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Review

# Limitations in small artisanal gold mining addressed by educational components paired with alternative mining methods

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ABSTRACT

Current solutions continue to be inadequate in addressing the longstanding, worldwide problem of mercury emissions from small artisanal gold mining. Mercury, an inexpensive and easily accessible heavy metal, is used in the process of extracting gold from ore. Mercury emissions disperse, affecting human populations by causing adverse health effects and environmental and social ramifications. Many developing nations have sizable gold ore deposits, making small artisanal gold mining a major source of employment in the world. Poverty drives vulnerable, rural populations into gold mining because of social and economic instabilities. Educational programs responding to this environmental hazard have been implemented in the past, but have had low positive results due to lack of governmental support and little economic incentive. Educational and enforced intervention programs must be developed in conjunction with governmental agencies in order to successfully eliminate this ongoing problem. Industry leaders offered hopeful suggestions, but revealed limitations when trying to develop encompassing solutions to halt mercury emissions. This research highlights potential options that have been attempted in the past and suggests alternative solutions to improve upon these methods. Some methods include buyer impact recognition, risk assessment proposals exposing a cost–benefit analysis and toxicokinetic modeling, public health awareness campaigns, and the education of miners, healthcare workers, and locals within hazardous areas of mercury exposure. These methods, paired with the implementation of alternative mining techniques, propose a substantial reduction of mercury emissions.



**Contents**



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## 1. Background: unaddressed difficulties

Challenges within the small artisanal gold mining (SAGM) industry evolved in an unyielding capacity as a result of the substantial amount of people involved. Over fifty million people in developing countries work in small artisanal mines within seventy different countries (Telmer and Veiga, 2008; Veiga and Baker, 2004). Miners are not the only people affected by mercury emissions within small artisanal gold mining; approximately five million women and children are also directly employed in artisanal gold mining (Veiga and Baker, 2004).

Many developing third-world nations have an abundance of gold imbedded in rural areas of the country. Gold, extracted from easily obtained and low-cost mercury, can provide a livelihood (Hilson, 2005); however, SAGM impacts populations within a lower socioeconomic status. Socioeconomic status remains a persistent, robust determinant in variation of rates of illness and death (Williams, 1995). Adverse health consequences may also negatively influence family dynamics, lifestyle and behavior, and manifest a depressed social structure. Poverty is a major cause of global environmental problems as a result of long-lasting social and economical injustices (Kohlhuber et al., 2006). Within these economically unstable environments, rural populations resort to gold mining. Depending upon market gold prices, gold production from artisanal gold mining can result in substantial financial gain, while the cost of living in rural settings can be less than $1.25 USD a day (Veiga et al., 2010; Chen and Ravallion, 2007). This economic factor encourages mining employment, creating the environment for mercury exposure for a substantial number of miners; consequentially, these populations suffer from detrimental repercussions, wherein chronic exposure to mercury results in dose-dependent neurotoxic effects (Lebel et al., 1996; Lebel et al., 1998).

Many small-scale miners involved in the extraction process of gold from ore use mercury. Amalgamation by mercury is inexpensive, an easily accessible and uncomplicated procedure, and extracts an adequate amount of gold from ore economically sustaining the lives of rural miners (Spiegel et al., 2006). The hazardous process of extracting gold from ore by mercury amalgamation has the potential to cause adverse health effects in people, as well as, overall widespread pollution in soil and sediment (Taylor et al., 2004; Babut and Sekyi, 2003). Gold mining is responsible for large releases of mercury into the environment; small artisanal gold mining releases are estimated to be approximately 400 t of airborne elemental mercury each year (EPA, 2011). In areas where mercury amalgamation is commonly used, randomly sampled fish tissue contains bioaccumulation of mercury that exceeds the United States Food and Drug Agency (FDA) regulation levels (Babut and Sekyi, 2003).

Environmental and social problems occur as a direct result of these emissions. Health disparities also occur in disadvantaged populations; the majority of these populations bear the burden of adverse health issues due to environmental degradation (Butler and McMichael, 2005). Poor health consequences of mercury exposure can be categorized dependent upon dosage level, exposure length, and multiple predictor variables of subjects. Reviewed data by the Environmental Protection Agency (EPA) states that acute, low-dose exposure to mercury can lead to respiratory symptoms such as chest pains, dyspnea, cough, hemoptysis, impairment of pulmonary function and interstitial pneumonitis (US EPA, United States Environmental Protection Agency, 2011). Acute, high-dose mercury poisoning can be fatal or lead to permanent damage within the central nervous system (Poulin and Gibb, 2008). Chronic, low to moderate-dose exposure is characterized by less pronounced symptoms such as fatigue, irritability, loss of memory, vivid dreams, and depression (US EPA, United States Environmental Protection Agency, 2011). Offspring exposed to mercury during fetal development suffered the greatest symptoms of central nervous system damage, with the most severely affected exhibiting blindness, deafness, general paralysis, hyperactive reflexes, and impaired mental development (Amin-Zaki et al., 1974).

Being able to mine gold without severe environmental implications will also promote health and safety in miners and their families. Promoting a natural environment allows terrain to be maintained, potable water to be sustained, and eliminates deterioration of the human health condition due to mercury toxicity. Past efforts have attempted to decrease and eliminate mercury emissions and exposure, but a sustainable economical solution has yet to be identified. Millions of dollars have been spent on industry-specific policies and regulations for decreasing mercury emissions in SAGM; unfortunately, much of this funding has failed to facilitate marked improvements (Hilson, 2007). Increased illegal mining activity, continued mercury pollution levels, and few proposed alternative livelihoods exacerbate the problem (Hilson, 2007). Interventions designed to curb these long-lasting SAGM environmental exposures should rely heavily on education and imparting information. Future improvement programs focused on eliminating mercury emissions and exposure should be enforced by governmental agencies in order to implement awareness control methods (Hilson, 2005).

## 2. Purpose of the review and conceptual approach

The current state of research regarding attempted or potential solutions for SAGM remains ill defined (Hilson, 2009). The goal of this review is to evaluate previous efforts aimed at addressing mercury exposure in SAGM. By looking at the positives and negatives of each existing solution, information can be properly displayed and other relevant outcomes may become visible by combining alternative interventions. The overall aim is to establish a resource pool of information on sustainable measures that can potentially prevent and mitigate the environmental consequences of SAGM. Factual accumulated data on selective principle aspects and outcome indicators that can assist in developing an authentic and practical perspective on SAGM include: previous or current methods addressing mercury emissions and exposure data, general health effects of mercury exposure, public health infrastructure, the country's overall economic and political state and statistics of burden of disease at a population level.

### 2.1. Review methods

Given the broad spectrum of information available from a variety of factors, a basic approach was taken in researching and analyzing data. An initial search was conducted through multiple search engines, including PubMed, Web of Science, and ScienceDirect peer-reviewed journal articles. These articles pertained to small artisanal gold mining, mercury exposure or a conglomeration of both. Studies that primarily focused on large-scale gold mining were excluded from the review.

Experts in the general field of gold mining were contacted and interviewed in multiple sessions. The interviewees were selected from varying backgrounds representing academic, governmental, and non-governmental sectors. Each expert was questioned similarly; overall, opinions were sought in order to examine the human health and environmental consequences of mercury contamination and small artisanal gold mining. Interviews were conducted for several months and records were documented and stored; this information was carefully reviewed and assigned categorically while alternative mining issues were discussed.

### 2.2. Challenges

This review focused solely on human exposure to mercury from small artisanal gold mining; moreover, additional exposures, health outcomes, or other environmental contamination issues were not specifically addressed. Information was categorized based on intervention methods. Public health infrastructure and economical development within the variety of countries was addressed, but remained difficult to categorize. Because of the difficulty in gathering dispersed information and assembling applicable data; pertinent information gaps may