Evaluation of the project: Improvement of the working conditions of small-scale and artisanal mining in Ecuador...

Conference Paper · June 2014

DOI: 10.13140/2.1.2868.6089

5 authors, including:

Isabel Pazmino
Universidad Técnica de Ambato (UTA)

Diana Ayala
Instituto Nacional de Investigación Geológico ...

Patricio C Velasquez-Lopez
Universidad Técnica de Machala

Evaluation of the project: Improvement of the working conditions of small-scale and artisanal mining in Ecuador. Historical background, current situation, and actions for the future

I.C. Pazmiño[1],*, G.A. Muñoz[2], D.K. Ayala[1], P.A. Espinosa[1], and P.C. Velásquez[1]

[1] Instituto Nacional de Investigación Geológico Minero Metalúrgico (INIGEMM), Quito, Ecuador.
[2] Universidad San Francisco de Quito, (USFQ), Cumbayá, Ecuador.
* Corresponding author: isabel_pazmino@inigemm.gob.ec

Abstract

Small-scale gold mining in Ecuador takes place under precarious conditions basically due to lack of technology, illegality, informality and inequity. For these reasons, the Ecuadorian Government, through the Ministry of Natural Non Renewable Resources and the National Institute of Research in Geology Mining and Metallurgy (INIGEMM), is executing a project to improve the working conditions of small-scale and artisanal mining for gold and base-metal recovery. The project has seven different components in order to cover all the needs of the influence area, where one of these components is Technology Transfer. This paper presents the details of how this component is looking forward to boost technical education among small-scale miners, and to provide them of a better infrastructure to improve efficiency and performance of mining activities.

HISTORICAL BACKGROUND

Mining in Ecuador has been a common activity since pre columbian times. During the Colonial period, the “mita” was one of the activities that provided richness to support the demands of the Spanish kingdom. Detrimental and hazardous circumstances accompanied this activity. After this, mining had a great period of decadence and scarce opportunities of technological advances (Lane, 2010;Salazar, n. d.). In 1896, in the Zaruma-Portovelo region, in the province of El Oro, the South American Development Company (SADCO) executed the first large-scale operation during 53 years (PRODEMINCA, 2000). In the decade of 1980s, Nambija, in the province of Zamora Chinchipe, was discovered due to the high amount of gold carried by the Nambija River. A gold rush moved around twenty thousand people to Nambija, and they started non-technical and dangerous operations to recover the rich mineral and extract gold. Nambija was the center of gold production in Ecuador for several years (PRODEMINCA, 1999; Salazar, n.d.). However, the unsafe conditions applied in the mining activity to recover gold, plus the lack of technical studies and organization led to significant amount of landslides and deaths. Ponce Enriquez, in the province of Azuay, is a relatively young mining district. The floods produced by El Niño Current in mid-1980s, led to discover rich minerals under the vegetation layer removed because of landslides. Currently, this region is very active regarding mining activity (Tarras-Wahlberg et al., 2000).

In summary, the accelerated expansion of small-scale mining took place in the 80's, and legalization of small mining operations started in the next decade. In addition to this, the absence of legislation arose environmental and social issues. (MMSD América del Sur, 2002). Regarding the environmental impacts of small-scale and artisanal mining, most of them are caused by metals, metalloids and cyanide that are discharged into the rivers either dissolved or associated with suspended solids (Tarras-Wahlberg et al., 2000). Based on the precarious and disorganized growth of artisanal mining, technology was obsolete, safety conditions were almost null and the miners had no training at all. (INIGEMM, 2011)

CURRENT SITUATION

The Ecuadorian Mining Law describes artisanal mining as that performed manually or with basic tools and equipment in an individual, familiar or associative manner. Moreover, qualification as small-scale mining depends on the exploitation and processing capacity together, which is lower than three hundred tons per day. (Asamblea Nacional, 2009). In addition, the Mining Law established the execution of a mining census in order to gather information about localization, technical characterization and registration of mining activities. Consequently, different governmental institutions achieved the most recent Artisanal Mining Census in 2010 (MRNNR, 2010).

The main findings of the Census demonstrated that 22 out of 24 provinces in Ecuador have mining activities, and about 72% of these are concentrated in El Oro, Zamora Chinchipe and Azuay as illustrated in Figure 1 and Figure 2. A mining activity is defined as the mining itself, the ore beneficiation and commercialization.

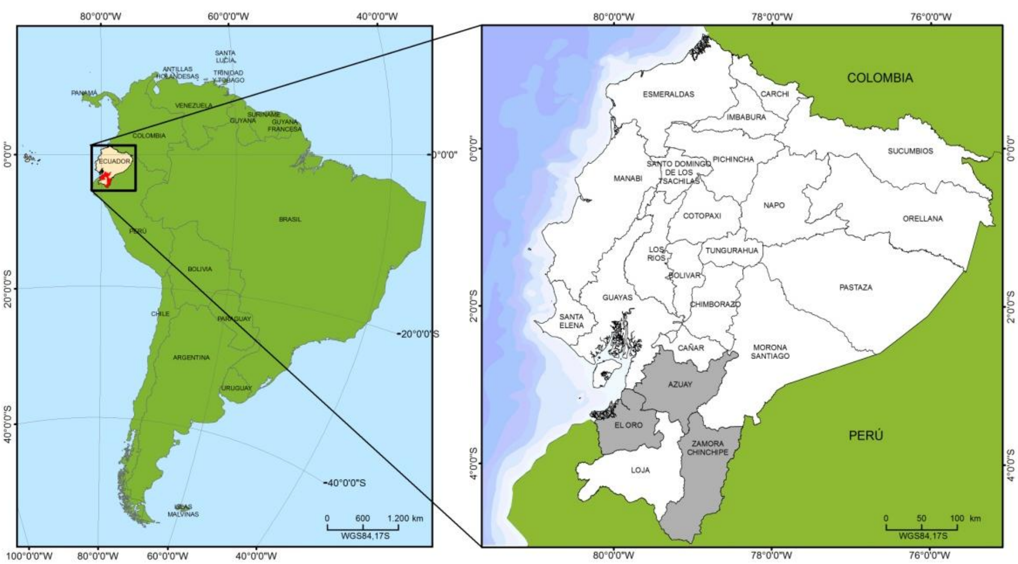

Figure 1. Location of Ecuador in South America and Azuay, El Oro and Zamora Chinchipe in Ecuador

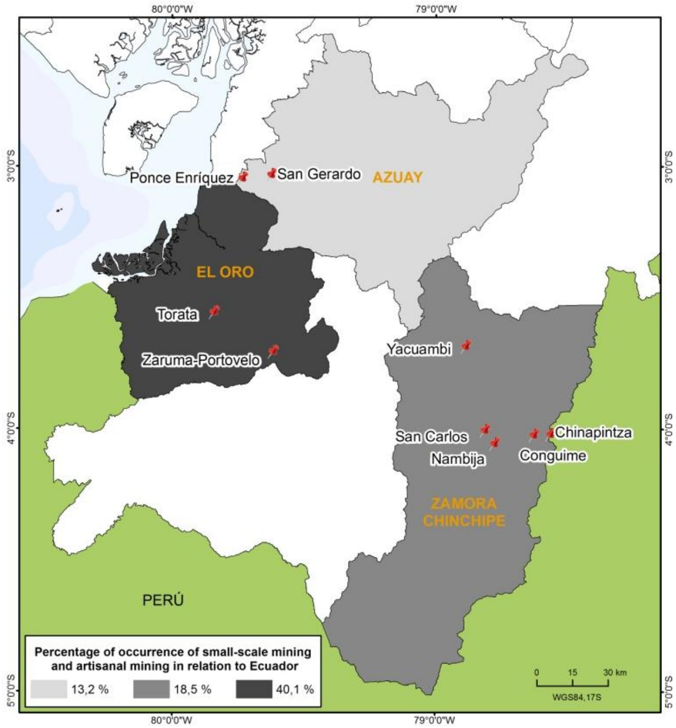

Figure 2. Percentage of occurrence of small-scale and artisanal mining in Zamora Chinchipe, El Oro and Azuay and principal mining locations. (MRNNR, 2010)

The Ministry of Non-renewable Natural Resources, through the National Institute of Research in Geology, Mining and Metallurgy INIGEMM, is executing the Project of Improvement of the working conditions of small-scale and artisanal mining since 2011 in Azuay, El Oro and Zamora Chinchipe. The main goal of the Project is to improve the working and living conditions of small-scale and artisanal miners and their families. In order to achieve the objectives of the Project, the technical staff assures effective technical assistance and transfer of clean technologies to develop sustainable mining (INIGEMM, 2011).The project has seven different components:

1. Creation of awareness and diffusion
2. Land use and formalization support for the small-scale and artisanal mining
3. Technology transfer and improvement of the working conditions of the small-scale and artisanal mining
4. Working, health and safety conditions improvement
5. Environmental management improvement
6. Social management improvement
7. Management, follow-up and monitoring

Each component has a specific objective. The first seeks awareness for small-scale and artisanal miners, their leaders, local authorities and the population directly affected by mining. During the first two years of the Project, 1341 people have received awareness about good practices in small-scale and artisanal mining. The second looks for means of planning to support land use and formalization. In regard with the third component, it contains two main branches: mining and extractive metallurgy. Both look for technical assistance through training in order to improve the mining exploitation system and the ore processing. The fourth component looks for means that guarantee the reduction of risks in health and safety. The fifth component, studies the existing contamination in river basins directly affected by mining. The sixth component promotes the improvement of the living conditions of the miners and their families through coaching and advice about reinvestment, inclusion and regularization. Finally, the seventh component monitors and follows the advancement of the Project. (INIGEMM, 2011).

The extractive metallurgy technicians of the project studied specific operations and processes that are commonly used for ore processing, either alluvial or underground. The operations studied are: amalgamation drums, gravimetric concentration in sluice boxes and Chilean mills. The main findings are explained below.

Gold recovery from underground ore through amalgamation drums

Amalgamation is the most applied method in artisanal and small-scale mining either as a principal operation or as a complementary. The locations of Ponce Enríquez and Portovelo present an amalgamation drum usage of 50% and 65% respectively. However, Nambija has no gold recovery process other than amalgamation. The equipment employed is commonly known as “chancha”. This device consist of a metallic drum, similar to a small ball mill. Figure 3 shows an amalgamation drum. This apparatus is very popular due to the low capacity of processing, so it is preferred especially for artisanal miners in spite of its low efficiency. Three amalgamation drums were analyzed in Portovelo in the province of El Oro, Ponce Enríquez in Azuay and Chinapintza in Zamora Chinchipe. The actions included analyzing the amounts of gold recovered and lost, the effectiveness of mercury (Hg) for gold recovery, the amount of Hg recovered and the quantity that is lost in the tailings.

Figure 4 shows results of three amalgamation tests conducted in specific plants in each region of study. Gold recovered in El Oro reaches 71,6% and the gold lost is 28,2%. In Zamora Chinchipe, the amount of gold recovered is 33,3% and the gold lost in the tailings reaches 60,6%. Finally, the gold recovered in the amalgam in Azuay is just 9,7% and the gold lost is 90,3%. The great amount of losses is due to the high gold content in the tailings and the large volumes discharged. The gold content in the tailings goes from 22,7 g/t to 79,1 g/t (INIGEMM, 2013a; INIGEMM 2013b, INIGEMM, 2014a).

Figure 3. Amalgamation drum

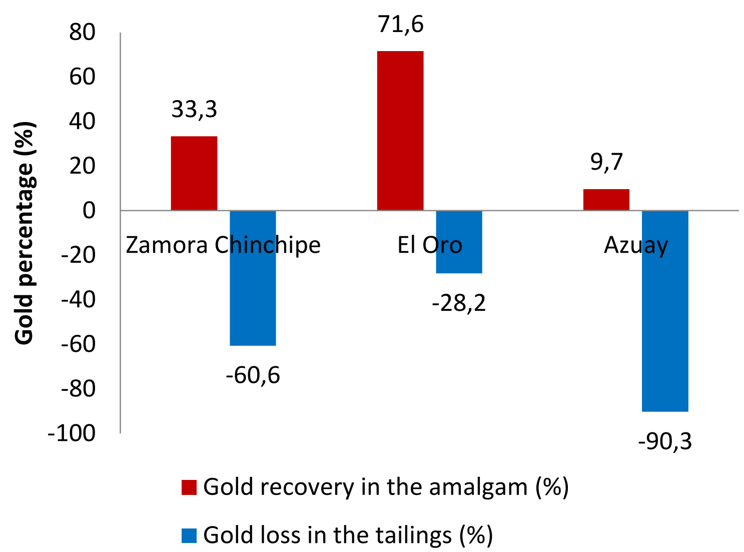

Figure 4. Distribution of gold in the amalgam and the tailings

Moreover, a mercury mass balance let asses the effective usage of mercury. The concentration of Hg in the tailings goes from 3,3 % to 14,8 % because of the inefficient separation between the amalgam and the tailings as shown in Figure 5. In a study performed by Velásquez-López et al. (2010) the amount of mercury registered in the tailings reached 27,5 %. Equally, the amount of mercury used effectively goes from 2,1% to 18,1%. The ore may behave in this manner due to its lack of selectivity, poor preparation and inactivity of its surface. The non-amalgamated mercury was recovered after pressing the amalgam in a tissue. The rates of recovery were from 73,2% to 94,6%. In summary, the amalgamation process applied in Azuay has the lowest performance in both gold recovery and effective usage of mercury (INIGEMM, 2013a; INIGEMM 2013b; INIGEMM, 2014a).

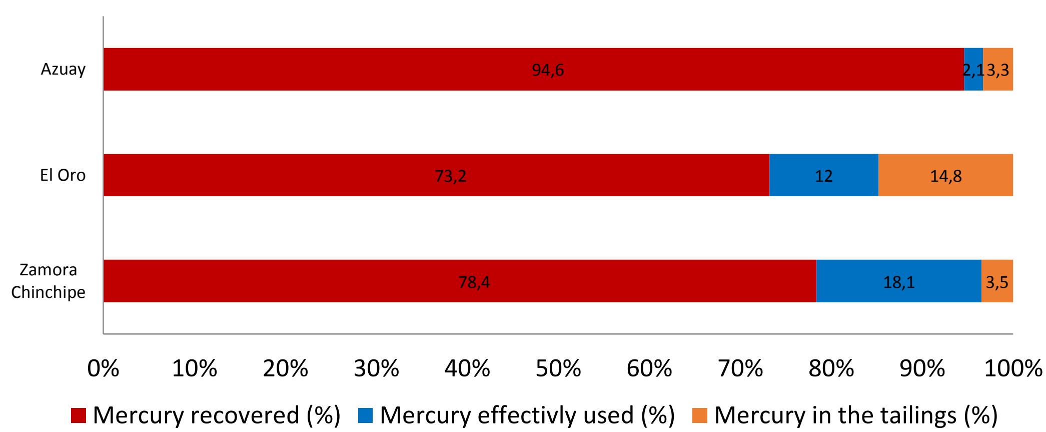

Figure 5. Distribution of mercury in amalgamation process streams

Gold recovery from alluvial ore through gravimetric concentration

The Zamora-Chinchipe-Upano alluvial mining district is one of the most important of the country. Part of this is located in the province of Zamora Chinchipe, where the project takes place. The processing of alluvial ore takes place by gravity concentration in three or more sluice boxes. These are disposed one after the other in a zeta letter arrangement with an inclination between 5° to 12° as shown in Figure 6. An excavator feeds the ore into a hopper, and high-pressure water, which is not usually controlled, washes the ore. The valuable materials travel through the sluice boxes, and the heavier particles are trapped into the carpets or tissues that cover the inclined plane.

The metallurgical team of the project performed a study in nine alluvial operations in three different zones known for the alluvial mining activity: San Carlos de las Minas in Zamora, Congüime in Paquisha and La Paz in Yacuambi.

Due to the heterogeneous nature of the feed mineral, the gold occurrence was low. However, the tailings presented a gold content that varied from 0,17 g/t to 9,98 g/t. In addition, the size of the gold was studied. Gold between 44 µm and 88 µm reached 65% of the total gold present in the tailings as shown in Figure 7. As a result, it demonstrated inefficiencies of gravity concentration. In addition, the excessive amount of water used without control to wash the mineral may explain the poor gold recovery. Operations E and F, where the amount of coarse gold in the tailings was low, had the lowest pulp volume discharge and the lowest gold concentration of 0,17 g/t and 0,38 g/t respectively. However, further investigation is recommended. In addition, some evidence of the usage of mercury in the gravity concentration device was found in the tailings. In one case, the concentration of mercury reached 2,57 mg/kg (INIGEMM, 2013c).

Figure 6. Gravity concentrator in sluice boxes

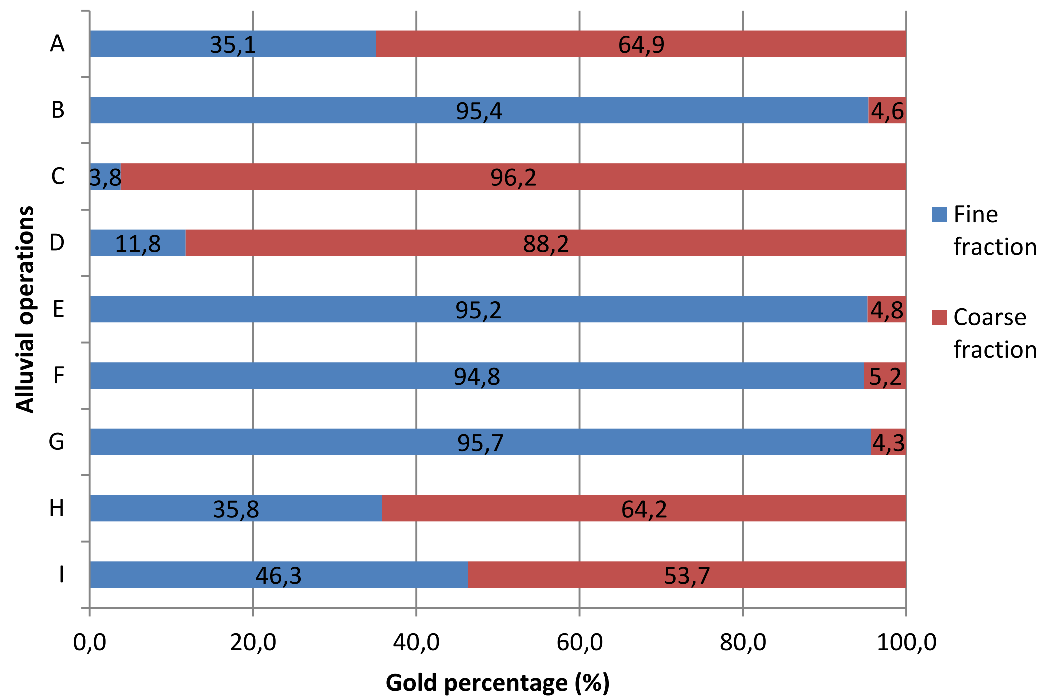

Figure 7. Distribution of alluvial gold in two different size fractions in the gravity concentration tailings

Characterization of the Chilean mill discharge

In Nambija, nineteen discharges of Chilean mills were studied in order to analyze the grinding level and the size of the gold grains. The Project team carried out the study in two specific locations: North Condominium and South Condominium. The grinding level in the North was better than that of the South with a media of 122 µm and 217 µm correspondingly. Besides, the size of gold in the North Condominium is, in its majority, below 44 µm. This explains that gravity concentration by means of sluice boxes is not effective on this site. On the other hand, the majority of gold content for South Condominium was on the coarser fractions. Nevertheless, this is related to the grain size too (INIGEMM, 2013d; INIGEMM, 2014b).

ACTIONS FOR THE FUTURE

The Ministry of Non Renewable Resources is developing the National Development Plan of the Mining Sector for the period 2011-2015. This document considers small-scale and artisanal mining activity as a dynamic gear of local economy by means of generation of job places and regional development. Equally, all the efforts are in agreement with the basic policies of the Ecuadorian Constitution and the development model of the National Plan for Good Living (MRNNR, 2011).

All the experiences recovered from the field during 2012 and 2013, led to an action plan for 2014. Currently, the Project technical staff directs its efforts to the improvement of the working conditions with safety, social inclusion, involvement and environmental concern. In fact, the technology transfer component, with its extractive metallurgic branch, is working on two defined fronts: Improvement of the on site activities and the development of metallurgical processes without the usage of mercury.

The first stage started with the development of methodologies for sampling and tracking of the most common unit operations used in small-scale and artisanal mining, such as: amalgamation drums, Chilean mills, sluice boxes for underground material and alluvial ore, cyanidation with activated carbon or zinc cementation and flotation. These procedures intend to help on site studies in order to avoid systematic errors due to the instrument, the operator or the measurement. In the end, the analysis performed would lead to find bottlenecks and improvement opportunities to pursue the goal aligned with the eradication of mercury in ore beneficiation processes.

At the same time, a metallurgical laboratory is projected to develop specific operations and processes based on the characteristics of the ore in order to benefit not only the gold but also all the metals and minerals of value.

REFERENCES

ASAMBLEA NACIONAL, 2009, Ley de Minería.

INIGEMM, 2011, Programa de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 1-7.

INIGEMM, 2013a, Evaluación y diagnóstico preliminar de una planta de beneficio de minerales por amalgamación en el distrito minero de Portovelo, Proyecto de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 6-8.

INIGEMM, 2013b, Evaluación y diagnóstico preliminar de una planta de beneficio de minerales por amalgamación en el distrito minero de Ponce Enríquez, Proyecto de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 8-10.

INIGEMM, 2013c, Estudio de la actividad de recuperación de oro secundario en equipos de concentración gravimétrica tipo zeta en la provincia de Zamora Chinchipe, Proyecto de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 8-22.

INIGEMM, 2013d, Evaluación y diagnóstico del proceso de recuperación de oro primario en el sector Condominio Norte del distrito minero Nambija, provincia de Zamora Chinchipe, Proyecto de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 5-12.

INIGEMM, 2014a, Evaluación y diagnóstico del proceso de recuperación de oro primario en un tambor amalgamador en Chinapintza, provincia de Zamora Chinchipe, Proyecto de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 4-11.

INIGEMM, 2014b, Evaluación y diagnóstico de la pulpa de descarga de molinos chilenos en el sector Condominio Sur del distrito minero Nambija, provincia de Zamora Chinchipe, Proyecto de mejoramiento de las condiciones de trabajo de la pequeña minería y minería artesanal, 4-14.

Lane, K., 2004, Unlucky Strike: Gold and Labor in Zaruma, Ecuador, 1699-1820. Colonial Latin American Review, 13 (1), 65-84.

MRNNR Ministerio de Recursos Naturales No Renovables, 2010, Censo Minero Artesanal 2010, 16-22.

MRNNR Ministerio de Recursos Naturales No Renovables, 2011, Plan Nacional de Desarrollo del Sector Minero, 9-34.

MMSD América del Sur, 2002, Minería, Minerales y Desarrollo Sustentable en América del Sur, 441-448.

PRODEMINCA, 1999, Monitoreo ambiental en las áreas mineras en el sur del Ecuador 1996-1998, 17-20.

PRODEMINCA, 2000, Medidas Ambientales Emergentes y el Establecimiento de un Plan Maestro Ambiental en el Distrito Minero Portovelo-Zaruma y la Cuenca del Río Puyango. Plan Maestro Ambiental, 24-25.

Salazar, E., n. d., Principales hitos de la minería en el Ecuador, Energía y Minas, 85-89.

Tarras-Wahlberg, N., Flachier, A., Fredriksson, G., Lundberg, S. y Sangfors, O., 2000, Environmental Impact of Small-Scale and Artisanal Gold Mining in Southern Ecuador: Implications for the Setting of Environmental Standards and for the Management of Small-Scale Mining Operations, Ambio, 29 (8), 484-491.

Velásquez-López, P., Veiga, M., y Hall, K., 2010, Mercury balance in amalgamation in artisanal and small-scale gold mining: identifying strategies for reducing environmental pollution in Portovelo-Zaruma, Ecuador, Journal of Cleaner Production, 18, 226-232.