KNOWLEDGE-SHARING IN ARTISANAL MINING COMMUNITIES: MERCURY, TECHNOLOGY AND SUSTAINABILITY IN DEVELOPING COUNTRIES

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ABSTRACT

As gold has risen in value and artisanal gold mining has increased in many low income countries, there has been an increasing need for sustainable development models that promote environmental protection while enhancing the contribution of this activity to poverty alleviation.

Artisanal mining provides a critical source of income for an estimated 15 million poverty-driven miners around the world, mainly in Africa, Asia and Latin America. However, its environmental impacts are often extensive, with mercury pollution posing major threats to human health and diverse ecosystems. 1000 tonnes of mercury are polluted annually into the environment due to mercury misuse in artisanal gold mining. This paper reviews community development models pioneered by local community practitioners and international experts as part of an initiative by the United Nations Industrial Development Organization, which can help to overcome environmental, social and economic challenges. We discuss the introduction of various technical options, from simple innovations that allow mercury containment, recycling and re-use, and also emphasize the importance of technologies of grinding and crushing that can be developed from local materials to further enhance income potential.

While various past development efforts have sought to reduce mercury-related problems, we conclude that sustainable development should seek to intertwine knowledge-sharing on environmental goals with concrete ways of improving economic well-being. We demonstrate how such models of knowledge-sharing can help to catalyze local innovation, technology-sharing and community organization. We also discuss how this knowledge can be applied by governments to create capacity-building policies as well as regulations that support sustained improvement in mining standards.

INTRODUCTION

As gold has risen in value (US$ 260/oz in Mar 2001, US$ 725/oz in May 12, 2006) and artisanal gold mining has increased in many countries, there has been a heightened need for sustainable development models that promote environmental protection while enhancing the contribution of this activity to poverty alleviation.

In over 55 countries, artisanal mining provides a critical source of income for rural populations, especially those that have been driven out of other sectors due to failed commodity markets or agriculture conditions. In 1999, the International Labor Organization estimated that there were 15 million small-scale miners around the world (ILO, 1999), with an estimated increase to follow as a result of limited occupational opportunities in poor economies. Such mining usually involves rudimentary, inefficient and environmentally unsound forms of extraction and processing, causing extensive mercury pollution.

Global recognition of this sector has increased in recent years. Development institutions such as the World Bank have recently emphasized the significance of the sector as a contributor to poverty alleviation, resulting in the creation of the Communities and Small-Scale Mining (CASM), for example. Governments have begun to change legislation to provide formal recognition to this sector, with recent legal developments in Ghana and Tanzania within the past ten years that recognize “artisanal” mining as a distinct activity—and one that has the potential to contribute to poverty alleviation. Along with these developments in the sector, there is an ever more present need for finding new ways of improving the sustainability of the activity and decrease environmental impacts. In particular, developing efforts to reduce mercury pollution is critical. Globally, poor amalgam-mation practices cause as much as 1000 tonnes of mercury to be emitted into the environment per year, contaminating the air, soil, rivers and lakes (Veiga and Baker, 2004).

In this paper, we review efforts to bring technological improvement and environmental protection together in artisanal mining communities. We focus on community development models pioneered by the Global Mercury Project, which was launched in 2002 by the United Nations Industrial Development Organization (UNIDO) to promote the adoption of technologies to reduce mercury use and emissions while strengthening capacities for maximizing gold recovery.

The project focuses on six countries — Brazil, Sudan, Indonesia, Laos, Tanzania and Zimbabwe. We first review the results of the environmental and health assessments conducted by the project in selected areas, which found that vapor intoxication is the main pathway of mercury exposure in mining communities, and we draw attention to risk communication and mitigation strategies. Secondly, we demonstrate how a training model for disseminating technological solutions, developed by local community practitioners and international experts, can help to overcome environmental, social and economic challenges.

We discuss the introduction of various options, from simple innovations that allow mercury containment, recycling and re-use, and emphasize the importance of technologies of grinding and crushing that can be developed from local materials to further enhance income potential.

While various past development efforts have sought to reduce mercury-related problems, we conclude that sustainable development should seek to intertwine knowledge-sharing on environmental goals with concrete ways of improving economic well-being. Such models of knowledge-sharing can help to catalyze local innovation, technology-sharing and community organization.

This knowledge can be applied by governments to create capacity-building policies as well as regulations that support sustained improvement in mining standards. To meet these goals around the world, we conclude that an increase in international support is vital, particularly to promote inter-national and inter-regional knowledge-sharing and capacity-building assistance.

GOLD MINING AND MERCURY: GLOBAL CHALLENGES

Artisanal and small-scale mining (ASM) is generally a practice which uses rudimentary techniques of mineral extraction and operates under hazardous conditions. Driven significantly by poverty, ASM is usually undertaken by workers with limited technical knowledge of the long-term impacts of their mining activities on the environment and on their health and/or with limited capacity to mitigate the hazards (Veiga, 1997).

Ecological impacts caused by ASM activities include diversion of rivers, water siltation, landscape degradation, deforestation, destruction of aquatic life habitat, and mercury pollution (Mol and Ouboter, 2004). Direct impacts of ASM on human health can include acute mercury poisoning, silicosis, neurological and kidney damage, cardiovascular and respiratory dysfunctions, as well as injury and fatality from landslides, cave-ins, and chronic physical overexertion (Hinton et al., 2003a).

Often working in tunnels with explosives and being exposed to mercury, cyanide and other toxins, ASM provides a primary source of earnings for a rapidly growing number of people around the world, particularly in regions in Africa, Asia and Latin America where alternative sources of income are limited. According to the International Labour Organization, the number of small-scale miners worldwide increased by up to 20% between

1989 and 1999 (ILO, 1999). Estimates made more recently, in 2004 by the United Nations Industrial Development Organization (UNIDO), indicate that there are as many as 20-30 million small-scale miners in more than 55 countries, roughly equivalent to the global workforce of large-scale mining. It is estimated that 80 to 100 million people worldwide are directly and indirectly dependent on ASM for their livelihood (Veiga and Baker, 2004). As this population continues to increase, there is an urgent need to develop the capacity of small-scale miners to minimize the risks associated with mining practices in their communities and shift toward safer, cleaner and more sustainable methods.

The Global Mercury Project (GMP) was launched in 2002, by UNIDO with support from UNDP and GEF, aimed at removing barriers to the adoption of cleaner practices of small-scale gold mining. The project sought to provide a platform upon which knowledge could be generated to meet diverse community challenges. In particular, it was envisaged that the GMP would spearhead the search for opportunities to reduce negative health and ecological impacts caused by mining through a series of multi-stakeholder consultation processes and capacity-building campaigns in affected communities. Partnering with government ministries, local authorities, health organizations and miner associations, the project undertook assessments of health, ecological, social, economic, and technological factors in participating communities. This knowledge, it was hoped, could be effectively utilized to design and implement intervention strategies that target the causes of poor practice, ill health and pollution.

ADDRESSING ENVIRONMENTAL AND HEALTH IMPACTS

Due to the informality and unregulated nature of many ASM operations throughout the world, the full extent of this activity and its ecological and health impacts is difficult to determine. Gold is easily sold and traded in markets that are not dependent on the stability of local governments; consequently, is by far the most important mineral extracted by ASM in developing countries. The number of ASM *gold* miners alone is estimated at 10-15 million people, including 4.5 million women and 300,000 children (Veiga and Baker, 2004). Because mercury amalgamation is simple and inexpensive, it is the gold concentration method most used in ASM.

Mercury misuse in ASM has produced thousands of polluted sites with impacts extending far beyond localized ecological degradation, often presenting a serious, long-term health risk to individuals residing in mining regions. Amalgamation employs metallic mercury to trap fine gold, with mercury often being discharged with contaminated tailings and/or volatilized into the atmosphere. The usual practice is to burn the amalgam in a pan or shovel in open air bonfires, with the inhalation of mercury vapor posing a serious health risk.

Due to inefficient techniques, an estimated two grams of mercury are released into the environment for each gram of gold recovered (Veiga and Baker, 2005). Metallic mercury is also transformed into methylmercury in aquatic systems, which becomes biomagnified in the food chain.

Communities reliant on fish, especially carnivorous fish, as a primary food source are particularly susceptible to accumulation of high levels of methylmercury and to neurological damage in cases of acute intoxication (Webb et al., 2004; Ikinguara and Akagi, 1996; Mergler 2002). Methylmercury can also cause sterility and is easily transferred from pregnant women to their fetuses, with effects ranging from spontaneous abortion to neurological symptoms in the child (WHO, 1990).

In 1990, UNIDO began coordinating international efforts to provide technical assistance to small-scale miners, promoting the replacement of low gold recovery, high mercury consuming and discharging practices with more environmentally sound and high-yield gold extraction alternatives. Following a gold rush in developing countries in the 1980s and early 90s, it was acknowledged that both regulatory (top-down) and community capacity-building (bottom-up) strategies needed to be pursued. Working with governments and community stakeholders from Venezuela, Ghana and the Philippines, UNIDO carried out programs to develop local capacity to assess and minimize mercury emissions caused by mining and provide high-level technical advice to government officials to design regulations and institutional reforms.

In 2001, with financial assistance from the Global Environment Facility (GEF), UNIDO identified hot spots with the potential for affecting international waters due to especially high levels of mercury pollution in streams and rivers. These efforts culminated in the solidification in August 2002 of a longer-term initiative, the GMP, supported by GEF, the United Nations Development Program (UNDP), and UNIDO, to demonstrate ways of overcoming barriers to the adoption of strategies that limit mercury emissions in ASM.

LESSONS FROM SIX PILOT COUNTRIES

The GMP currently focuses its efforts in six main pilot countries, each representing diverse ecosystems: Brazil (Amazon), Lao PDR (Mekong), Indonesia (marine environment), Sudan (Nile), Tanzania (Lake Tanganyika) and Zimbabwe (Zambezi).

The project is complemented by a suite of ongoing activities that are supported through participating countries' resources and/or bilateral programs. As a capacity-building initiative that combines expertise in mining engineering, health promotion, economic development, and environmental planning areas, the GMP seeks to provide a strong link between researchers and practitioners to implement solutions.

The specific goals are:
1) to reduce mercury pollution of international waters by emissions emanating from small-scale gold mining;
2) to introduce safer and cleaner technologies for gold extraction and to train people in their application;
3) to develop capacity as well as the policy, regulatory and economic mechanisms that will enable the sector to minimize mercury pollution;
4) to introduce environmental and health monitoring programs; and
5) to build capacity of local laboratories to assess the extent and impact of mercury pollution.

The countries participating in the GMP were selected based on the importance of ASM to their populations, preliminary assessments of mercury use, and support of the national and regional governments for capacity-building activities. Also a major factor was the potential of international waters to be impacted by mercury from mining.

Most ASM activities within the six GMP countries are conducted within basins of major ecological significance and that cross geographical boundaries, e.g., basins of the Amazon, Nile, Lake Tanganyika, Zambezi River, and Mekong River. As such, the negative environmental impacts within these basins can affect many countries including those with ASM activities as well as neighbouring countries.

Project assessments found that gold mining activities in Brazil dump nearly 40 tons of mercury annually, with significant pollution risks to Amazon Basin, the largest drainage system in the world which also constitutes the largest reserve of biological resources. Nearly 150 tons of mercury is dumped annually into the environment in Indonesia, affecting the Java Sea and nearby waters (Veiga and Baker, 2004). Little investigation had been previously undertaken to address the mobility of mercury emanating from small-scale mining through international waters, and the GMP represents the first effort to implement a global action plan.

Following its launch, the GMP conducted exhaustive consultations with stakeholders to formulate an appropriate community assessment and capacity-building agenda—with numerous Task Force Meetings held in each of the countries. These reinforced the widely held view that implementation of technical solutions required detailed knowledge of the cultural, social, economic and organizational context on a site-specific basis in addition to a thorough understanding of mercury exposure pathways and mobility through the diverse ecosystems. Numerous studies have noted that a major barrier to the adoption of cleaner mining practices is that the impacts of mercury misuse are complex and difficult to see immediately, thus masking the dangers (Hilson, 2002a; Hinton et al., 2003b). Another significant barrier is that many small-scale miners are unaware of cost-effective ways to eliminate the hazards. Recognizing these barriers as nuanced and widespread, the participants generally agreed that, to develop effective site-specific training programs, a variety of expertise was needed to create synergy in the process. As well, sociological surveys enabled communities to describe their customs, share their knowledge on social, environmental and health aspects in the area, and give feedback on the project before further assessments and training programs were undertaken.

Information on the effects of mercury on human health exists but is inadequately disseminated in developing countries (Hilson, 2002b). A key early accomplishment of the GMP was the training of a cadre of regionally-based public health personnel in the assessment of clinical signs and symptoms of mercury poisoning and methods of improving environmental health in mining areas.

In each country, these partnerships were strengthened while integrated health and environmental assessments were conducted in the project sites, using GMP protocols that provided a framework for combining biogeochemical, socio-demographic, and technical analyses (Veiga and Baker, 2004). Results showed that symptoms of mercury intoxication are especially widespread in miners in Zimbabwe, Indonesia, Brazil and Tanzania, with alarmingly high levels of intoxication found in miners in all six countries who spent significant amounts of time burning mercury amalgams. Neurological disturbances such as ataxia, tremors and coordination problems were found to be common among this group. In Kadoma, the main project site in Zimbabwe, 70% of miners (69% of child miners) were intoxicated, many of whom showed tremors, a typical sign of mercury-induced central nervous system damage. With extremely high mercury concentrations in breast-milk samples from nursing mothers in GMP communities, infants are especially at risk.

In addition to problems from mercury vapour, the assessments found that mercury methylation is a severe ecosystem hazard in project sites in Brazil, Indonesia and Zimbabwe, with particularly harmful impacts on the fish-eating communities where mercury accumulates in aquatic biota.

Technical and socio-economic studies in all participating communities assessed current equipment and practices, needs of the miners, and accessibility of new equipment. In all GMP communities except those in Brazil, women and children engage in open-air mercury amalgamation at home, with entire families exposed to mercury vapour.

Combined use of mercury and cyanide in mineral concentration was also identified as particularly dangerous and widespread, and practices that involve the amalgamation of whole ore (all the ore mined) also caused excessive amounts of mercury to be used and leaked into the surrounding soils and streams.

SHARING KNOWLEDGE FOR DEVELOPMENT

1. Meeting Community Concerns

Between March of 2005 and 2006, a series of international workshops was held in all six countries to determine how to transfer knowledge effectively from the assessments into the community intervention phase of the project. This phase focuses on capacity building - training and demonstrating solutions to miners, families, and authorities - with emphasis on affordable and easily accessible ‘homemade’ equipment, such as amalgamation retorts (made of kitchen-bowls) which contain mercury vapour and decrease mercury use in the amalgamation process (Babut et al., 2003). During this phase, GMP efforts aim to reduce mercury use and promote safer, healthier and more cost-effective mining practices; strengthen community organization; improve access to equipment through micro-finance programs; enhance participation of miners in environmental planning processes; and assist authorities in the implementation of needed regulations and reforms.

Due to the importance of amalgamation to the ASM process and their immediate livelihood, convincing miners to eliminate mercury use because of health hazards is difficult. As one miner mentioned at a meeting in Brazil, "*Mercury is a problem, but we also depend on it.*" Moreover, particularly in the case of Africa, lack of sanitation, widespread infectious diseases and limited access to health care have resulted in generally poor health conditions in ASM communities, such that any program directed exclusively at reducing the comparatively invisible health impacts from mercury is hard-pressed to garner local interest. As such, the capacity building approach adopted by the GMP does not focus on mercury issues alone, but rather on the myriad of intertwined health, environmental and socio-economic challenges in these mining communities.

It is worth noting that previous projects on mercury management in developing countries have tended to adopt frameworks based on hazard awareness, technical training *or* regulatory changes, with short-term agendas and limited resources for integrating multiple disciplines and strategies (Hilson, 2002a).

Moreover, authorities have tended not to combine health and environmental planning processes in mine sites and are often unfamiliar with ways to support educational programs on the ground (Hinton et al., 2003a,b).

Seeking to better connect miners, field practitioners, experts and authorities, the GMP model involves team members with diverse expertise in community development disciplines to bridge diagnostic, risk communication and knowledge translation models.

The collaboration to build sustainable solutions through a transdisciplinary approach proved critical in developing the GMP community training curriculum (Table 1), which recognizes that each community faces different challenges and that the need to alleviate poverty and address malaria and HIV AIDS is primary in many GMP communities where mercury pollution is also a problem. The project's multi-faceted training curriculum is designed to remove barriers to the adoption of cleaner practices by:

- improving miners' income through more efficient gold recoveries
- enhancing access to equipment and ability to fabricate local equipment
- strengthening business keeping skills
- enhancing access to microcredit
- strengthening technology-sharing and community organization (e.g. cooperatives)
- demonstrating the benefits of containing mercury emissions (economic and environmental health)
- demonstrating ways of reducing mercury hazards as well as other occupational health and environmental problems
- implementing disease mitigation and health care measures (vaccinations, HIV prevention controls, prenatal and postnatal care, etc)
- improving sanitation and management of waters

Table 1: GMP Education and Training Program in Small-Scale Mining Communities: Modules for the Train-the-Trainer Process

TRAINING MODULES	KNOWLEDGE FROM COMMUNITY PRACTICE	KNOWLEDGE FROM ACADEMIC DISCIPLINE
Module 1: How to Produce More Gold	Underground mining methods: winches, windlasses, Wheelbarrows dewatering	Mining Engineering
	Mine safety: ground stability; ventilation; timbering; personal protective equipment	Mining Engineering and Occupational Health and Safety
	Alluvial mining methods: control of siltation; gravity concentration	Mining and Mineral Processing Engineering; Watershed Management
	Mineral processing methods: liberation and concentration of gold: crushing and grinding; gravity concentration; safe extraction with mercury	Mineral Processing Engineering
Module 2: How Mercury Makes Us Sick	Pathways of exposure: metal and methylmercury; vapor, skin, ingestion.	Environmental Toxicology
	How to recognize symptoms	Healthcare
	Effects on children and women (esp. pregnant women)	Epidemiology; Gender Studies
Module 3: How to Use and Re-use Mercury Safely	Safe extraction of gold from concentrate: amalgamate concentrate--not whole ore.; use amalgamation barrels; properly dispose of amalgamation tailings;	Mineral Processing Engineering; Occupational hygiene
	Burning amalgam in retorts to contain vapor (outdoors and away from houses)	Mineral Processing; Occupational hygiene
Module 4: How to Make More Money	Participating in the formal economy: how to become a legal miner; how to secure mineral rights	Law, Economics and Sociology
	Managing money: double entry bookkeeping	Business and Accounting
	Selling gold for a better price: government and cooperative gold buying/marketing schemes	Economic Policy
	How to access more efficient equipment: micro credit and renting	Economics and Business
	Alternate forms of organization: how to form co-operatives and partnerships	Business and accounting; Political Science
Module 5: How to Protect Water Supplies and Improve Sanitation	How mercury behaves in water: siltation and mercury transport; bioavailability of metal mercury; methylmercury	Hydrology and Toxicology and Chemistry
	How to manage animal and human waste: bacteria and parasites; how to build toilets	Water and Sanitation Engineering;
	How to access clean drinking water: hydrological cycle; the water table; rainwater management	Hydrogeology; Integrated Watershed Management
	How to manage mining waste: tailings impoundment; reclamation	Environmental Policy; Civil Engineering; Agricultural Science
Module 6: How to Prevent HIV, Malaria and other Diseases	Prevention of HIV transmission: condom use; empowerment of women; safe use of scarification implements	Healthcare; Epidemiology; Gender Studies; Anthropology
	Malaria: use of netting and other preventative measures; how and where to obtain treatment	Healthcare; Epidemiology
	Mercury poisoning, tuberculosis and other diseases	Healthcare; Toxicology

Training also encourages strengthening community organization to legalize miners who do not currently possess land rights and to adopt changes collectively.

Finding innovative ways to promote participation is fundamental to enable affected populations to initiate solutions in a way that can be sustainable and maximize limited resources.

The first phase of the GMP emphasized participatory processes in developing capacity-building models that are country-specific and community-specific, wherein community members identified what equipment is needed most and what techniques should be demonstrated. The second phase of the project seeks to involve as many community members as possible in the training workshops and to encourage participation of new players.

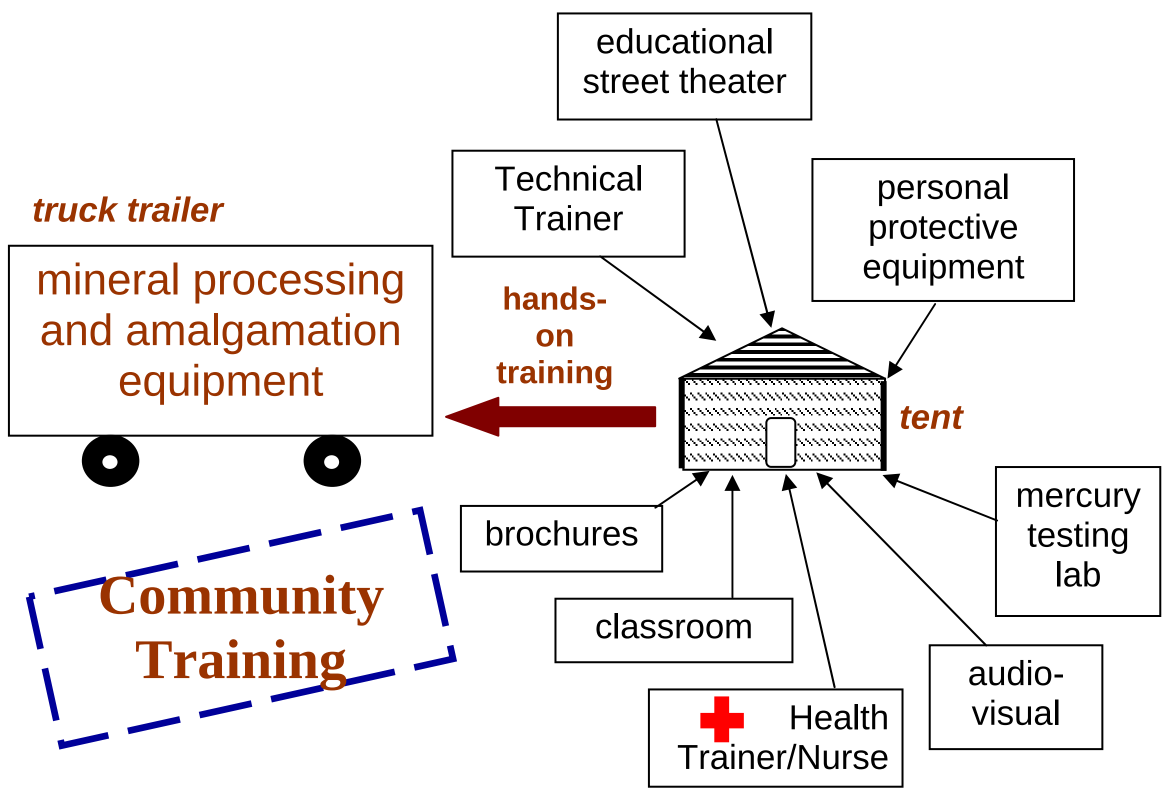
To reach broad audiences, communication methods were locally determined to build upon the cultural roots and institutional strengths of the communities, such as using soccer events, music, street theatre and circuses to attract people to training workshops; education events at schools and through religious organization; and radio and television campaigns to promote awareness of mining issues as well as GMP activities.

Enhancing participation is especially vital throughout the implementation of the Transportable Demonstration Units (TDUs), which provide platforms for community training on improved technological options for mining and mineral processing as well as environmental health and safety.

Parallel to the activities of the TDU education center, media campaigns are designed to draw people to these events and address the critical misperception that mercury is not dangerous because, like HIV-Aids, its toxic effects are not immediate.

GMP participants noted that the success of many previous training initiatives was limited because they relied upon permanent, immobile structures for technological demonstrations which were not adaptable to new locations and thus restricted participation. Heeding these lessons and the fact that artisanal miners are typically mobile and transient, the GMP mobile units were designed to travel to different highly-populated zones to maximize community participation and bring solutions to miners where they work.

Figure 2: Design of Transportable Demonstration Units (TDUs)



The consultation processes revealed that gender-specific approaches are indispensable.

The recognition of the important role of women in ASM has taken on considerable importance as more than 30% of the world's artisanal miners are women, the majority of whom work in the mineral processing aspect - including amalgamation with mercury (Hinton, 2003).

As women are also predominantly responsible for food preparation, they are in an excellent position to address health risks associated with consumption of mercury-contaminated foods.

Because women are often associated with transporting and processing materials as opposed to digging, they are not always identified as “miners” (Sasapu and Crispin, 2001; Hinton et al. 2003a), and thus there is an especially important need to promote the inclusion of women in community planning processes at miner association workshops and other venues. GMP efforts focus on training women specifically, reducing exposure risks to women (especially pregnant women) and their families, and promoting gender equity in community planning.

2. Sharing Knowledge for Technology Transfer

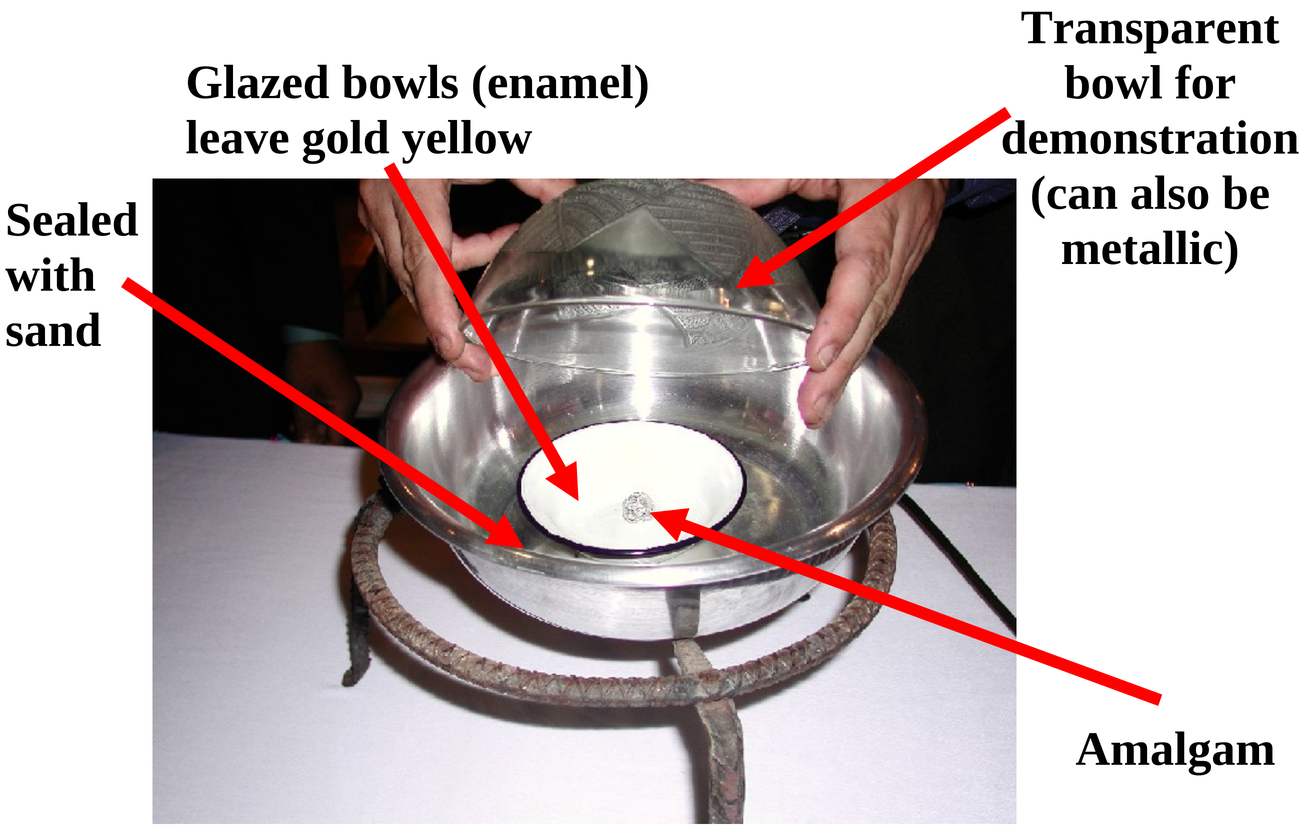
Although the international price of mercury tripled between 2004 and 2005, mercury remains widely used by small-scale miners. Observations and discussions with miners reinforced the need for focussing attention during training activities on simple ways of reducing mercury emissions. In a pilot project conducted in 2005 in Manica District, Mozambique, the GMP trainers performed with retorts showed that mercury emissions can be contained in such a way that allows 95% of the mercury to be reused. Miners expressed that the relatively inexpensive nature of this technology made it feasible. We discuss this demonstration experience below.

Various types of retorts can be used to reduce mercury emissions. Retorts allow for the heating of the amalgam in a chamber, releasing mercury that condenses as it passes through the cooling pipe thereby allowing it to be collected and reused later.

In the first demonstration, a kitchen-bowl retort was used (consisting of two salad bowls - one bottom and one top as the cooling chamber) and a small stainless steel cup (amalgam chamber) where the amalgam is introduced. (If ordinary steel is in contact with retorting amalgam, rather than stainless steel, the gold becomes brown, reducing its market value). A glass bowl was used as a cover, so that the miners could directly see the result of the amalgam transformation by visual observation of the color change (Figure 3).

Miners indicated, however, that the time taken to burn the amalgam and cool down the retort was longer than expected (20 minutes for 2 grams of amalgam) basically because it is difficult to cool down the glass cover. A substitute kerosene burner (stove) was purchased to speed up the retort-burning time and steel bowls used as the cover for rapid cooling with water. The entire retorting and cooling process for 6g of amalgam took 10 minutes. The retorts are sealed with wet sand around the cover. The amalgam is heated in a bonfire and mercury is evaporated to be condensed on the surface of the cover; then mercury droplets fall on the sand.

Figure 3: Retort for Containing Mercury Releases

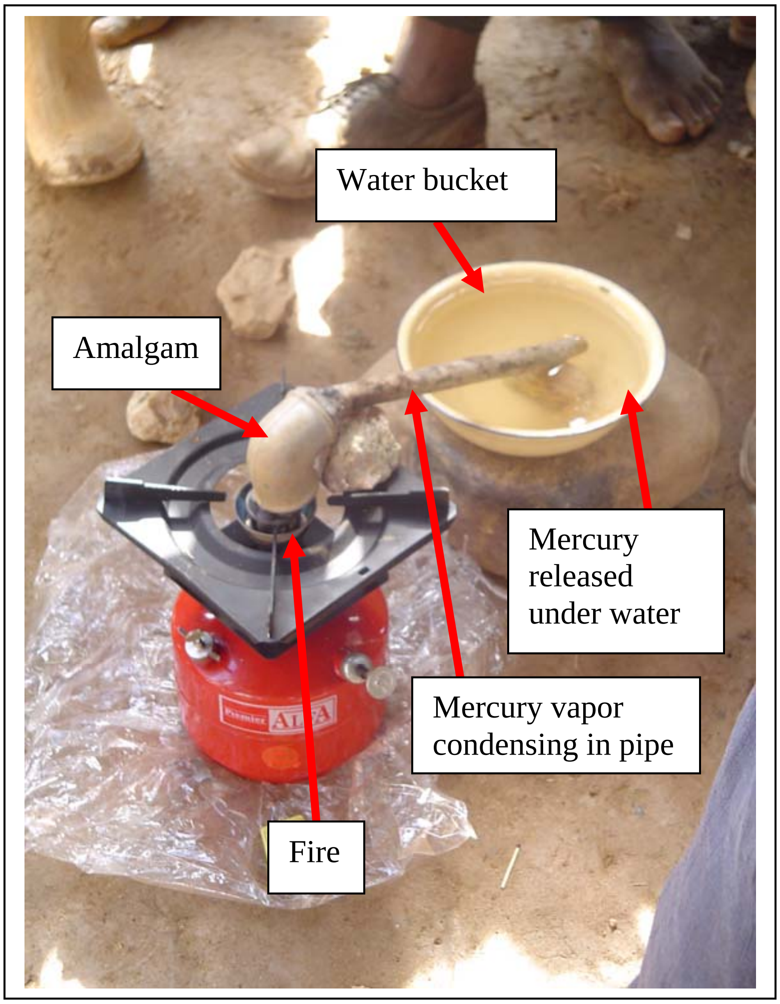


A home-made retort built with standard plumbing water pipes was also demonstrated (Figure 4). The distillation chamber was made by connecting an end plug into which the amalgam is placed (amalgam chamber) to a 1/2" plumbing pipe. The size of the retort was 1.5" (and can vary from 1/2 to 3"). The condensation tube was 50cm long and curved downwards through an elbow bend to permit good condensation of gaseous mercury without the use of a coolant, with the tip of the tube extended into the water in the plastic bowl.

The galvanized steel pipes and connections were previously burned over the kerosene stove to remove the inherent zinc layer on the steel.

After demonstrating the use of retorts, the mercury condensed in the sand was panned and recovered using a simple method in which droplets of mercury are transferred to a plastic recipient with a saline solution. The process involves connecting mercury droplets to a positive pole of a flash-light battery, the negative pole remaining in the saline solution, such that the superficial oxidation layer of the droplets is removed and the mercury then agglomerated.

Figure 4: Home-made Pipe Retort



This experience established that retorts could be made easily and inexpensively and that all materials needed to fabricate these retorts were easily obtainable from local mechanical, electrical and general hardware suppliers in the local towns.

Materials and equipment that were not available off the counter could be easily fabricated in numerous engineering workshops in both towns.

The total cost for making one kitchen bowl retort (metallic) was US$3.30. The cost for making one home-made pipe retort was US$4.80. The 24 organizing members of the miners association in Manica District, representing 3764 miners in the area, agreed that the solutions brought to them were beneficial, reasonably inexpensive (in view of the economic benefits from re-using mercury), and easy to implement. Trainers were chosen by the association who proceeded to promote this solution to other miners.

Mercury analyser breath tests of miners and community members showed a pre-retort use average mercury level of 8.23µg/m³. Three miners who were regular amalgam burners returned the highest breath mercury levels on the Lumex Mercury Analyzer instrument. Mercury levels of about 30µg/m³ were recorded in the air as soon as these three severely intoxicated miners were close to the Lumex (likely due to the contamination in their clothing). Without the three most contaminated miners, the average pre-retort use breath Hg test was 3.12µg/m³. The average air Hg levels in the vicinity of miners was around 1μg/m³. Air in the village contained an average mercury contamination level of 0.4μg/m³.

Prior to the use of retorts, the levels of mercury in the air were measured between 0.30 and 0.60μg/m³, with an average of 0.412 μg/m³. In the air surrounding the kitchen bowl retorts, the average level of Hg measured was 40.87, 3.39, and 0.62 μg/m³ respectively for 0.1m high, 1m high, and a person's nose level (~2m from retort).

In the air surrounding homemade pipe retorts, the average level of Hg measured was 35.67, 2.11, 1.93 μg/m³ respectively for 0.1m high, 1m high, and a person's nose level (~2m from retort).

The WHO 1991 recommended TWA exposure limit for metallic Hg is 25 μg/m³ for long-term exposure (WHO 1991). The National Institute for Occupational Safety and Healthi has established a recommended exposure limit for mercury vapour of 50μg/m³ as a TWA for up to a 10-hour workday and a 40-hour workweek (NIOSH, 1992). Malm measured up to 60,000 μg/m³ of Hg in air when amalgam was burned in open pans in an ASM operation. When retorts were used, this concentration dropped to as low as 10 μg Hg/m³. Thus, the retorts appear to be highly effective in reducing mercury exposure. Moreover, the use of the retorts allowed the miner to re-use 95% of the mercury.

PROMOTING SUSTAINABLE LIVELIHOODS

The TDUs, while empowering miners to improve their practices individually, will also serve as forums in which community members can collectively plan safer, cleaner and more cost-effective practices through equipment-sharing and revenue-sharing arrangements.

Although attempts to create formal business cooperatives had generally not been made in mining in the participating countries, this approach may also prove valuable in various communities where individuals have little money to invest in equipment and receive exceptionally low prices for their gold. Moreover, it will be pivotal that introduction of grinders, crushers, other equipment pieces be accessible.

Currently, women are often delegated the role of crushing rocks by hand (such as in Manica District, Mozambique), causing inefficiency and severely arduous labour conditions.

Innovative solutions need to be seized in order to maximize the earning potential of miners, many of whom live far below the poverty line. In this regard, the GMP team is currently discussing with communities about the technologies that would be most accessible and suitable to them through a series of demonstration and training workshops. Efforts to remove barriers to access (e.g. through the promotion of micro-credit) are also critical to meet these goals.

A process of discussions with governments has yielded positive steps. In the 6 pilot countries, the GMP team has engaged the governments to address the issues by pursuing policy development strategies that address both regulation for ASM and assistance for ASM.

Based on the Health and Environmental Assessments that were completed by the GMP, it is concluded that regulatory measures should be instituted to address mercury hazards, particularly to require the use of retorts, to require the retorting be done in centralized locations (away from water bodies, and away from villages), and to require that licensing be mandatory for retorting centres. Assistance measures, meanwhile, are necessary to support miners through technical assistance, education services, and to encourage legal trading of gold in markets that will allow miners to earn fair wages.

THE WAY FORWARD

ASM is often characterized by extensive negative environmental, health and socioeconomic impacts. However, ASM also provides livelihoods for a growing number of people in developing countries around the world.

With little or no investment capital or technical knowledge, miners are in great need of resources to help them minimize these impacts. Where alternate economic strategies are viable, these must also be pursued.

Worldwide awareness of health and environmental problems and the growing number of children involved in ASM, combined with the reality that mercury contamination crosses national boundaries, has led to much needed international collaboration. Simple technological solutions now exist that can reduce mercury exposure while promoting more cost-effective operations.

However, there are several major challenges to their implementation; chief amongst these is that controlling mercury emissions requires addressing the driving forces and pressures that have been barriers – including poverty and disease.

Linking experts from different disciplines to create common frameworks for hazard reduction is clearly needed. Especially as the artisanal mining sector in developing countries has seen few examples of long-term community-based efforts combining biomedical, technical, sociological, economic and cultural aspects, new and positive examples are greatly needed.

Another challenge is that governments where ASM is widespread have limited resources, and top-down initiatives based on regulatory approaches are limited, especially due to widespread illegal mercury markets and mining activities. Bottom-up initiatives based on participation and cooperation between miners, government and nongovernmental agencies offer greater promise for community impact.

Recognizing the need for synergy between policymaking and practice, the GMP is encouraging the involvement of local inspectors in training workshops along with leaders of mining groups. The effectiveness of the various interventions need to be carefully monitored.

Training needs to be broadened to address communities that have hitherto not been reached, and in this respect, a train-the-trainer effect is greatly needed.

Through the Global Mercury Project, the United Nations has opened up numerous collaborative opportunities, embracing a model that combines environmental protection with livelihood development to address these challenges. Alliances with new donors and partners, including the private sector, could further reinforce these global efforts in the future.

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