Using Performance Indicators to Evaluate an Environmental Education Program in Artisanal Gold Mining Communities in the Brazilian Amazon

The Tapajos River Basin in the Brazilian Amazon is the location of one of the largest concentrations of artisanal and small-scale miners in the world. Today, 40,000 miners produce 8 t of gold \( \text{annum}^{-1} \) and at least double this amount of mercury is released into the environment. This region was selected under the Global Mercury Project, a United Nations program that aims to reduce the environmental and health impacts caused by mercury through the application of cleaner technologies and increased awareness. A group of educators provided support to miners, training 4200 people in 141 mining locations. The effectiveness of this training was evaluated based on 20 performance indicators. After 120 days of training, an absolute improvement of approximately 29% had been achieved. As a result of this training, it is estimated that annual mercury emissions in Tapajos have been reduced by 1762 kg or around 10% of the total mercury released in the region.

INTRODUCTION

About 100 million people are directly or indirectly involved in artisanal small-scale gold (Au) mining activities (ASM) worldwide and about 10% of this contingent is located in the Amazon Basin (1). Brazil produces 30 t \( \text{annum}^{-1} \) of gold, and it is believed that 8 t are produced by artisanal and small-scale miners in the Tapajos River Basin region (2). These activities have resulted in the release to the environment of at least two parts of mercury (Hg) per one part of gold produced. Apart from mercury contamination, ASM also causes river siltation (sediments in suspension) as well as destruction to flora and fauna.

Sponsored by the United Nations Development Programme’s Global Environment Facility, the Global Mercury Project (GMP) began in Brazil, launched by the United Nations Industrial Development Organization (UNIDO) in 2002. This project aims to reduce mercury emissions through the introduction of simple technologies, education campaigns, and environmental awareness. According to the Municipal Environmental Agency of Itaituba, the main supporting city for miners in the Tapajos River Basin, there are about 40,000 miners engaged in the extraction of alluvial, colluvial, elluvial, and primary gold in the region. In the 1990s, this area witnessed the world’s largest gold rush when 1 million miners produced around 100 t of gold \( \text{annum}^{-1} \) from more than 2000 mines (3). Tapajos still has one of the world’s largest concentrations of mines and the area extends for 98,000 km² (4, 5). In this vast area, there are three main villages that support the miners’ activities: Creporizão, Creporizinho, and São Chico. These villages, which are the focus of the intervention work by the GMP team, are located in the Crepori River Basin (Fig. 1), a tributary of the Tapajos River.

Worldwide, most assistance programs in artisanal mining sites have been restricted to monitoring the levels of mercury in the water, soil, and biota; very few programs have brought techniques to the affected communities to improve gold recovery and reduce the emissions and exposure to mercury vapor (6–9).

The GMP strategy adopted to implement cleaner techniques and make communities aware of the dangers of mercury misuse consisted of a straightforward approach in which all technical solutions were simplified and made understandable to miners and were designed to be easy to implement locally. The curriculum was discussed with local miners and community members and reflects their expectations to address their specific problems. Local miners, community leaders, and/or technicians were trained by experts in geology, mining, and metallurgical and civil engineering, as well as by health and social workers. These locals, in turn, provided training to artisanal miners responsible for dissemination of the simple ideas and procedures that emphasize “less mercury, produce more gold and have better health” (this is the actual motto of the GMP).

The GMP supported the implementation of technologies that facilitated both economic and environmental improvements. Besides Brazil, the GMP has also been operating in other developing countries, including Sudan, Tanzania, Zimbabwe, Indonesia, and Laos. These countries and the project sites within them were selected based on requests from their governments and the existence of important transboundary river or lake basins. The GMP has also supported the development of regulatory mechanisms to enable local governments to assess and control environmental impacts resulting from ASM activities (10). The implementation of training programs in the project sites included the use of transportable demonstration units (TDUs). The purpose of these mobile classrooms is to disseminate knowledge of less-polluting techniques to concentrate and amalgamate gold.

The trainers use small pieces of equipment for demonstration, but it is up to the miners and trained local manufacturers to modify, improve, or purchase these machines. A tent, a simple structure made of wood and straw, and/or an existing building serves as a classroom, office, and laboratory. This approach eliminates the need to establish fixed training centers where miners have to stop their activities and commute to these facilities to be trained. In the case of the TDUs, miners are trained while working and receive instructions about the advantages of changing their behavior.

Programs that emphasize the reduction of environmental impacts must have instruments to evaluate their effectiveness. Indicators are quantitative and qualitative specifications used to measure the achievement of objectives (11). Evaluation of results is one of the biggest challenges in an environmental education program. It is a common mistake to assume that the number of people involved in a training program is the best indicator of results. The number of trainees is, in fact, an important piece of information, but does not reveal the consequences of the training as the main goal is to change...
attitudes. There is no universal “silver bullet” for resolving the complex social problems associated with artisanal mining, but when implemented in a culturally specific context, the trainers must bring an effective strategy to address cultural beliefs, socio-demographic status, women’s autonomy, economic conditions, physical and financial accessibility, community stability, and disease patterns and health services issues (12).

Overall, the ultimate goals of the Environmental Education Program of the GMP are to reduce pollution caused by artisanal mining activities, thereby protecting human health and local water bodies; introduce cleaner technologies for gold extraction; develop community awareness about all environmental and health impacts from artisanal gold mining; and reduce informality by encouraging the legalization of the mining activities.

The main objectives of this paper are to i) report results of GMP work in the Amazon site; ii) underscore the critical importance of selecting sound, simple, and traceable performance indicators to evaluate the effectiveness of the actions taken to reach the objectives and goals of the GMP in the Tapajos region; iii) propose criteria to evaluate adequate performance indicators; and iv) correlate the success of the indicators with the objectives of the project.

Mercury Use in ASM Communities in Tapajos

Worldwide, around 70% of the mercury used by ASM is lost to the aquatic system due to the amalgamation of the whole ore using copper plates or grinding with mercury. Around 20% to 30% of the mercury is lost to the atmosphere when amalgams are burned in open pans. Assessments in artisanal gold mining areas have confirmed that the mercury vapor intoxicates not only miners, but their families and the neighboring communities (1). The amalgamation of the whole ore is responsible for the largest mercury losses in the mines. The contaminated tailings, with 50 to 200 ppm mercury that passes through copper plates, go into the water streams and are subject to oxidation, complexation with organic matter, and mercury methylation (13, 14).

Once the mercury collects fine particles of gold from concentrates or from the whole ore, miners squeeze the amalgam in order to remove excess mercury by filtration in a piece of fabric. This results in an amalgam usually composed of 60% gold and 40% mercury (6). When the amalgam is roasted in open air pans with a blowtorch to separate mercury from gold, mercury vapor is inhaled and accumulates in critical organs, especially the kidneys and brains of exposed miners and community members (15–26).

Rodrigues et al. (27) conducted an environmental and health assessment on behalf of the GMP. They collected 658 samples from soils, sediments, and water in two Tapajos mining sites, and found the worst scenario in the São Chico site. This area has witnessed a gold rush since the beginning of the 1990s and about 3 t of gold were produced with the consequent release of 7.5 t of mercury to the environment. It was found that over 50 000 m² of soil is covered with mercury-contaminated tailings. The mercury level in the tailings ranged from 4 to 300 ppm mercury (mg kg⁻¹), and river sediments ranged from 7 to 14 ppm mercury. Rodrigues et al. (27) showed that mercury is already bioavailable since fish samples have shown high concentrations of mercury in muscles. This problem is exacerbated by the fact that some miners are extracting residual gold from mercury-contaminated tailings by cyanidation using a heap leaching process. The sodium cyanide dissolves not only gold, but also mercury, forming mercury cyanide. The residual mercury cyanide complex stays in the tailings (in the heap) and is mobilized by rain water reaching the water streams. It is expected that water-soluble mercury cyanide is either more bioavailable or is more easily biomethylated than metallic mercury. The kinetics of mercury and cyanide in the ecosystem is a subject that deserves more investigation. The GMP identified sites in Indonesia, Zimbabwe, and Brazil where there are higher levels of mercury in fish when mercury and cyanide are used together than when only amalgamation is applied (28).

In the monitoring program, in a lagoon receiving effluents from a cyanidation operation at the São Chico site, an average of 2.53±3.91 mg mercury kg⁻¹ in 73 samples of fish was found (27). These levels are especially high when one considers that the fish sampled were very small (18.75±14.42 cm). The average mercury level of 31 samples of carnivorous fish was 4.16±5.42 mg mercury kg⁻¹ and one sample analyzed contained 21.9 mg mercury kg⁻¹. The permissible maximum level for human consumption, according to Brazilian law, is 0.5 mg of total mercury kg⁻¹ of fish (29). A similar situation was found in the Talawaan River in Indonesia (30) and Zimbabwe (31).

Levels of mercury in the urine of people directly involved with amalgamation were as high as 78.5 μg mercury g⁻¹ of creatinine (27) when the normal level should be below 5 μg mercury g⁻¹ creatinine (32). About 50% of miners in the GMP sites showed paresthesia due to mercury vapor exposure (27). Other typical symptoms included tremors, poor balance, ataxia, and concentration problems. The use of retorts can substantially reduce the emission of mercury to the atmosphere as well as occupational exposure.

The general working and living conditions at both the São Chico and Creporizinho GMP mining sites are very rudimentary, and the incidence of malaria, parasitosis, and other diseases is very high. The main source of mercury contamination is through vapor inhalation during the amalgam burning process. Since these artisanal miners do not consume fish regularly, the mercury levels in hair averaged 3.16±2.63 ppm for 136 people in São Chico and 1.82±1.53 ppm for 116 people in Creporizinho, in spite of the high concentrations of mercury in fish muscles (27).

Figure 1. Location of the Tapajos River Basin in the Brazilian Amazon (5).

[Map of the Tapajos River Basin]
Profile of Miners

A simplified survey to profile the socioeconomic conditions in the Tapajos region was applied by the GMP team to 376 miners. About 99% of miners are male, and women are only indirectly involved in the mining activities, as cooks and clerks in the local commerce. The level of prostitution is also high. No child labor (i.e., involving children under 14 years old) was observed in the area; the youngest miner found was 16 years old and the eldest was 75 (with a mean age of 32 years). The level of illiteracy or basic reading and writing is around 60%. Although artisanal miners in general do not establish roots where they work, most of them have been involved in this activity for more than 10 years in the region. The mobility of miners is very high and they move frequently from one mine site to another where they believe they will find “easier” extractable gold. Almost 70% of miners live away from their families and their home towns. This causes many social impacts, since families are left behind and women have to raise their children alone.

The average gold production is about 18 g month$^{-1}$ miner$^{-1}$, which corresponds to an income of USD350 month$^{-1}$. This is basically twice the minimum legal salary in Brazil, but the cost of living in mining sites is far higher than the Brazilian average due to the difficulties of transportation. For example, a 2-liter bottle of Coca-Cola costs USD1.50 in regular markets in Itaituba city, but in some remote mining sites the price escalates to USD10.00. However, this income is an average value, and it is not uncommon for miners to spend months without any production. The amount of mercury consumed is about 40 g month$^{-1}$ miner$^{-1}$, but this depends on the amount of gold they produce. In the Tapajos, usually the mercury lost : gold produced ratio ranges from 1 to 3 since there are miners amalgamating gravity concentrates (but not using retorts) and others using copper plates to amalgamate the whole ore. The local price of mercury is USD150 kg$^{-1}$ (January 2007), while the mean international price in 2006 was around USD21.9 kg$^{-1}$ (33).

MATERIALS AND METHODS

Training Program and Awareness Campaign

Concepts of the International Organization for Standardization’s Quality Management Systems (34) have been employed with the purpose of ensuring the effectiveness of the training process. The GMP strategic plan involved capacity building and preparation of a team of trainers. These actions resulted in significant success in the mining community of Creporiço (the jump-off village for the artisanal miners in the region), where 13 of the 60 people who participated in the training-of-trainers program were selected as trainers—in other words, as multipliers of the GMP concepts.

The training program included teaching the following topics: how to increase gold recovery, how to recycle mercury, how to use retorts, impacts of mercury on health and the environment, mercury in the gold shops, how to protect water, how to diversify the miners’ economy, how to legalize a mining site, tailings management, how to improve mercury amalgamation, use of latrines and mosquito nets, how to filter water, garbage disposal, and reforestation of degraded areas. Special booklets were developed with language tailored to the miners. A strong awareness campaign for the community members was also associated with the miners’ training. Trainers spent three to five months in direct contact with miners, providing advice on changes to be introduced in their operations.

Evaluation of Effectiveness

Using the balanced scorecard methodology (35), the success of the project was evaluated based on the degree of incorporation of better practices in daily mining activities. Each mine site was evaluated before, and 120 days after, the training.

Sutter (36) suggests that a good performance indicator should be pertinent, in that it should represent well the phenomenon being studied; operational, in the sense that it is easily understandable, collectable, and measurable; accumulative, such that it can be related to other indicators to show evidence and trends; and economically appraisable, in the sense that it can be related to impacts on costs. Performance indicators have to be strongly correlated with the objectives of the program as the reason for the existence of indicators is to evaluate whether or not the objectives have been accomplished. It is possible to set different weights for each indicator according to distinct relevancies they may have; however, the exclusion of weights simplifies the process and eliminates another subjective variable.

Selecting Performance Indicators

The main performance indicators were selected based on public consultation and technical factors affecting gold production and environmental impacts. The GMP’s goals were to improve performance in the following five general objectives: i) legalization of mining sites; ii) adoption of techniques to...
increase gold recovery; iii) protection of water and forest resources; iv) reduction of mercury use; and v) improvement in water quality, sanitation, and overall health.

For each of these general objectives, a number of performance indicators were selected, representing good practices expected to be implemented. A total of 20 performance indicators, described below, were used in the evaluation of 141 mining sites after 120 days of training.

General Matrix of Evaluation

Once objectives have been established, measuring procedures can be identified and implemented with the intention of supporting management’s ability to monitor the project’s progress toward achievement of its goals (37). The goals are marks established to evaluate the success of the project objectives. The project manager may want to set goals for each indicator that represents realistic challenges to be achieved. The intensity of the action is an executive decision that can be either conservative or ambitious. There is no universal standard for goals; they are subjective, and what makes them reasonable is basically a good balance between challenge and feasibility.

The degree of accomplishment (DA) is the result of a comparison between the observed situation and the intended goal. For example, if a preliminary evaluation showed that only 20% of the miners used retorts to burn amalgam and the ideal situation (goal) was 100%, it would be more realistic if the project manager determined that the goal should be for at least 80% of miners to end up using retorts. If, after training and re-evaluation, it was observed that 40% of miners were using retorts, this would indicate a DA of 50% (currently = 40%, goal = 80%).

The absolute improvement (AI) is the difference between the observed result after training and the preliminary evaluation (before training). Again, using the same example as above, the AI would be 20% (currently = 40%, previously = 20%).

RESULTS AND DISCUSSION

An explanation of the selected performance indicators for each of the general objectives is shown as follows.

Legalization of the Mining Sites

Environmental license: In each mining site, the trainer verified the existence of the environmental license issued by the governmental agency (Secretary of Environment of the State of Para—Brazil) and trained miners about the need for compliance. Mining permit: in each mining site, the trainer verified the existence of the mining permit issued by the governmental agency (Brazilian National Department of Mining) and trained miners about the need for compliance. Receipt issued by gold buyers: In order to avoid tax evasion during gold commercialization, receipts must be issued by the gold shops whenever miners sell their gold. As such, the miners were trained to request receipts when selling gold.

Techniques to Increase Gold Recovery

Use of more effective methods to find gold: Most artisanal miners find gold deposits by guessing based on their own experiences. This process increases the environmental impact due to the amount of earth removed unnecessarily and consumes time, fuel, and other resources. Miners were trained to count on specialized technicians working with geochemical prospecting techniques to identify gold anomalies (e.g., panning and counting gold specks). Working correctly with existing equipment: The basic equipment used by local artisanal miners to mine and concentrate gold includes hydraulic monitors and sluice boxes with carpets, or hammer mills and copper plates. They were taught how to use this equipment more effectively, eliminating riffles, adjusting the angles of the zigzag sluice boxes, using adequate carpets, adjusting hammers in the mills, and replacing copper plates with carpets. Methods to recover more fine gold: The most effective way to show miners that their recovery is not satisfactory is by reprocessing their tailings and recovering more gold either trapped in coarse fragments or in particles too fine to be recovered by rudimentary concentration processes. Miners were shown how to increase gold recovery by grinding with a ball mill to liberate gold and by concentrating gold with a prototype of an inexpensive centrifuge developed by Falcon Concentrators especially for artisanal miners. Maintenance and stock of supplies: Most miners are extremely informal and do not plan their activities. Equipment maintenance is not a priority for most miners. Usually, it takes time to find spare parts when equipment is broken. They were encouraged and trained to establish a preventive maintenance scheme.

Protection of Water and Forest

Refill of old pits with tailings: When artisanal miners work with alluvial and colluvial gold along the riverbanks, they just dump the tailings into the river. They were trained to return sediments to back-fill old pits. The soil is therefore contained, and the reclaimed water is used in ongoing operations. Revegetation of degraded areas: The GMP identified only one mine owner (Canaan Mine) conducting revegetation in his area as well as refilling old pits. Miners were informed of the advantages of rehabilitating degraded areas, and some of them have started a modest plantation of fruit trees (such as mango and cashew trees) for their own consumption. Tailing containment: Sometimes miners work in new areas where no old pits are available to receive tailings; then they dispose of tailings over land or in the rivers. In any case, miners were taught to build a triple barrier made of palm leaves that retain a large part of the tailings. The quality of the reclaimed water is evaluated visually according to the level of suspended matter.

Reduction of Mercury Use

Mercury activation and recycling: Considering the current low level of miners’ education, capitalization, and awareness of health risks, the elimination of amalgamation cannot be accomplished in the short term. Therefore, the GMP has
concentrated efforts on reducing mercury use. Miners learned how to activate mercury by using an electrolytic process with a car or motorbike battery and 10% table salt solution (38). This simple process forms a sodium amalgam, which is more coalescent and effective in the amalgamation process than pure mercury. Sodium amalgam is easily recovered and less mercury is lost by “flouring” (droplet formation). This was promptly assimilated by the miners since more gold has been recovered from the gravity concentrates. Amalgamation in designated places: Amalgamation of concentrates in confined pools eliminates the losses of mercury to rivers. Miners were taught how to excavate a small pool far away from rivers, lined with canvas or a plastic sheet. Miners amalgamate the concentrates in these pools and, if any mercury is lost with the tailings, it becomes confined and can be recovered later on. Use of retorts during the burning process: This is one of the most important goals of the GMP as retorts reduce miners’ exposure to mercury vapors and recover mercury to be reused. Many different types of retorts were demonstrated to miners, such as those made with kitchen bowls, salad cups, or water pipes (12). The GMP also bought retorts from a local manufacturer and donated them to miners. The measured mercury recovery was above 95% using this local retort. Use of mercury-free technology: There are some miners using cyanide, but they do not have sufficient understanding of this technique, making the practice as dangerous as the use of mercury. Some of them use amalgamation followed by cyanidation, exacerbating environmental problems. The GMP has implemented a new and affordable technique to preconcentrate gold by gravity concentration (e.g., using a sluice box or a centrifuge) and to leach the concentrate with cyanide in a small ball mill. This is still in a preliminary phase, but the results are very promising in terms of the potential to completely replace amalgamation of concentrates.

Improving Health and Sanitation

Use of latrines: This is not part of the miners’ culture, so they were trained in latrine construction methods. The benefits of using latrines were discussed with miners and community members. Use of filtered drinking water: Most miners consume water from the local streams and rivers or wells. They were taught to use ceramic filters, which can be bought locally, or to simply boil water before consumption. Biosand filters (39) were also donated to some sites to be tested. Transport of these cement filters in the roadless Amazon is difficult due to their great weight (around 130 kg), but they are suitable for established mining areas with road access. The GMP has also developed alternative ways to build lighter biosand filters. Prevention of malaria: It is common to find miners who have had malaria over 50 times. Fortunately, there are efficient medicines for treatment of malaria in the Amazon, but prevention is better because healthy miners can work more effectively. Miners were taught to use mosquito nets and screens on their windows whenever suitable (most of them live in tents). By refilling old pits, they will also contribute to reducing the mosquito population. The GMP also promoted an initiative of a local miner, Mr. Paulo Carneiro, who is using an extract of the leaves of the neem tree (Azadirachta indica) as a repellent against the malaria-carrying Anopheles mosquito (40). Safety: One of the most common accidents is landslides that occur when miners use hydraulic monitors or when they dive into the river. Another common accident involves the exposure of miners’ hands to unprotected motor belts. During evaluation of the areas, the trainers took into consideration the potential risks and how miners understood the risks. Proper garbage disposal: Miners commonly dump garbage everywhere, with a strong preference for rivers. They were taught how to bury garbage to keep the mining area free of plastic bags, bottles, and other types of garbage. Training also included instruction regarding how to burn the garbage to minimize mosquitoes and to cover the hole before leaving the area. Practices of environmental education, health, and awareness of miners: Virtually all of the miners visited during the training said that this was the first time they had received formal training on environmental, health, and technical procedures. The trainers persuaded mine owners or managers to provide regular and formal talks to the miners, encouraging them to adopt the good practices brought by the GMP trainers.

Table 1. Degree of accomplishment (DA) and absolute improvement (AI) after training (141 mining sites evaluated).
Performance Indicators

The training program in the Tapajos region of the Brazilian Amazon has introduced 20 good practice indicators. Overall, conformity to the indicators before the program was 22.2\% (Table 1); in other words, around 31 of the visited mining sites were complying with the performance indicators. The average goal was set to 40\% and the overall result was 51.0\% after 120 days, leading to an AI of 28.8\% and a DA of 110.0\%.

Taking as an example indicator number 19 (proper garbage disposal) in Table 1, before the training and awareness campaign, only 16.3\% of the evaluated mines disposed of their garbage properly. Based on previous evaluation, the experience of the team leader, and discussion with partners, the project manager set a goal of 50\%, believing that this target would be challenging but achievable. By the second evaluation, 120 days after the training and awareness campaign, 100\% of the evaluated mines were disposing of garbage properly. As the baseline was 16.3\%, the AI was 83.7\%. Based on a comparison of the current result (100\%) and the goal (50\%), the DA was 200\%. This same rationale applies for all indicators.

For short-term comparison, the AI is a solid measurement of success. The DA is multifaceted, as it may be low, high, or extremely high depending on how conservative or ambitious the project manager is when setting the goals. Conservative goals lead to higher DAs, while ambitious goals lead to lower DAs. For this reason, goals have to be set as realistically as possible.

These results show that at least eight good practices have had a high impact: refill of old pits with tailings (i.e., sluice boxes were removed from the rivers; indicator #8 in Table 1), tailing containment (#10), activation and recycling of mercury (#11), amalgamation in designated places (#12), use of retorts (#13), construction and use of latrines (#15), use of filtered water (#16), and garbage disposal (#19). Based on these results, the most successful general objectives were the protection of water and forest, reduction of mercury use, and health and sanitation. The objectives regarding the legalization of mines and the increase of gold recovery were not as successful as others. Changes in behavior regarding the legalization of the areas are more difficult to achieve as the government presence in the region is not strong enough to provide mechanisms of registration and control. Thus, even when the miners take the initiative to legalize their mines by obtaining all necessary documents, the government bureaucracy and lack of resources do not facilitate field access for inspectors or access of miners to bureaus, and licenses are not issued. It is difficult to encourage miners to step forward to legal requirements when they are aware that there is no real consequence for operating illegally. The limited success of this objective demands solutions other than training miners about legal procedures. It also includes recommendations for the federal government in terms of simplification of processes, which invariably requires a more realistic regulation, considering the perspective of artisanal miners and their social context.

The short-term objective gold recovery also requires more time and effort to achieve measurable results. In contrast to objectives related to environmental, health, and sanitation practices, which require low investment and a strong change of attitude, increasing gold recovery requires some investment, which is certainly one of the barriers to overcome. The GMP also established partnerships to design a microcredit program that might help miners to invest in simple technologies.

In addition to the performance indicators for the training and awareness campaign, the following achievements are also highlighted:

- Number of miners trained: 4200 miners, representing 7% of the miners’ population in the region.
- Number of biosand filters implemented: 10.
- Number of retorts donated: 60 (most donations occurred after the evaluation, so the total impact of donation was not measured yet).
- Implementation of the TDU and awareness campaign, including demonstration of hammer mill, ball mill, centrifuge, carpeted sluices, and amalgamators; dissemination of brochures, posters, and DVDs; organization of community meetings and lectures; and so on.
- Prototypes of mercury vapor filter implemented by the GMP’s partner, the US Environmental Protection Agency, in local gold shops.

A previous evaluation showed that only 4.3\% of miners were recycling mercury by using retorts. As the average mercury consumption per capita was 40 g month\(^{-1}\), this led to a consumption of 2016 kg mercury \(annum\)\(^{-1}\) by the 4200 miners involved in the training process. By introducing mercury activation and retorts, these simple measures have resulted in mercury consumption of 5 g month\(^{-1}\)capita\(^{-1}\). In other words, the training reduced 1762 kg \(annum\)\(^{-1}\) of mercury that would have been lost to the environment. There is an opportunity to prevent at least 17 t of mercury from being lost to the environment if the training reaches other mining sites in the Tapajos region. Another important measure would be better control of the miners’ access to mercury. Brazilian miners buy mercury locally in equipment supply shops without any requirements. Most mercury enters the country legally for “dental use” (as labeled on a mercury vial bought in the village of Crepurizão) and is diverted to gold mining. In 2006, according to United Nations Commodity Trade Statistics Database (41), Brazil officially imported 44.2 t of metallic mercury from Kyrgyzstan (13.8 t), the United States (8.1 t), Spain (8.0 t), Kazakhstan (5.8 t), Mexico (3.3 t), Germany (1.2 t), as well as Peru and Japan (hundreds of kilogramos). Mercury use in Brazil is controlled by Decreto 97.634 of 1989 and users have to obtain a special authorization from the Federal Environmental Agency (IBAMA). However, due to strong bureaucratic barriers, it is virtually impossible for an artisanal miner to have an official authorization to use mercury, and the federal agency controlling mercury use and trading does not provide miners with any training or information on how to use it safely. The result is “illegal” sales within the country, pollution, and intoxication.

References and Notes


