

The Trajectory of Lost Mercury in Artisanal and Small Scale Gold Extraction in Ghana*

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Al-Hassan, S., Yaganuma, L. and Odoi, B. (2019), "The Trajectory of Lost Mercury in Artisanal and Small Scale Gold Extraction in Ghana", *Ghana Mining Journal*, Vol. 19, No. 2, pp. 35-40.

Abstract

The Artisanal and Small Scale Mining (ASSM) industry is of great importance to the Ghanaian economy. It provides employment for the teeming youth directly and indirectly and produces gold for the local goldsmiths, among other benefits. Concomitant to their operations, ASSM causes significant environmental pollution with chemicals, predominantly mercury. Mercury is used by small scale miners in the processing of ore mined because it is relatively easy to use and readily available. The laws regulating small scale gold mining in Ghana do not forbid the use of mercury even though there is a loud outcry against the use of mercury in small scale gold mining. The operations have resulted in the discharge of mercury into the environment indiscriminately. No attempt is made by the miners to recover lost mercury hence all of it is lost to the environment. This paper presents the findings of a study that investigated the trajectory of the mercury lost into the environment. The results showed that 2 g of mercury was lost to the environment for every gram of gold recovered through ASSM; 39% of it was lost to the atmosphere due to roasting of the amalgam whilst the remaining 61% was lost into water and spillage onto the ground.

Keywords: Mercury, Atmosphere, Pollution, Environment, Socio-economic

1 Introduction

Ghana abounds with tremendous amount of ubiquitous gold mineralization. This and the high level of unemployment have encouraged prolific small scale gold mining throughout the country. Small scale mining companies in Ghana are estimated to number over 150, 000 of which about 70% operate illegally on concessions belonging to large scale mines, and individual private owners. Within the Tarkwa area alone, small scale mining can be found near residences, forests and along rivers. Mining operations are undertaken all year round by about 20 000 companies out of which 90% are illegal (Mensah, A. K. *et al.*, 2015). The socio-economic importance of Small Scale Mining (SSM) cannot be over emphasized since SSM has created employment, stimulated local industries and commerce, provided social facilities and has also contributed to national economies. However, their operations have significant environmental challenges. This paper presents the use of mercury by artisanal and small scale miners in Ghana and the trajectory of the mercury lost in their operations.

1.1 Effects of Mercury Pollution

Mercury in water or wet lands forms methylmercury by microbial activity which is very toxic and concentrates in animals (Anon., 2013a). The majority of human exposure to mercury and the health risk that comes with mercury exposure are from consumption of marine food. Mercury in air may settle in water bodies through raindrops, in dust or by gravity (Anon., 2014). Thus, once mercury has

entered the environment, it cycles between the air, land and water until it is eventually removed from the system through burial in deep ocean sediments or lake sediments and through entrapment in stable mineral compounds (Anon., 2013a). It has the tendency to travel through the atmosphere far from its source of emission, thus causing global contamination of fish, birds, mammals and the human food chain. Measures are put in place globally by influential institutions to impound the continuous pollution being caused by mercury users.

Groups of people most sensitive to effects of mercury pollution are pregnant women, infants and young children. The effects of mercury can be short-term or long-term. Some short-term effects are cough, sore throat, shortness of breath, chest pains, nausea, vomiting and diarrhea, increased blood pressure, and metallic taste in mouth. Long-term effects include fatigue, changes in vision and hearing, excessive shyness and anxiety, forgetfulness, loss of appetite, and sleeping problems (Anon., 2014).

1.2 Use of Mercury by ASSM

Mercury (Hg), the only liquid metal, has been part of the mining industry since 2700BC where it was used for the amalgamation and concentration of precious metals by the Phoenicians and Carthaginians. Presently, mercury is used by small scale miners in more than 50 developing countries (Tschakert and Singha, 2007). Between 1994 and 1999, roughly 25 000 kg of mercury was imported to Ghana, mostly from Europe and Canada, 97% of

*Manuscript received August 23, 2019

Revised version accepted December 07, 2019

<https://dx.doi.org/10.4314/gm.v19i2.5>

which was destined for the ASSM sector (Tschakert and Singha, 2007).

In Ghana, panning with mercury amalgamation remains the method of choice used by many small scale miners in the extraction of gold from both alluvial and hard rock mining sites (Amegbey and Eshun, 2003). Gold concentration is done by gravity methods by panning or sluicing. Sluicing is done using sluice boards which are cheap and locally made as shown in Fig. 1. The board is lined with a blanket, towel, jute sack or some more expensive material such as 'astro turf'. The concentrate obtained from washing the 'pregnant' blankets or towels after concentration is further concentrated by panning (Yalley, 2011). Mercury is then added to the concentrate and mixed thoroughly for effective amalgamation. The mercury with gold is obtained and excess mercury is squeezed out to obtain an amalgam using a piece of fabric. The amalgam is then heated to vaporize the mercury and to obtain impure gold (sponge gold) subjected to further refining.



Fig. 1 Gravity Concentration by Sluicing

Amalgamation is the preferred choice used in the recovery of gold by small scale miners in most developing countries. Mercury is enjoying widespread usage in small scale mining industry because it is cheap, easily accessible, easy to use and most importantly, the process is transparent (Anon., 2011).

Through amalgamation, mercury can either be lost to the atmosphere, land or water. Loss to the atmosphere is as a result of heating of amalgam; loss to water through squeezing excess mercury out of the amalgam; and loss to the ground due to spillage. The burning of amalgams is mostly done in open air without retorts, thus vaporising all the mercury in the amalgam into the atmosphere as highly toxic vapour. In 2010, an estimated amount of 1 960 tonnes of

mercury was lost to the atmosphere globally out of which artisanal and small scale mining contributed 727 tonnes, making it the largest sector accounting for more than 37% of total emission (Anon. 2013a). Virtually all the mercury used is released to the environment (Anon. 2013b). It is also estimated that one or two grams of mercury is lost for every gram of gold produced in small scale mining (Tschakert and Singha, 2007). The mercury law in Ghana stipulates good mining practices in the use of mercury, yet it does not include guidelines in terms of handling and disposing of the chemical.

2 Resources and Methods Used

2.1 Small Scale Gold Mining and Processing Methods in Ghana

The methods used by small scale miners for exploiting gold deposits over the years have not changed though there have been some modifications in some of them. The main factor that dictates a mining method used for exploiting any deposit is the nature of the location where it is found, spatial distribution of the mineralization and its nearness to the surface. These methods include dredging (Anomabo and chan fan methods), underground (ghetto) method and open cast/pit (dig and wash) method (Tekpor, 2005). Details of these methods have been dealt with extensively by many writers including Yamoah, 2002; Tekpor, 2005; Acheampong, 2009.

Generally, ore from small scale mines is processed using gravity concentration methods to obtain concentrates by panning or sluicing and panning. Hard rock requires comminution to liberate the gold particles before gravity concentration. Comminution can be done by pounding with pestel and mortar, hammer milling using *chan-fang* and disc mills. Alluvial ore, mostly gravel, does not go through comminution. This is because the material is weathered with free gold. Thus, the major activity involved is digging the gravel and concentrating by washing it using sluice board. Fig. 2 shows a flow chart of ore processing used by small scale miners.

2.2 Amalgamation and Trajectory of lost mercury

Amalgamation on site is done by mixing unknown mass or volume of mercury (depending on the miner's choice) with gold concentrates to bond with the metal to form an amalgam where the middling's (tailings) are discharged of. Excess mercury is squeezed out using a rug or handkerchief. Since the gold particles are larger than the pores of the rug, they remain coagulated with some of the mercury forming the amalgam. Mercury is stored in eye-drop

bottles at amalgamation sites and handled with bare hands without any Personal Protective Equipment (PPE). That is, mercury is poured into the bare palm of miners before dropping it into concentrate to control overuse.

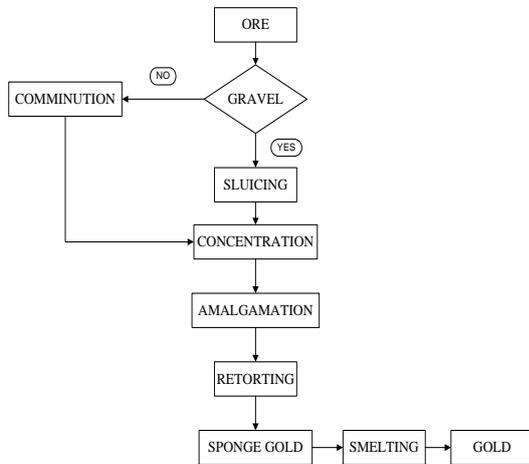


Fig. 2 Fig. 2 Steps Used by Small Scale Miners in Ore Processing (Modified after Frimpong, 2012)

The amount of mercury lost to water and tailings is dependent on miner’s carefulness and dexterity. In the process of burning amalgam to obtain gold, mercury is lost to the atmosphere as vapour. This is because mercury has high vapour pressure and easily vaporizes with application of heat. Also, some uncovered stored mercury is also lost to the environment through vaporization.

3 Results and Discussion

3.1 Data Collection and Analysis

Mercury (Hg) to be used for concentrate was poured into a pan and readings were taken of initial weight of mercury used (A). It was then used for amalgamation; and excess mercury (Hg) was squeezed out of amalgam, the squeezed-out mercury

Table 1 Format of File of Mercury Losses

(A) Initial Weight of Hg (g)	(B) Weight of Hg Squeezed (g)	(X) = (A – B) Total Hg Lost (g)	(C)Weight of Amalgam (g)	(D) Weight of Au (g)	(Y) = (C – D) Hg Lost To Environment (g)	(Z) = (X – Y) Hg Lost To Ground and Water (g)
8.40	7.60	0.80	1.10	0.60	0.50	0.30
3.70	2.90	0.80	1.50	0.90	0.60	0.20
6.10	4.10	2.00	1.50	0.80	0.70	1.30
5.40	2.80	2.60	2.60	2.80	2.50	0.10

was weighed (B). The amalgam obtained was weighed (C). After heating to vaporize the mercury in the amalgam, the resulting sponge (porous) gold was weighed (D). A sample of 124 were obtained from two small scale mining sites. Table 1 shows how the data was managed.

Three ratios were calculated and their summary statistics were found. These are (using notations from Table 1): grams of mercury lost per gram of gold recovered, X/D; mercury lost into the water and the ground to gold recovered, Z/D; grams of mercury lost into the atmosphere per gram of gold recovered, Y/D.

3.2 Discussions

Fig. 3 shows the total grams of mercury loss per gram of gold (Au) recovered.

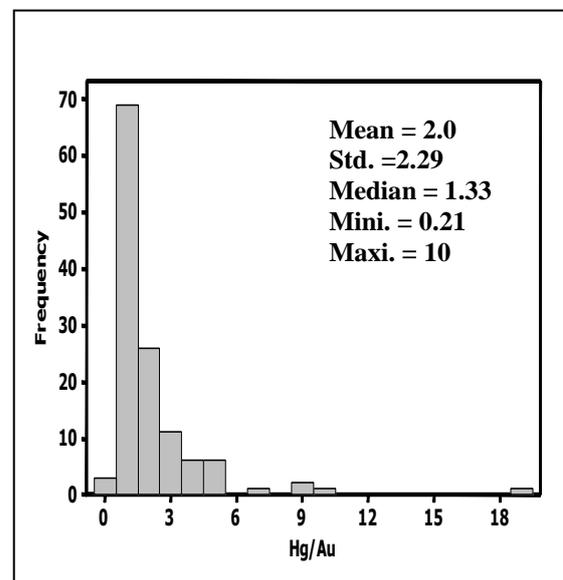


Fig. 3 Histogram of Ratio of Total Mercury Lost per Gram of Gold Recovered

Analysis of the data indicates that on average 2 g of Hg is lost to the environment per gram of gold recovered. Fig. 4 shows the histogram of ratio Hg loss to the atmosphere, as a result of roasting of the amalgam, and weight of gold recovered. The mean of the ratio is 0.78 g. Thus, 0.78 g of Hg is lost per gram of gold recovered.

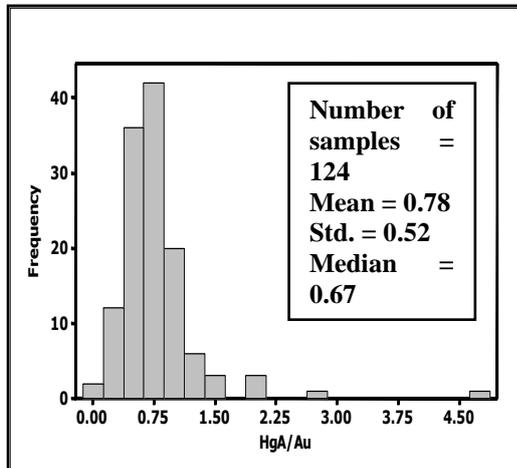


Fig. 4 Histogram of Mercury Loss to the Atmosphere per Gram of Gold Recovered

In the process of squeezing out mercury from amalgam, some of it is lost to the water and tailings; and some also spill on to the ground. On average 1.22g of Hg is lost per gram of gold recovered. The histogram of the ratio of mercury loss to the environment per unit gold recovered is shown in Fig. 5.

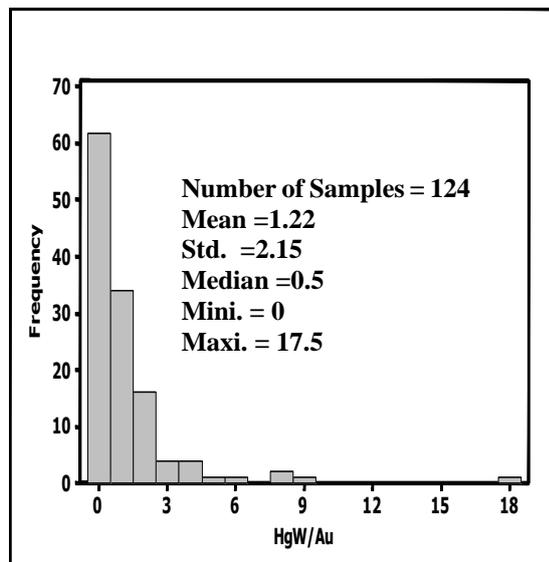


Fig. 5 Histogram of Mercury Loss to Water and Spillage on the Ground per Gram of Gold Recovered

Fig. 6 shows no linear relationship between mercury loss into water and spillages and the total mercury

recovered. This appears to be largely due to carelessness on the part of miners. The amount of mercury evaporated from the amalgam appears to be related to the amount of gold in the concentrate. This is evident in Fig. 7 with a high correlation coefficient of 0.77. The ANOVA test conducted at 5% level of significance failed (as shown in Table 2). This indicates that although the amount of mercury resident in the amalgam is directly related to the amount of gold in it, no reliable linear model can be established due to high random errors.

Table 2 ANOVA for Correlation of Total Mercury loss and Gold Recovered

Source	df	Sums of Squ.	Mean Sums Squ.	F-Test	P-value
Regression	1	220.58	220.58	167.7	0.00
Residual	123	161.78	1.32		
Total	124	382.36			

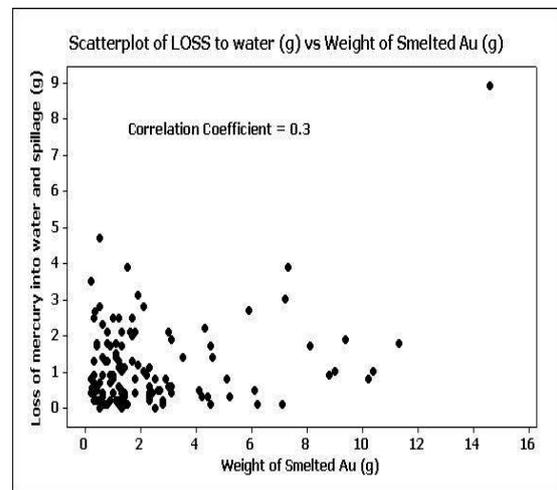


Fig 6 Scatter Plot of Mercury Loss into Water against Total Mercury Recovered

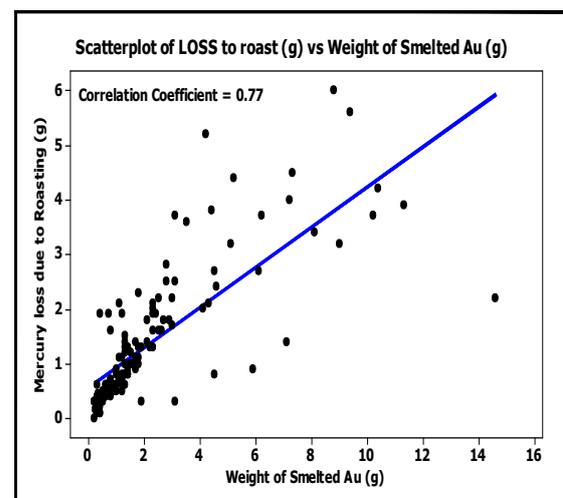


Fig. 7 Scatter Plot of Mercury Loss due to Roasting Against total mercury recovered

4 Conclusions

It was quite obvious from the study that:

- i. Small scale miners use mercury indiscriminately. No measurement of any form was considered in measuring the volume or weight of mercury to be used for a given volume or weight of concentrate;
- ii. Two (2) grams of Hg was lost for every gram of gold recovered. This is higher than the global average of between 1:1 and 1.3:1 for concentrate amalgamation (UNEP, 2012).
- iii. About 1.22 g (61% of total mercury lost) was lost to the ground (due to spillage) and water; the remaining 0.78 g (39%) was lost into the atmosphere due to roasting of the amalgam;
- iv. Mercury loss into water and spillage was mainly a result of carelessness on the part of miners as most of it could be reclaimed. They showed no concern when mercury poured on the ground;
- v. Amalgamation sites used by small scale miners were mostly within human settlements or close to rivers, hence directly polluting them; and
- vi. Amalgams were heated in closed areas in the presence of miners, making vaporized mercury to be directly inhaled by the miners and other people living nearby.

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