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Trace-elements Exposure Levels in Artisanal *"Galamsey"* Mines in Wassa-West District, Ghana

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Abstract: In order to assess trace-elements exposure levels in artisanal mines within the Wassa-West District of Ghana, Instrumental Neutron Activation Analysis (INAA) method was used to analyse fingernails of some miners. Mean concentrations were recorded for four trace-elements, namely mercury (Hg): 8.14 μg/g, gold (Au): 1.09 μg/g, Arsenic (As): 5.53 μg/g and antimony (Sb): 0.60 μg/g. These concentration levels and their health implications for the miners, as well as the environment impact of artisanal mining activities and some remedial mitigation actions were analysed.

Keywords: Fingernail, INAA, trace-element

INTRODUCTION

Artisanal gold mining, referred to in local language as "*galamsey*", activities in Ghana contribute to the revenue base of the economy. However, the method of extraction and processing of gold from the ores may pose a health hazard if safety standards are not followed. The traditional method involves excavation of gold bearing ores from shallow or deep mine shafts underground. The ore obtained are crushed or pulverised either by hand or by mechanical mills (Fig. 1a) into very fine grains. The resultant product is sieved using ladies headscarf (Fig. 1b) to get a fine powder of particle size between 65 to 180 μm (Rambaud *et al*., 2003). The pulped ore is washed in a long shallow tray with a roughened bottom (Fig. 1c) to remove unwanted portions. The recovered product is amalgamated using mercury. To extract gold from the amalgam, the mercury is burned off in open air on a miniature blacksmith's furnace (Fig. 1d), resulting in the release of mercury and other trace-elements into the atmosphere contaminating soils, plants and water bodies (Golow *et al*., 1996). These elements can be particularly dangerous for human health. Studies of trace-elements in human specimen (blood, urine, hair and toe/fingernail) demonstrated that they can be indicative of exposure level and lead to a better assessment of potential health risks (Garland*et al*., 1996; Karagas *et al*., 1996; Lin *et al*., 1998; Ranft *et al*., 2003).

There are very few methods for determining trace elements in samples and one of such methods is the Instrumental Neutron Activation Analysis (INAA).

This study assesses the level of toxicity in fingernails obtained from *galamsey* miners directly exposed to toxic elements through amalgamation activities in the arseno-pyrites gold mines in Wassa-West district of Ghana.

MATERIALS AND METHODS

In 2007, some galamsey miners from five mining towns (Tarkwa, Aboso, Akoon, Agona and Nsuta) in the Wassa-West District of Ghana were sampled to participate in this study.

Social and occupational questionnaires were administered to each identified *galamsey* miner after which fingernail clippings from all ten (10) fingers were collected using a stainless-steel clipper. The fingernails were scraped with a stainless steel blade to remove adhering matter. Each sample was washed three times with 10 mL of buffer solution, air-dried and immediately weighed and packaged for irradiation. Finally gold, mercury, arsenic and antimony single-element standard reference materials were packaged for analysis under the same conditions as the samples. The prepared samples were irradiated for 1 h at a neutron flux of 5×10^{11} neutrons/cm^2/s in the inner channel of a 30 kW Miniature Neutron Source Reactor at the Ghana Research Reactor-1 (GHARR-1) Centre. After irradiation, the samples were allowed to decay for 24 h in order to reduce the activity to safety levels and to minimise the background effects. Each sample was counted for 30 min and the peak areas of interest obtained from the spectra were used in concentration calculations as follows (Simonits *et al*., 1975):

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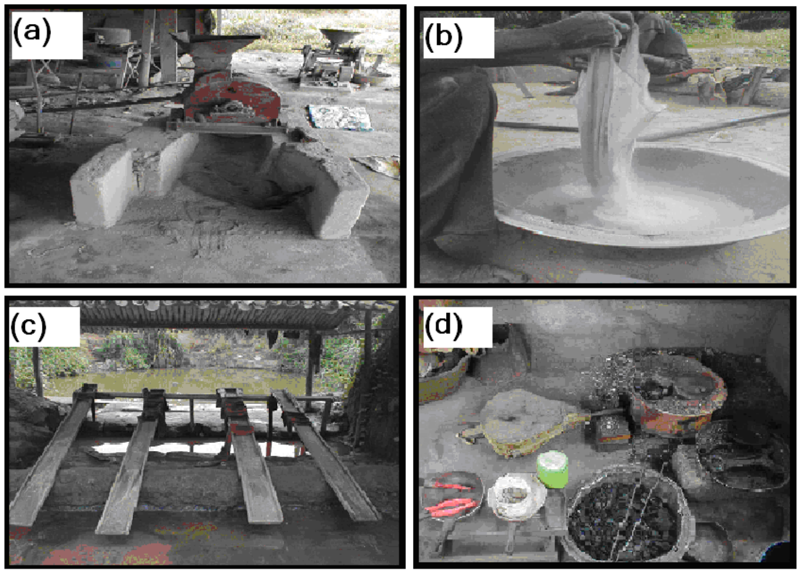

Fig. 1: (a) Side view of a belt operated crusher, (b): Miner sieving gold powder in an open topped pan using a mesh, (c): Wooden sluice boards for gravitational separation of gold bearing nuggets, (d): A typical artisanal gold refinery

$$\rho_{sam} = \frac{\left[\left(P_A/t_c\right)CD\right]_{sam}(\rho W)_{std}}{\left[\left(P_A/t_c\right)CD\right]_{std}W_{sam}}$$

Finally, statistical analyses of the results and their inferences were made.

RESULTS AND DISCUSSION

Demographic characteristics of the studied population (Table 1) indicate a relatively young group with about 75% having ages below 36 years. The number of years participants have been engaged (working experience) in the galamsey mining activities varied between 3 and 28. Trace-elements concentrations in the fingernails (Table 2) show great variations between subjects within each mining site and between mining sites. This could be attributed to a combination of factors: the stage(s) of involvement of individual miners in the mining processes (described above), the observance of safety standards and the number of years they have worked in the mines. These however were not established by a correlation study.

A glance at statistical summary of the data (Table 3); reveals mean concentration values for the different trace-elements with large standard deviations. Over 80% of the data points fall within one (1) standard deviation, making our data hardly normally distributed.

Comparing trace-elements levels determined in this study with data available from previous studies on both exposed and non-exposed subjects, some observations were made.

Table 1: Demographic and other characteristics of the studied population

Conditions	Sample size
Female subjects	9
Male subjects	21
Total subjects	30
Working experience: ≤5 years	11
Working experience: 6-10years	6
Working experience: >10 years	13
Age distribution (years)	
Median age	30
Range	17-58
25^{th}, 75^{th} percentiles	30, 36

$25^{th,}$ 75^{th} percentiles: 30% of participants have ages below 30 years whiles 75% are less than 36 years old

A study on subjects from Dumasi in Ghana, revealed a mean Hg concentration in fingernails of 3.0 μg/g (range: 0.9-12.6 μg/g) for a control group and 8.5 μg/g (range: 1.4-55.7 μg/g) for the chronically exposed small-scale miners (Rambaud *et al*., 2003). The mean concentration of 8.14 μg/g (range: 1.09-37.45 μg/g) obtained in this present study appears in agreement with the values cited by Rambaud for the chronically exposed group.

Average gold concentration of 0.58 μg/g (range: 0.27-2.05 μg/g) was reported in fingernails of apparently normal subjects, with higher concentrations in those who wore gold wedding bands (Kanabrocki *et al*., 1968). Compared with the previous findings, mean concentration of 1.09 μg/g (range: 0.06-5.74 μg/g) recorded in this work is about twice those reported for the non-exposed subjects.

In a study based on analysis of fingernails from healthy individuals living in a relatively non-industrial

Table 2: Trace element concentration results of fingernail samples from *Galamsey* miners in Wassa-west district

	Concentration (μg/g)					Concentration (μg/g)			
Sample code	Hg	Au	As	Sb	Sample code	Hg	Au	As	Sb
Abs1-1	2.22±0.08	0.76±0.04	1.15±0.04	0.39±0.02	Nsu1	3.83±0.10	1.13±0.09	1.17±0.07	0.63±0.02
Abs1-2	8.53±0.11	0.44±0.03	25.88±0.87	0.60±0.03	Nsu2	3.58±0.08	0.06±0.01	2.09±0.10	0.08±0.01
Abs1-3	12.35±0.3	80.20±0.03	21.97±0.93	0.33±0.02	Nsu3	12.94±0.17	1.55±0.08	0.86±0.03	1.35±0.05
Abs1-4	4.21±0.11	0.80±0.04	12.39±0.66	0.76±0.04	Nsu4	27.74±0.31	0.47±0.07	3.84±0.14	0.43±0.03
Abs1-5	7.23±0.15	1.10±0.07	1.26±0.06	1.68±0.03	Tak1	1.19±0.06	0.08±0.01	0.31±0.04	0.08±0.01
Abs2-1	4.81±0.13	0.18±0.03	1.19±0.06	0.27±0.01	Tak2	1.09±0.06	0.06±0.01	0.24±0.05	0.08±0.01
Abs2-2	7.90±0.11	1.55±0.07	0.81±0.05	0.34±0.02	Akn1	37.45±0.82	5.74±0.11	24-.98±2.11	0.28±0.01
Abs2-3	6.72±0.13	0.08±0.01	3.84±0.19	0.33±0.02	Akn2	7.91±0.09	0.74±0.04	2.50±0.11	0.34±0.02
Abs2-4	1.09±0.06	0.07±0.01	0.98±0.08	0.69±0.04	Akn3	6.46±0.12	1.61±0.05	0.24±0.05	0.48±0.03
Abs2-5	9.14±0.13	2.11±0.09	7.91±0.27	1.04±0.03	Akn4	12.82±0.20	0.37±0.06	2.66±0.11	0.51±0.02
Abs3-1	9.21±0.17	0.94±0.05	2.16±0.09	1.11±0.06	Akn5	1.09±0.06	0.12±0.02	1.01±0.06	0.53±0.02
Abs3-2	1.09±0.06	0.17±0.02	4.27±0.12	0.86±0.03	Ago1	1.09±0.06	3.33±0.09	1.49±0.07	1.01±0.05
Abs3-3	1.09±0.06	0.88±0.04	3.61±0.17	1.58±0.07	Ago2	4.21±0.06	5.21±0.11	16.91±4.54	0.25±0.01
Abs3-4	15.02±0.2	20.70±0.06	5.60±0.11	0.12±0.01	Ago3	30.08±0.29	0.11±0.03	5.87±0.19	0.64±0.04
Abs3-5	1.09±0.06	0.93±0.06	3.27±0.10	0.72±0.03	Ago4	1.09±0.06	1.24±0.04	5.52±0.14	0.49±0.02

Table 3: Statistical summary of trace-elements concentrations

Trace-element	Min (μg/g)	Max (μg/g)	GM (μg/g)	Mean (μg/g)	Stdev (μg/g)
Hg	1.09±0.06	37.45±0.82	4.61	8.14	9.11
Au	0.06±0.01	5.74±0.11	0.52	1.09	1.40
As	0.24±0.05	25.88±0.87	2.62	5.53	7.34
Sb	0.08±0.01	1.68±0.03	0.45	0.60	0.42

GM: Geometric mean; Mean: Arithmetic mean; Stdev: Standard deviation; Min: Minimum; Max: Maximum

environment, (Hewitt *et al*., 1995) mean antimony (Sb) concentration of 0.05 μg/g was reported. In this present work, a mean value of 0.60 μg/g (range: 0.08-1.68 μg/g) was obtained. This is considerably higher than (about 10 times) those reported by Heiwitt.

Geometric mean arsenic concentrations of 0.098 μg/g (range: 0.01-2.03 μg/g) and 0.090 μg/g (range: 0.01-2.57 μg/g) were reported in toenails from a basal cell carcinoma group and a squamous cell carcinoma group respectively (Karagas *et al*., 2001). In the present study arsenic (As) concentrations in fingernails ranged from 0.24 to 25.88 μg/g with a geometric mean of 2.62 μg/g. These are high values that could equally be of health concern.

CONCLUSION

All four elements (Hg, Au, As and Sb) detected in fingernails of the *galamsey* miners, in the Wassa-West District of Ghana, were on the average at concentrations that depict high exposure levels. Some individual concentrations were also critically high, raising health concerns.

This study provided the opportunity to directly measure trace-elements in specimens collected from the exposed persons and also use fingernails as biomonitors of exposure level; which was usually a difficult task due to the reluctance of participants in giving out samples.

It is recommended that routine health screening for populations and frequent monitoring programs be carried out in the mining areas by both the Ghana Health Service and the Environmental Protection Agency (EPA) to ensure best practises of safety and standard procedures.

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