavy metals selected for analysis were Arsenic (As) and Mercury (Hg). These heavy metals were selected based on their toxicity and prevalence in the study area. The study reveals the extent of heavy metals contamination in the available water and sediments in mining endowed enclaves in Ghana.

METHODOLOGY

Location of the Study Areas

The study was conducted in Wassa Amenfi (West, East and Central) Districts (figure 1) in the Western Region of Ghana.

Amenfi West

Amenfi West Municipal is located in the middle part of the Western Region of Ghana. It is bounded to the west by Sefwi Wiaso and Aowin Suaman districts, to the south by Jomoro and Ellembele, to the south east by Prestea-Huni Valley and to the north by Bibiani-Anwiasi-Bekwai and to north-east by Wassa Amenfi East. It lies between latitude 5° 30' and 6° 15'N and longitude 1° 45 W and 2° 11'W. It has a total land area of 3,464.61 Square kilometers and made up of over 250 communities (Ghana Statistical Service (GSS), 2014).

Amenfi East

The Wassa Amenfi East District is one of the districts in the Western region of Ghana. The district can be found in the middle part of the region. It lies between Latitudes 5°, 30' N and 6°, 15' N, Longitudes 1°, 45' W and 2°, 11' W. It is bounded to the west by Wassa Amenfi West District, to the east by Mpohor Wassa East District, to the south by Prestea Huni Valley District and to the north by Upper Denkyira West and East District (GSS, 2014).

Amenfi Central

The district is located in the middle part of the Western Region of the country. It has an estimated land size of 1,845.9 square kilometres with 131 communities. It is bounded to the church North by Bibiani-Anhwiaso-Bekwai and Upper Denkyira West Districts and Sefwi-Wiawso Municipal; to the North-West by Aowin District; to the South by Prestea Huni-Valley; to the East by Amenfi East District and to the West by Amenfi West District. It lies between latitudes 5° 20'N and 6° 7'N and longitudes 2° 9'W and 2° 27'W (GSS, 2014).

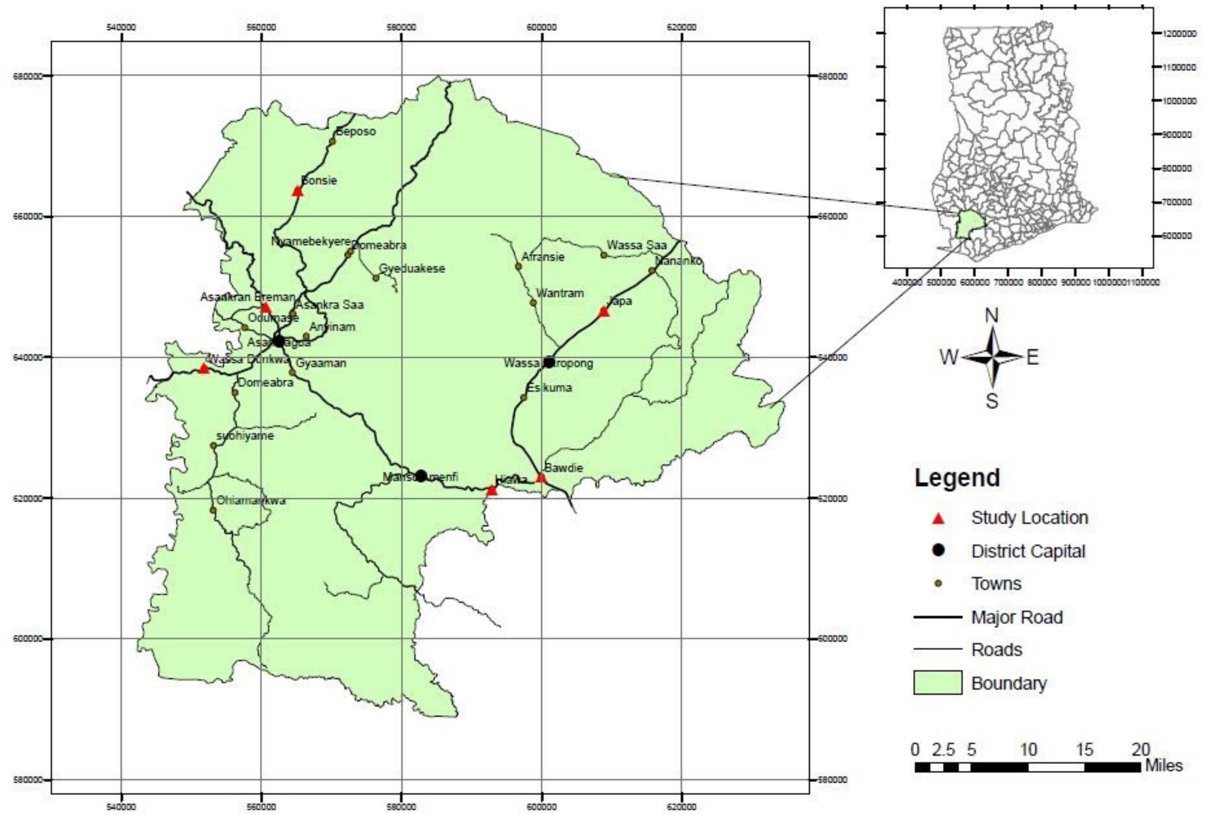

Figure 1: Map of study area; Wasa Amenfi (West, East and Central)

Analytical Protocols

The study involves laboratory analysis of water and sediments. Samples were taken from the selected mining sites within the study areas (Wassa Amenfi West, East and Central) of the selected mining companies.

Table 1: Mining Companies

S/N	Mining Company	Location
1	Obeng Mine(OM)	Japa
2	Akropong Community Mine(ACM)	Bawdie
3	Awino Mine(AM)	Wassa Dunkwa
4	Prince Express(PE)	Hiawa
5	Minta Mines(MM)	Bonsie
6	Breman Community Mine(BCM)	Asankran Breman

Sampling

A total of thirty (48) samples, 24 each of water and sediments samples were taken. At each mining site 4 samples each of water and sediments samples were taken and studied were studied. Water and sediment samples were taken to the laboratory to determine level of mercury and arsenic. The levels of two (2) heavy metals; Arsenic (As) and Mercury (Hg) in the water and sediments samples from the selected research area were studied. The selection of these heavy metals was based on their prevalence and toxicity. Spot points each of a defined area on a section of each of the mining sites were coordinated using a handheld GPS (Garmin-etrex 10) and mapped out.

Sampling Treatment

Samples were collected from the surface of the stagnated water surface using 1.5L high density polyethylene bottles. Water sampling bottles were rinsed twice with the water before sampling done at each site. Samples were sealed and transported in an ice chest to the laboratory. Water samples were acidified with concentrated nitric acid, well labelled, kept over ice in an ice chest according to the standard method (APHA, 1995) to maintain them at a temperature below 4°C during transfer from the field to the laboratory.

Laboratory Analysis for Hg and As

Metal digestion was done using the Milestone Acid digestion method. A 5 ml volume of each water sample was pipetted into a 20 ml teflon tube. Concentrated acids of 6 ml nitric acid (HNO_3, 65%), 3 ml of hydrochloric acid (HCl, 37%) and 0.25 ml hydrogen peroxide (H_2O_2) was added to each sample. The samples were placed in an ETHOS 900 microwave digester for 3 min. After digestion, the samples were allowed to cool to room temperature and the solutions then diluted to 20 ml with distilled water. The liquid extracts were used for the determination of arsenic and mercury using VARIAN AA240FS fast sequential atomic absorption spectrophotometer under the recommended instrument parameters. Two standard reference materials - IAEA 356 from the National Institute of Standards and Technology, USA, and NIVA SLP 0838 PROVE I from Norway was used for the validation of the analytical results. The concentration of each metal was calculated using the formula:

Final concentration (mg/l) = concentration of metal x dilution factor x nominal volume/Sample volume (ml).

RESULTS

Heavy Metals (Hg and As) Present in Water and Sediments within Mining Area

The analytical values and % differences in heavy metals content in both water samples and sediments components relative to international standards are summarily presented (Tables 1, 2).

Heavy metals analysed in water and sediments were

Table 1: Analytical levels (ppm) of detected heavy metals in water and sediments in mining sites

Labels	Sediment Samples		Water Samples	
	Hg	As	Hg	As
Minta(A)	0.116±0.001	0.084±0.002	0.086±0.001	0.004±0.001
Pe(B)	0.145±0.003	0.085±0.001	0.022±0.003	0.008±0.001
Breman(C)	0.093±0.006	0.084±0.002	0.062±0.002	0.006±0.001
Akcm(D)	0.064±0.003	0.085±0.001	0.060±0.004	0.004±0.001
Obeng(E)	0.057±0.003	0.079±0.003	0.010±0.002	0.005±0.001
Awino(F)	0.113±0.001	0.087±0.001	0.052±0.002	0.005±0.001
Mean	0.098	0.084	0.049	0.005
Std	0.003	0.002	0.002	0.001
Cv (%)	0.029	0.020	0.048	0.188
P-Value	0.010	0.000	0.008	0.000

Table 2: Percentage difference in levels (ppm) of heavy metals relative to International standard

Parameter	Heavy metals		(%) Differences between minimum and maximum values		International standard recommended levels		Samples with values above expected international standards	
	Hg	As	Hg	As	Hg	As	Hg	As
Water	0.049±0.002	0.005±0.001	0.051-0.047 = 0.004	0.006-0.004 = 0.002	0.001	0.1	All	None
Sediments	0.098±0.003	0.084±0.002	0.101-0.095 = 0.006	0.086-0.082 = 0.004	0.05	10	All	None

mercury and arsenic. For the sediments, Hg ranged from 0.057-0.145ppm. PE had the highest Hg value of 0.145ppm and Obeng had the lowest of 0.057ppm. The Hg in sediments were above the WHO maximum permissible limit of 0.05ppm. Arsenic levels in the sediments ranged from 0.084-0.087ppm. Awino had the highest As level of 0.087ppm and Minta and Breman having the lowest As level of 0.084 ppm. Samples of arsenic were below the WHO MPL of 10ppm. Hg in water samples ranged from 0.010-0.086ppm. Minta had the highest Hg value of 0.086ppm and Obeng had the lowest of 0.010 ppm. The Hg in the water samples were above the WHO MPL of 0.001ppm. Arsenic levels in the water samples ranged from 0.004-0.008ppm. PE had the highest Arsenic level of 0.008 ppm and Minta and AKCM had the lowest Arsenic level of 0.004 ppm. The As in the water samples were below the WHO MPL of 0.01 (Table 1). There were significance differences ($p<0.05$) in the levels of Hg and As of the various mining sites for the water and the sediments. All the samples (water and sediments) taken from the various mining sites had Hg above the recommended levels whereas As for samples were below the recommended levels (Table 2).

DISCUSSION

Heavy metals concentrations in mining areas are well known around the globe, however the levels differ from region to region depending on the level of operations and activities engaged at the mining site. Furthermore, the impacts of mercury and arsenic on human health and the environment are well documented (Eisler, 2003; Schwarzenbach *et al*., 2010; Spiegel and Viega, 2010; Cordy *et al*., 2011; Gibb and O'Leary, 2014), and small-scale mining is the largest human source of mercury emissions, contributing around 35% of total anthropogenic emissions globally (UNEP, 2013). In this study, the levels of Hg and As in the sediments were higher than the water. Mercury levels in both water and sediments were above the WHO limit and as such workers were at risk of being exposed to the adverse effect of mercury compound. Again, there were significance differences ($p<0.05$) in the levels of Hg and As of the various mining sites for the water and the sediments. The results of the study was in line with Wiafe *et al*., (2022) who stated that the mean concentration of Hg in the soils of the study area were 2.02 mg/kg, which exceeded the WHO permissible limits. They further stated that the soil and water samples were polluted with heavy metals, particularly Hg and Cd. Again Kouadio *et al*., (2023) reported that the concentrations of mercury in the water sampled are very often above the limit value set by the WHO (1 µg/L). These relatively high mercury concentrations in these waters suggest the high usage of mercury in gold mining in Wassa Amenfi West, East and Central of the selected mining companies in Ghana. The lack of appropriate methods for removing the mercury used to amalgamate the gold accounts for these relatively high soil mercury values. The mercury levels found in soils at no-mining sites correlate well with those found in water, and justify the fact that some gold miners amalgamate gold concentrate outside the mine. Soelistijo and Mili (2014) recounted that mercury was identified as the main chemical used by the miners that is known to be the main chemical used in laterite gold mining. The mercury vapor and its converted methyl mercury are noted to bioaccumulate in vital organs of humans when entered into rivers/streams (Idowu, *et al*., 2013). Since miners in the study areas were not conscious of the harmful effects of mercury, they predispose themselves to the dire effect of mercury through several means. This may include inhalation, adsorption through the skin and ingestion. The adverse health effects that are associated with Hg and mercuric compounds in humans includes possible carcinogens; damage of the brain, lungs and kidneys; damage of developing fetuses; high blood pressure or heart rate; vomiting and diarrhea; skin rashes and eye irritation. A study conducted in Obuasi region described the region to be one of the regions in the world with elevated levels of As which has been attributed to the richness of arsenopyrite (FeAsS) mineralization in the gold-bearing ore (Ahmed *et al*., 2000; Bernard & Duker, 2007). In this study, the As level were relatively below the WHO permissible limit. Despite the arsenic levels below the WHO limit, continuous exposure has detrimental health effect The highest toxicity level of As is seen in the inorganic forms As(III) and arsenate As(V) which are the predominant forms in mine tailings. Indeed, the excavation of soil to reach the ore, the crushing and processing of rocks generate large quantities of tailings containing sulphide minerals and cause the leaching of large volumes of metals such as arsenic (Fashola and Ngole-Jeme, 2016; Bretzler *et al*., 2017). The low levels of arsenic in this study could be attributed to small scale mining companies not generating large quantities of tailings and as such little volumes of sulphide that lead to release of arsenic. Therefore, the little effect of acid mine drainage (AMD) could explain the relatively low concentrations of arsenic found in soils in all the mine sites. Despite the low levels of arsenic, continuous exposure is detrimental to the health of miners

CONCLUSION

The study established that there is presence of mercury and arsenic in the mining sites in the study area. There was high usage of mercury in the mining operations of the mining companies in this study. Levels of Hg in water and water sediments recorded at the study area were above the recommended limit whiles that of As recorded were below.

There is the need for government to ensure proper monitoring, surveillance, evaluation and regulation at both the local and national level of mining operations. There should be enforcement of more stringent water and land monitoring and pollution scheme through Environmental Protection Agency (EPA) and the Minerals Commission.

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