UNIDO's Strategy for Reducing the Impact of Artisanal Gold Mining on the Health and the Environment
- Study case in Ghana –

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We all realize that Government, national and international institutions, industry and society in general become more and more conscious of the burden imposed on our planet by the unsustainable use of resources and release of toxic chemicals.

In most of small-scale mining activities, it is the lack of awareness and technical knowledge that results in uncontrolled land degradation, over consumption of water and release of toxic chemicals to the environment. This problem particularly affects developing countries in Africa, Asia and Latin America where artisanal mining represents the only alternative to the subsistence farming activities for rural population.

Additionally, recent cycles of floods and droughts as well as dramatic effects of structural adjustment in many developing countries have led more and more farmers to artisanal mining. For example, in the gold sector, the activity has increased steadily for the past 20 years. Now it almost accounts for one quarter of the world gold output. With the lack of other viable alternatives, the gold rush in the artisanal sector does continue. According to a conservative estimate, 1.5 million people are directly involved in small-scale gold mining, whereas several million people are economically dependent on these activities. The widespread application of the so-called amalgamation process has made mercury a global pollutant.

Therefore, since many years, continuous efforts have been made by UNIDO to provide assistance to the small-scale mining sector. In particular, the Organisation has focused its assistance on artisanal gold mining and reduction of mercury emissions emanating from this sector. The requests for assistance were forwarded to UNIDO especially by those governments which had become aware and concerned about the dangers involved in these activities.

Diagnostic missions of UNIDO revealed that the technologies currently in use have grave and far reaching effects on the environment. As the issue of impact on health and environment is multifaceted and complex, Governments requested support, especially in education, training and technology transfer for improving the situation.

1. The present situation of Artisanal Gold Mining

Small-scale gold mining activities are often unplanned and undertaken by workers who do not have the technical know-how. Therefore, pits, which can reach 30 metres depth, are not secured and landslides claim numerous lives. Abandoned pits are left unmarked representing a hazard for population and livestock. Abandoned sites are not rehabilitated leaving an unfertile and permanently ruined habitat.

For most miners, amalgamation represents the easiest and most effective method to recover the finest gold fraction. However, it is well known that the process is devastating to health, not only to users but also to those indirectly involved, including the unborn, through peripheral contamination and introduction into the food chain. Within the last years, life threatening mercury pollution has been identified in most developing countries where artisanal gold production is taking place. Moreover, panning and amalgamation are commonly done along rivers resulting in water pollution and destruction of riverbanks. The resulting siltation decreases quality of drinking water and affects all kind of aquatic life.

Burning the gold bearing amalgam releases some hundred tons of mercury vapors every year into the atmosphere. Since they quickly return to the river ecosystem with rain, they add up to the mercury spillage occurring during amalgamation.

2. UNIDO's intervention programme to assist the Artisanal Gold Mining Sector

More than 10 countries have requested UNIDO's assistance in different projects related to artisanal gold mining. In general these governments have inadequate resources, lacking capacities and insufficient institutional framework to control informal gold mining activities and the resulting mercury pollution. UNIDO's approach in addressing this problem is to replace low recovery, high mercury consuming and discharging processes with environmentally safe and high-yield gold extraction alternatives that will sharply reduce or eliminate the use and discharge of mercury. In this respect, UNIDO offers cross-disciplinary programmes, comprising measures for environmental protection, raising awareness and training, introduction of new technologies and equipment with training on their utilization and manufacture.

3. Implementation strategies

Health and environmental services in countries affected by small-scale gold mining lack the capacity to properly monitor mercury pollution and intoxication. Therefore, UNIDO assists national laboratories in upgrading their capacities. Whenever necessary, certified institutions assist local laboratories in collecting and analyzing environmental and health data. At the end of such projects, sustainable monitoring systems should have been established.

Since the major consequences of small-scale mining derive from a lack of awareness, campaigns are conducted to inform mining communities on the dangers of their activity. Training on safer alternative processing methods put the emphasis on health and economical benefits, which can be obtained by using cleaner technologies. This aspect becomes especially important in the absence of alternative livelihoods. Retorts, which allow the recycling of mercury thus drastically limiting its release to the environment, are introduced. Miners and local manufacturers are trained on how to produce and use improved gravimetric separation equipment, which allow a better recovery while reducing the amount of ore which has to be brought in contact with mercury. To encourage the development of entrepreneurship, training also deals with bookkeeping, mining regulations, gold marketing and the potential benefits of mining associations in a micro-financing scheme.

Women miners represent a high proportion of the mining community, often higher than 50%. However, due to traditional and social reasons, they are still marginalized. To address this issue, UNIDO is undertaking special efforts to ensure that women participate and benefit equally from the introduction of new equipment and processing techniques. Considering their important role as family caretaker, the success of any project depends on their integration during implementation.

Additionally, assistance is provided to Governments regarding an assessment or amendment of the present mining legislation and regulations governing small-scale mining operations.

Furthermore, assistance can be provided to address other barriers hindering the development of the small-scale gold mining sector, such as weak institutional set-ups, lack of access to technology and information and inefficient law enforcement programmes.

4. UNIDO specific intervention in Ghana

In 1999, France financed a UNIDO project in **Ghana** aimed at assessing health and environmental impacts of alluvial small-scale gold mining. For this project, international institutions collaborated with national experts of the Noguchi Memorial Institute for Medical Research to undertake a survey of the level of mercury intoxication in a selected mining community and the extent of pollution in the vicinity of mining sites. Moreover, awareness-raising campaigns were conducted. These campaigns, while placing the emphasis on mining techniques and sustainable use of natural resources are also a mean for conveying information on mining legislation and basic marketing practices. Additionally, maintenance-free retorts, for the recycling of mercury are introduced to miners living in the most affected areas. The site selected for the project was the village of Dumasi due to its long history of gold extraction.

Approximately 2000 people live in the Dumasi. Some of them are actual mine workers, farmers or shopkeepers but most of them are "Galamsey" i.e. illegal gold panners.

The ore is extracted from the neighboring BGL mine and brought back to the village where it is crushed either by hand or by mechanical mills. The resulting product is concentrated in sluice boxes on hemp tissues. Finally, the concentrate is refined by washing it in a pan, and then amalgamated with mercury. Mixing of mercury with the concentrate is done by hand. When the amalgam appears homogenous, it is squeezed, in order to eliminate excess mercury and residual water. Gold is recovered by burning the amalgam in open pans.

4.1. Health survey

The following activities were undertaken for the health survey:

- Assess, through a questionnaire, the general health condition of members of mining communities and on indications for symptoms of mercury poisoning.
- Evaluate/estimate the occupational health risk in people directly exposed to mercury through amalgamation activities.
- Evaluate/estimate the occupational health risk of people living in the vicinity of gold extraction plants and gold melting shops.
- Check general health condition of directly exposed people and non-directly exposed members of mining population.
- Take hair, urine, and blood samples according to state of the art in clinical studies.
- Assess the health condition of people affected by mercury poisoning, for example regarding buccal health, alterations in hand-writing, muscle pain, typical neurological and organic dysfunction.

A study group of 187 persons was chosen and the distribution is given in figure 1:

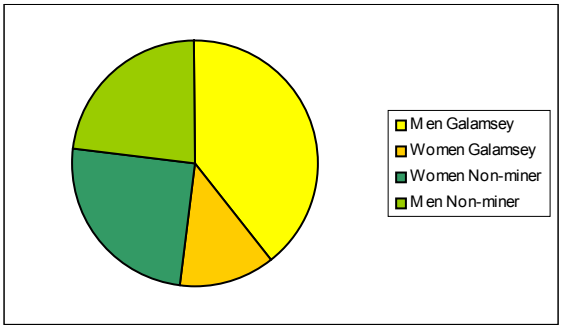

Figure 1: female/male and Galamsey/non-miner distribution of the study group in Dumasi

4 of the men and 2 of the women Galamseys claimed not having any contact with mercury. The population is relatively young, especially among the Galamseys. For most of Galamseys gold extraction is a recent activity (0 to 5 years). While 60% of the male were able to write, this percentage decreases greatly in women.

Mercury intoxication symptoms such as sleeping disorders and tremors were often reported. 13 people were identified with slight neurological problems, 5 of them being Galamseys.

Mercury contents in human samples are given in table 1.

Hg content in	Blood ($\mu g.l^{-1}$)	Urine ($\mu g.l^{-1}$)	Urinary Creatinin ($\mu g.g^{-1}$)	Hair ($\mu g.g^{-1}$)	Nails ($\mu g.g^{-1}$)
Mean	24.4	23.85	15.54	3.85	3.99
Maximum	96	252.9	193	44.6	55.7
Minimum	1	1.1	1	0.39	0.66
Stand.deviation	*16.9*	*40.3*	*25.4*	*4.67*	*5.44*
Number N	*180*	*102 **	*102 **	*148*	*161*
Reference for non-exposed population	*<10*		*<5*	*<2*	*<2*
Biological limits	*15 (BEI)*	*100 (BAT)*	*35 (BEI)*	*10 (WHO)*	*10 (WHO)*

BEI: Biological Exposure Index
BAT: Biologischer Arbeitsstoff-Toleranz-Wert (Deutsche Forschungsgemeinschaft)

****Excessively diluted urinary samples (creatinin < 0,50 g.l^{-1}) as well as very concentrated ones (creatinin > 3 g.l^{-1}) cannot be used for biological monitoring. In such a case, new samples should normally be taken. The difficulties encountered in taking sufficient quantities of urine, often because of the strong perspiration of the villagers, led us to first check the creatinin contents of the collected samples: of 118 samples of urine, 16 were eliminated because of creatinin values above the limit of 3 g.l^{-1}. For the 102 samples selected, the results are expressed in µg Hg.l^{-1} of urine and µg Hg .g^{-1} of creatinin in the urine.***

Table 1: Summary of mercury exposure in the investigated population

For each of the three biological samples (blood, urine and hair/nails), 3 classes were defined:

- Class 1: Under reference value for general non-exposed population.
- Class 2: Above level indicating obvious contamination.
- Class 3: Between the two above mentioned limits.

The figure 2 represents the distribution of persons in the 3 classes for blood samples. Results for urine, hair and nails have been summarized in a single representation in figure 3.

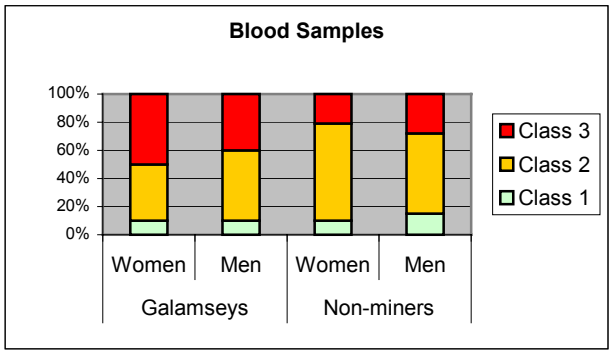

Figure 2: distribution of different group of the study group among the 3 contamination classes for blood

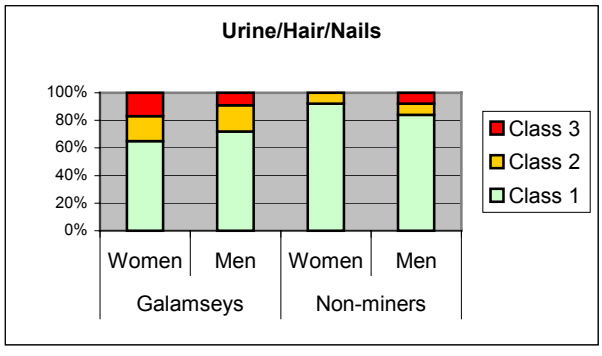

Figure 3: distribution of different group of the study group among the 3 contamination, classes for urine, hair and nails

While Galamseys are more exposed than non-miners, people in Dumasi generally present high mercury blood levels, regardless of their activity. 12 of the male Galamseys present class 3

levels for more than one indicator. They are younger than average and also more illiterate. Among the 13 persons identified with slight neurological problems, 6 are in class 3 for at least one indicator.

As a conclusion, there is strong evidence of mercury exposure among Dumasi population even if mercury concentrations in biological samples do not reach levels where symptoms usually appear. This could explain why few neurological disorders are reported. However, chronic intoxication cannot be ruled out, even in the non-miner population, which is exposed through the environment.

4.2. Environmental Survey

The following activities were undertaken for the environmental survey:

- Investigate the situation of the environment surrounding the small-scale mining site by taking samples of waters, sediments, soils, fish, poultry and vegetables where pollution can be assumed.
- Evaluate the nature and extent of the mercury pollution in a selected river system and adjacent agricultural sites.
- Introduce and set-up a monitoring system for continuous water quality assessment.
- Formulate measures for the remediation and possible rehabilitation of hot spots in the river systems and vicinities.

The first and obvious environmental issue in the area of concern relates to important modifications of the topography. Although most of it results from the industrial mine operations, artisanal miners have an obvious impact at a local scale. Even though not quantified, the installation of sumps along local rivers strongly disturbs the discharge regime and increases turbidity of downstream rivers. Erosion, emanating from digging and tailing piles is also easily identified with orange-colored water and can result in acid rock drainage through rainwater leachates of excavated sulfides compounds. Consequently, various metals from ore minerals are dissolved in acidic water, and may be released into the adjacent rivers.

Annual mercury consumption in Dumasi, considering an average daily gold production of 0.5 to 1.0 gram *per capita* can be estimated at 450 kg.

According to the industrial mine water quality monitoring, the only matter of concerns is the turbidity of water. Locally, pH is suspected to be low as arsenic and copper are dissolved into water.

Conversely to those optimistic results, Dumasi population expresses concerns regarding water quality:

- Groundwater pollution: metallic taste, brownish coloration of white clothes when washing, black-blue coloration of some vegetables (e.g. plantain) when in contact with the water. Several boreholes within the village show these specific characteristics.
- Changes in surface water quality.
- Health problems, linked, at least in part, to water quality.
- Soil degradation, crop failure.

Following this preliminary study, sediment, soil, ground and surface water, fish, chicken and vegetable samples were collected and analyzed for total mercury content. Principal results for inorganic samples are given in table 2 below.

Hg content in	Borehole water ($\mu g.l^{-1}$)	Surface water ($\mu g.l^{-1}$)	Well water ($\mu g.l^{-1}$)	Sediments ($\mu g.g^{-1}$)
Mean	0.165	0.28	0.34	13.47
Maximum	0.27	0.76	0.5	93.1
Minimum	0.12	0.14	0.18	0.64
Stand.deviation	*0.05*	*0.27*	*0.23*	*28.1*
Number N	*8*	*5*	*2*	*10*
*Threshold level 1**	*0.07*	*0.07*	*0.07*	*0.13*
*Threshold level 2***	*0.7*	*0.7*	*0.7*	*0.7*

** For water: no effect threshold (France) - For sediments: Threshold Effect Level (France)*
*** For water: lowest "no observed effect conc." (France)–For sediments Probable Effect Limit (France)*

Table 2: Summary of mercury levels in water and sediment samples

While none of the water samples exceeds France recommended values, all sediment samples exceed the consensus threshold concentration and most of them exceed the probable effect concentration. These results could be attributed to the mercury discharged during the amalgamation process but also, to a lesser extent, to the condensation of mercury released to the atmosphere during open burning of the amalgam.

A lot of fish samples exceed the widely used health standard with 60% being higher than the US-FDA action level of 1 ($\mu g.g^{-1}$).

When comparing results from Dumasi with studies in polluted areas around the world, similarities appear, especially with the Aby Lagoon in Côte d'Ivoire. Dumasi is on the catchment area of the Tanoe River, which, in turns, drains into this lagoon. The parallel gives an idea of the magnitude of mercury pollution in the whole auriferous basin. Mercury-containing sediments, through successive suspension – settling events, travels down rivers. Population eating fish and shellfish at distant location from the pollution origin might be exposed to mercury contamination. Samples taken at different points downstream from Dumasi confirm the fact that contaminated sediments are transported away form the pollution location.

Hg content in	Fish ($\mu g.g^{-1}$) ww*	Plantain ($\mu g.g^{-1}$) ww*	Cassava / Sugar cane ($\mu g.g^{-1}$) ww*	Chicken ($\mu g.g^{-1}$) ww*
Mean	0.93	0.05	0.011	0.045
Maximum	1.59	0.052	0.018	0.057
Minimum	0.13	0.047	0.002	0.031
Stand.deviation	*0.41*	*0.003*	*0.008*	*0.012*
Number N	*17*	*2*	*3*	*4*
WHO limit for dangerous level	*0.5*	-	-	-

** dw: dry weight*

Table 3: Summary of mercury levels in food samples

Results for food samples are presented in table 3 above. Due to contacts with contaminated water and sediments, fishes are the main source of mercury intake and because of the bioaccumulation characteristic of the toxic metal, carnivorous species are more affected.

Unfortunately, no published standard exists for food products other than fish. The amount absorbed will be calculated from respective proportion of each food item in the diet of Dumasi population. It will then be compared to acceptable daily intake values.

However, results in table 3 show that vegetables in general and chicken do not contain high levels of mercury. The sole sample of Cocoyam analyzed was found to contain 0.38 $\mu g.g^{-1}$ (ww). This is 7 times the highest concentration in other vegetables and the tuber nature of the plant is supposed to be the reason for this high mercury intake.

According to calculation, the daily maximum amount of mercury intake without risks is reached for 45g of fish, or 45g of cocoyam, or 240g of chicken, or 300g of plantain. These figures clearly show that Dumasi population is at risk of mercury contamination.

With regard to the dependence of the Dumasi population on water, the monitoring system to be put in place should concentrate on the aquatic media. National experts accompanied the international experts at any stage of the surveys and they received training on sampling methods. Since sediment samples analyses are easier to carry out than fish's, the continuous monitoring will concentrate on sediment completed by a limited number of fish analyses. The regular survey of mercury contamination will allow the demonstration of the effectiveness of the activities undertaken during the project such as the training of miners and usage of retorts.

The project was successful in its achievement and France has agreed on financing a second phase targeting hard rock gold mining. This second phase is currently under implementation.

5. The way forward

UNIDO, with the assistance of the GEF has developed and is now implementing a global project where similar activities will be undertaken. The project will focus on selected sites where transboundary pollution is at stake, namely:

- Amazon River basin in Brazil.
- Java Sea in Indonesia.
- Mekong River in Lao PDR.
- Lake Victoria in Tanzania.
- Nile River in Sudan.
- Zambezi River in Zimbabwe.

The project will provide a wide database on mercury pollution and small-scale mining issues, which will be useful for other governments when discussing and assessing the situation in their own countries. Replicablity of the implementation strategies will promote the development of new projects.

Conclusion

The implementation of project related to reducing mercury emissions has resulted in an increased awareness about this problem in developing countries. This is reflected by the increasing number of requests for technical assistance and an obvious interest of some governments and donor agencies in supporting these activities. Moreover, results published in numerous international events help to increase the knowledge of the scientific community on the issue. Coordination is of utmost importance as it will promote sharing information on success and failure, identify areas where joint efforts may create synergistic benefits.

References:

[1] Babut M, Sekyi R, Rambaud A, Potin-Gautier M, Tellier S, Bannerman W, Beinhoff C. Improving the environmental management of small-scale gold mining in Ghana: a case study of Dumasi. Journal of Cleaner Production 19-04-2002. JCLP766.

[2] Babut M, Sekyi R, Rambaud A, Potin-Gautier M, Tellier S, Bannerman W, Beinhoff C. Assessment of environmental impacts due to mercury used in artisanal gold mining in Ghana. Paper presented at the 6th ICMGP, Minamata, Japan, 15-19 October 2001. BC83.

[3] Rambaud A, Casellas C, Sackey S, Ankrah N, Potin-Gautier M, Bannerman W, Claon S, Beinhoff C. Mercury exposure in artisanal mining community in Ghana. Paper presented at the 6th ICMGP, Minamata, Japan, 15-19 October 2001. HE10.