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A SHORT REVIEW OF ENVIRONMENTAL AND HEALTH IMPACTS OF GOLD MINING

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Abstract

Gold mining is attracting increasing attention in many countries of the world. On the other hand, this sector causes numerous environmental and human health issues. The main problems are associated with: (i) Acid Mine Drainage (AMD) with low pH values and high concentrations of heavy metals, (ii) using large quantities of hazardous chemicals such as mercury and cyanide and (iii) mining dust. Degree of the impact depends of the scale mining (small or large scale), type of mine (surface and underground) as well as of the chemical reagents that use in the production process. Modern technology has made it possible to reduce environmental impacts of mining activities.

This brief review looks at the gold mining sector (industrial and artisanal) and its key impact on environmental as well as on health of workers and communities (residents who live in proximity to the mine)..

Keywords: pollution, air, soil, water

I. Introduction

Mining is a profitable industry, but it is also one of the most pollutant source for terrestrial and aquatic ecosystems [1–3]. All environment components suffer the consequences of metal mining activities (including all phases of the mining cycle): preparation of the mining site, excavating, dewatering, crushing, grinding, separation, smelting, refining, management of tailings and waste-rock [1]. Furthermore, environmental pollution affects the health of both miners and communities living around mining complexes [2, 4–6]. Degree of the impact depends of the scale mining (small or large scale), type of mine (deep or open cast mine) and the use of hazardous materials in the extraction and processing stages [1–3, 7]. The old abandoned mines that were not closed "lege artis" also can cause environmental and human health dangers. [8–10]. Note, the abandoned mine sites are those mines that are no longer operational, not actively managed, not rehabilitated, causing significant environmental problems, and for which no one is currently accountable for the site's remediation or rehabilitation [10]. Within the environmental impact category, air and water/soil pollution are interconnected [11]. The term pollution of the environment refers to an increase of a concentration of pollutant relative to its natural level. An important fact is that pollutants transported more rapidly over long distances from mine by atmospheric aerosol than by other media such as water and soil [12].

Metal mining generate large volumes of waste (referred to as tailings) containing hazardous minerals from the original ore and metals that are concentrated in solid wastes or drainage [13–15]. Some effluents generated by the gold mining industry contain large quantities of toxic substances such as cyanides, mercury or sulfuric acid [16]. In arid areas, mine tailings are subject to aeolian dispersion and water erosion, while in temperate environment they are a source of metal leachate or metal-rich acidic wastewater [17]. In the case of water erosion, metals and other potentially undesirable elements introduced into water bodies; dissolved metals become are more bioavailable to organisms [11 and references therein].

Mineral dust emitted from mining operations and mine tailings, may mobilize high levels of metals and metalloids [12]. The climate change can substantially increase the potential for dust emissions and its transport [18]. Therefore, the role of mining activities in the fate and transport of environmental pollutants could become increasingly important [12]. Removal of trace metals from the atmosphere by precipitation affects chemistry and biogeochemistry in the surface waters [11 and references therein]. Atmospheric transport of the particle–associated metals/metalloids contribute to health effects; exposed human population may develop respiratory, neurological and other serious health problems [12].

Mining industry introduces heavy metals to the environment in quantities many times exceeding natural soil background concentrations [4,19,20]. The most toxic ones, arsenic (As), cadmium (Cd), mercury (Hg) and lead (Pb), are associated with gold [4,19]. An important ecological property of metals is their persistence and ability to accumulate in ecosystems [21]. They can accumulate in human organisms through food chain causing serious maladies [20]. Miners may experience adverse health effects due to long periods of exposure to heavy metals in the soil [19].

Water is the biggest victim of mining [2]. Surface and groundwater pollution is one of the significant impacts of mining activity due directly influence in quality of life/health. The impact of mining on surface and groundwater is due to acid mine drainage (AMD), heavy metal and processing chemicals, erosion and sedimentation [2,22,23]. Sulfide–containing minerals, in the reaction with air and water form sulphuric acid i.e. acidic water mine waters ($pH < 7$) referred to as AMD or acid rock drainage (ARD) [22]. This process forming in any part at both active and abandoned mine sites where metal sulfides are exposed to air and water, including rock waste and tailings is one of the single greatest environmental challenge in the mining sector [8,9,22]. Due to the higher mobility of metals at low pH, acid mine waters usually contain high concentrations of toxic metals and metalloids and can cause serious ecological problems and can affect water quality and thus aquatic biota [8,9].

Leachates from mine tailings may be more aggressive than discharges from mine pits and underground workings [22]; this makes the management of waste dumps of utmost importance [13]. Through surface runoff and groundwater circulation, AMD from mines reaches surface and groundwater. The problem of AMD pollution does not finished with the closure of the mine, on the contrary, it can last for centuries. Flooding of abandoned mines leads to discharge of AMD into river valleys [8,9]. However, when ores contain a high proportion of minerals that can neutralize acidic waters, oxidation of mineral sulfides does not lead to the formation of AMD [14].

Spill, leak, or leach of toxic chemicals using to separate the target mineral from processing facilities into nearby water bodies may lead to large–scale water pollution [22]. Additionally, due the heavy use of water in processing ore and of discharging untreated water into rivers, mining have adverse impacts on the rivers surrounding the mines [2].

As mentioned above, also erosion of waste materials at mining sites can affect surface water quality. Besides, erosion of the exposed earth from the open-pit may carry substantial amounts of sediment into streams, rivers and lakes. Consequently, sedimentation and siltation of the receiving waters can result into significantly higher turbidity and conductivity, thus, affecting the physiology and behaviors of various aquatic species, including the fish [22]. Therefore, protecting water quality is a high priority environmental challenge in mining and mineral processing.

This article summarizes the basic literature information of the environmental and health risks associated with gold mining operations.

II. Different scales of gold mining operation (small and large)

According to scale of mining operations, studies of gold mining and health are divided into small–scale (artisanal, surface type) and large–scale (industrial, underground or open pit type) mining [1]. Artisanal and Small–Scale Gold Mining (ASGM) refers to the informal (illegal) occupational sector employing unskilled workers (and sometimes children). [4,7]. Work is typically done with minimal or no mechanization and without appropriate professional and environmental protection measures [7]. However, artisanal mining is very important for the economy of developing countries [24]. This method of gold production occurs in at least eighty countries in the Global South. Approximately 90% of all employment in gold mining and 20% of global gold production are based on small–scale extraction [25,26]. Large–scale gold mining (LSGM) requires huge capital investment [1]. This type of mining employs highly trained and educated personnel and uses sophisticated machinery [1]. Large-scale mining involves both deep pit and surface methods [1]. In the wake of increasingly environmental challenges posed by the mining sector, the ASGM sector receives much attention over LSGM [1]. However, in any system of mining there is potential environmental risks introduced.

2.1. ASGM and associated hazards

Small–scale gold miners use large quantities of hazardous chemicals (such as mercury or cyanide) in the extraction and processing stages to recover gold from ore [4,27]. Elemental mercury is used in extraction of gold from raw ore through amalgamation [27]. The amalgam is heated to evaporate the mercury and separate the gold. In a report "The World's Worst Pollution Problems 2016", the artisanal gold mining was identified as one of the world's top ten pollution problems due it releases more mercury into the environment than any other sector worldwide [28]. For example, in study in the Bolivian Andes found that mercury vapor levels at the two mining sites were approximately 30 times larger than reference concentration of the United States Environmental Protection Agency (USEPA) [4]. Likewise, one report estimated that 5 tons of mercury is released from ASGM operations in Ghana each year [2]. Further, in Myanmar it was found that the maximum mercury concentration in the atmosphere in the gold mining area reached 74,000 ng/m^3 that exceeded the WHO guideline of 1,000 ng/m^3 [27]. The vaporized mercury that is emitted into the atmosphere without any treatment, not only polluting the environment, but harming human health, especially the health of workers [27]. Therefore, workers involved in the gold mining operations, their families as well as surrounding communities can be exposed to dangerous levels of elemental Hg vapor [30]. Note, approximately 15 million people, including approximately 3 million women and children, participate in artisanal small-scale gold mining (ASGM) in developing countries [30]. It is important to note that inhalation of Hg vapor can produce harmful effects on the nervous, digestive, and immune systems and the lungs and kidneys (WHO 2007).

The ASGM had major effects on water bodies [2]. Releases of mercury to the environment can result in the contamination of freshwater fish with methylmercury. Consequently, ASGM community can be exposed to this very toxic substance from food sources [29].

In order to comply with modern environmental standards, reducing mercury use is a key step in realizing ASGM development opportunities. Esdaile and Chalker [31], in their work, emphasize that mercury–free gold mining is possible and they encourage researchers, funding agencies and journal editors in chemistry and allied fields to consider how they might marshal their resources and expertise to address this global mercury problem.

Cyanide is considered as one of the most cost–effective methods to extract bits of gold. It is faster and more effective at extracting gold than mercury amalgamation [7]. The process involves dissolution of gold from the ore in a dilute cyanide solution and extraction of the gold in a complex in the presence of lime and oxygen [6]. On the other hand, it is known that cyanide is a very fast–acting poison [32]. If cyanide is properly manufactured, handled and used, it does not pose a risk to human health or the environment. However, ASG miners use cyanide with minimal personal protection [6,7]. In one study on cyanide exposure in a gold mining community, in the Philippines, 35% subject respondents had elevated blood cyanide level and the adverse health symptoms [7]. The study of environmental impacts of gold mining in Essakane site (Burkina Faso) showed that the artisanal miners in the area are predominantly illiterate and do not have enough knowledge about the effects of chemicals such as mercury and cyanide [3]. Thus, to reduce the adverse effects of ASSM on the health of mining communities and the environment, among others, it is recommended better education of the risks as well as simple controls to reduce exposure [4].

In addition to Hg, ASGM sites are commonly associated with high levels of the toxic heavy metals such as arsenic (As), cadmium (Cd) and lead (Pb) [4, 19]. Mentioned metallic elements can cause adverse health effect in humans even at exposure to low concentrations. They are classified as human carcinogens according to the U.S. Environmental Protection Agency, and the International Agency for Research on Cancer [33]. In the study conducted in Bolivian Andes, in an area of ASGM operations, arsenic concentrations in soil were 3–4 orders of magnitude above background levels [4]. There is also evidence the arsenic contamination of the biotic and abiotic samples in proximity to mining sites [34]. Gold deposits frequently contain various forms of arsenic: arsenides, sulfides, and sulfosalts. Arsenic sources associated with gold mining include waste rocks, residual water from ore concentrations, roasting of some types of gold-containing ores to remove sulfur and sulfur oxides, and bacterially enhanced leaching [34]. Arsenic may be mobilized in aqueous environments where cyanide has been used to leach gold ores [35]. It has been noted that gold miners may have a number of health problems associated with arsenic, such as increased mortality from lung, stomach and respiratory tract cancer [34].

Mining activities such as rock drilling and related milling operations generate copious amounts of dust, which is mainly contain of crystalline silica. In particular, ASG miners are exposed to the crystalline silica dust. In the process of the separating the gold from the other minerals, when ASG miners crush and grind the ore manually, crystalline silica dust is released into the air. Exposure to dust is an important risk factor for many respiratory diseases. Constant exposure to silica dust can cause silicosis and significantly contribute to tuberculosis incidence rates in mining communities [3,6].

2.2. LSGM and associated hazards

The LSGM possess detrimental effects on the environment, due to their continued use of modern, sophisticated machinery and harmful chemicals, as well as extended blasting levels [1]. The research conducted on a single large–scale mining company in Ghana have been shown that large-scale gold mining operations threaten the environment. The study discovered the air pollution, noise pollution (due noise several species of animals migrated to favorable environments), deforestation. The LSGM have also caused excessive damage to the lands/soil of mining communities within mining area. It has been shown that agricultural land as well as forest reserves were reduced. The rivers and streams in the closeness to mining pits were greatly polluted by mine wastewater drainage and heavy run-off from the waste rocks at mining pit. [1].

Porgoa and Gokyay have been analized the environmental impacts of industrial gold mine (open-pits mining) activities in the Essakane area [3]. The results showed that exploiting of gold mine directly or indirectly contributes to air pollution. The use of cyanide to obtain the gold from ore constitutes a potential risk for the ecosystems, the local population's health, and livestock production. The results also showed that there is a significant degradation of natural landscape and topography of the soil.

III. Modern gold mining in Europe

The European gold mining industry is among the most modern and safest worldwide, and it based on "Best Available Techniques" (BAT) [37]. A modern gold mine uses high-tech processes, and automation to extract and process gold ore and the most up to date technology to protect human health and safety [37]. An overwhelming majority of modern gold mines operating around the world uses dilute solutions of sodium cyanide for gold recovery. Cheaper method that could replace cyanide, do not exist at this time. Only in some cases, the nature of the ore enables the use of cyanide-free processes such as gravimetric separation and flotation concentration [37]. It is important to highlight that the use of cyanide in ore processing is regulated by specific requirements enacted by the EU to aim the safe use and to prevent risks for human health and the environment. Cyanide is either recycled and re-used in the process or destroyed prior to any disposal of tailings. The fact that cyanide further naturally degrades in the tailings facility means that final concentrations in the tailings can even become very difficult to detect [37].

Note, a focus on environmentally responsible mining not only includes measures to protect human health and prevent accidents, it also includes modern mine site rehabilitation following the closure of the facility as to mitigate environmental effects and preserve biodiversity.

IV. Conclusion

This brief review looks at the gold mining sector and its key environmental as well as health impacts, both for miners and for the communities living around mine. Numerous quantitative studies shown the interlinkages between mining operations and effects on the landscapes, water and terrestrial ecosystems, and health miners as well as affected communities. These negative effects are caused by the physical degrading nature of mining, as well as the use of chemicals and other harmful substances in the mineral processing.

The principles of sustainable development have had a growing influence on the development of environmental policy. Mining can become more environmentally sustainable by developing and integrating practices that reduce the environmental impact of mining activities [23]. Implementation of the best available technologies, adequate trainings, and standard working practices should render mining safer occupation than ever before [38].

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