# SUSTAINABLE MANAGEMENT OF WASTE GENERATED IN ARTISANAL GOLD MINING IN ECUADOR

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***ABSTRACT***

*In Ecuador, artisanal alluvial gold mining is generally carried out on the banks of rivers, which brings with it a number of impacts on the environment that can be classified as negative, and among which is included the generation of effluents, the deforestation of primary forests, atmospheric emissions, the generation of polluting solid waste and the establishment of communities without sanitation services. Therefore, observations were made in some sites, as well as interviews and surveys, and from the information obtained, a SWOT matrix was elaborated, organizing the results in tables and bar graphs. In addition, a diagnosis of current waste management was carried out, where it was determined that it is inefficient, so that a design and proposal to improve waste management for artisanal gold mining companies in Ecuador was made. establishing metrics and indicators to control the development of proposals to improve solid waste management in the artisanal gold mining company.*

***Keywords**: Solid Waste Management, Artisanal Gold Mining, Mining Waste.*

## INTRODUCTION

In Ecuador, gold mining has existed as a means of subsistence sinceancestral times, and those who practice it, execute it in an artisanal way with manual instruments, extra and in C only small amounts of the metal and obtaining hardly any profits for family sustenance. But unfortunately, this activity entails a series of negative impacts on the environment, damaging not only the ecosystem, but also the health and life of the communities surrounding the mining extraction. Being the excavation, deforestation and the generation of solid waste typical of the activity, which contain a large amount of toxic andharmful chemicals, the main cause of these environmental impacts.

Therefore, it is urgent and necessary to implement in gold mining a Solid Waste Management that is efficient and that allows the proper management and disposal of these wastes, as well as the education and training of all those involved in the mining exploitation process.

Therefore, to address this problem, the methodology that will be applied in the development of the research, some important definitions, the scope and limitations of the same are raised in this work.

In addition, conceptual information on the relevant topics of the study, their importance and comparative and critical analyses of them are presented.

It also presents the diagnosis of the problem studied, elaborated fromthe information obtained which is shown in tables and bar graphs, as well as a proposal to improve the existing Waste Management and the mechanisms for its control and monitoring. Finally, the conclusions and recommendations are proposed according to the results obtained and the fulfillment of the objectives proposed in the research.

## PROBLEM STATEMENT

InEcuador's indigenous communities, gold mining is a deep-rooted activity, since it has been a traditional work for their subsistence for more than a century. This work has been developed using mainly hand tools, which is why it has been defined as artisanal mining and is based on family work, so it is possible to extract the mineral in very low quantities and obtain profits that only serve to maintain the economy of the family (Mining, Minerals and Sustainable Development [MMSD], 2002). Currently in our country, artisanal and small-scale gold mining (ASM) is mainly developed in five areas, and in these 25 mining sites have been identified. These identified mining activities (Ministry of the Environment, 2020)are developed both in galleries in a primary way, and on riverbanks in an alluvial way.(Ministry of the Environment, 2020)

Among the main environmental problems caused by artisanal gold mining are deforestation of primary forests, the establishment of communities without sanitation services, effluent and waste management, cyanidation, the use of mercury during amalgamation and the discharge of debris, tailings, tailings sands loaded with metals, sulfates and sulphides in rivers and streams (MMSD, 2002). Hence, it is necessary to develop an efficient waste management to be applied in the areas of artisanal gold mining in the different mining sites.

## JUSTIFICATION OF THE PROBLEM

According to Espinoza (2016), efficient waste management contributes not only to the change of behavior and habits of the different participants in the artisanal gold mining activity, but also makes important contributions to technology, by ordering processes and technifying extraction practices, allowing its application in different mining areas. Aproposal for a better management of waste from artisanal mining in Ecuador can be based on the results that will be achieved with the diagnosis and improvement of current management, as well as with the development of good practices, both operational and environmental.

It has been proven that artisanal gold mining when developed indiscriminately and without the respective control causes negative environmental impacts because it uses water components of the ecosystem such as rivers, lagoons and swamps, which are severely affected by the chemicals used for the separation of the metal (UNDP, 2021, p. 23). In addition, in the mining extractions of artisanal exploitation, fine solid materials called tailings, of varied composition, are discarded, which together with the chemical contamination of the waters, bring consequences to the biodiversity of the environment and to people (Espín *et al*, 2017, p. 5). Therefore, the implementation of efficient waste management to minimize these impacts is imminent.

Thus, it is necessary to diagnose the current procedures and their deficiencies, through the development of interviews, detailed observations and the application of instruments and surveys, in order to collect the required information, and subsequently present a proposal for improvement that provides new knowledge in the management of waste produced in artisanal gold mining and systematizes the procedures of this mining extraction. (Valdivia, 2021).

## METHODOLOGY

In order to present a proposal to improve solid waste management, an in-depth bibliographic review of research, government statistics and other national and international organizations was first

carried out, with the purpose of making a preliminary diagnosisof the situation; then an observation in different mining areas, choosing the Napo Province to apply interviews and surveys to artisanal miners and inhabitants of the areas under study; The questions in these instruments were clear, short and easy to understand so that the collaborators did not get bored and lose interest in participating. The data obtained were ordered and tabulated for interpretation, presenting the results in tables and bar diagrams. With the information obtained, weaknesses, problems and needs were identified, and the design of the proposal to improve Waste Management was developed in stages, following the hierarchy of solid waste management, to generate responses and guide about the corrective actions to follow, as well as the control and monitoring mechanisms.

Therefore, this proposal to improve waste management was raised to be developed using a descriptive, observational and prospective methodology, since in this way the factors of the study are not intervened or manipulated, it is simply observed, measured, analyzed to finally answer the questions, in this specific case make the improvement proposal.

The research was of an applicable type, since it was based on different investigations about waste management in artisanal gold mining in Ecuador. On the other hand, it was transversal, since it was focused on a period of time between five months, to carry out the diagnosis of the different elements involved in the management of mining waste.

The design of the research was non-probabilistic, since no equation or formula will be applied to determine the study sample. The population under study were artisanal gold miners present in different mining areas of Ecuador. The sample consisted of 15 artisanal gold miners, which will be selected for the ease of location and access.

The techniques used were the bibliographic, which is the review of bibliographic material that may exist, referred to a study. It is one of the main steps in the development of an investigation, it also includes the selection of the different sources of information (Garay, 2020); observation is a research technique that involves observing phenomena, events, cases, objects, people, actions, situations, among other aspects, in order to obtain information necessary for the development of an investigation. Therefore, a direct, open-ended, non-participant observation was applied; the entrevista, which is a technique widely used in descriptive studies and in the exploration phases to design instruments, and in qualitative research to collect data (Díaz *et al*, 2013). Hence, semi-structured interviews will be conducted with artisanal gold miners, with a certain degree of flexibility, in order to obtain information according to the purposes of the study; and finally, the survey, which is a technique used within a descriptive research design to produce and collect quality information at a qualitative and / or quantitative level. in an orderly manner (López & Fachelli, 2015). This was done to a group of artisanal miners, using a questionnaire.

To address the problems, and also to extract and collect information, instruments such as computer, notebook, tables and previously designed questionnaires were used.

The collection of data and information was carried out through a bibliographic review, observing the miners during the extraction of the mineral, conducting interviews and applying a survey to miners. Once the information was collected and the data obtained, they were ordered in tables and tables, presented in circular or cake diagrams to facilitate their analysis and interpretation, and finally the diagnosis and the proposal for improvement were made.

## RESULTS

Once the bibliographic review was carried out, which allowed to collect information about the background of the research, as well as the legal framework governing mining activities, and following the proposed methodology, we proceeded to make observations in artisanal gold mining, interviews and surveys to miners and inhabitants of mining areas, obtaining the results presented in Table 1.

**Table 1.** *Observations made in mining areas*

| Aspect to watch | Observed characteristics |
|---|---|
| Inhabitants | Most of the inhabitants are of ethnic origin, although people of mestizo origin and some whites were also observed, there is a lot of presence of children and young people, but the elderly were also observed; The presence of men and women equally could be observed. The inhabitants are friendly people and have a command of Spanish, although a little mixed with accents of their languages. |
| Communities | In the communities there was growth without planning, poorly built and deteriorated housing, absence of services and public spaces, dirty and deteriorated streets. |
| Rivers | Turbid, turbid, polluted waters were observed, with a large presence of excavations and diverted channel. Miners were observed in the area and leaders (mafias) who prevented the use of cell phones. |
| Solid waste | It was possible to observe a great presence of sand and tailings, arranged on the banks or beaches of the river, or in the center of the channel (islands). No other solid waste was observed. |

With the use of the SWOT organizational analysis tool, the diagnosis of artisanal mining in Ecuador will be presented, as shown in Figure 1.

**Figure 1.** *SWOT Analysis of Ecuador's Artisanal Mining*

| STRENGTHS | OPPORTUNITIES |
|---|---|
| • Preparation of a proposal to improve waste management<br>• Implementation of a solid waste management system that recovers waste.<br>• Extensive knowledge of the artisanal gold extraction process. | • Implement sustainable environmental practices.<br>• Staff training in environmental care.<br>• Price of the product in the market.<br>• Support from international organizations. |
| **WEAKNESSES** | **THREATS** |
| • Failure to comply with legal regulations.<br>• Production method that affects the environment and health. | • Bad image of the company and the artisanal mining sector in the region.<br>• Strict environmental legislation.<br>• Negative publicity of the productive sector. |

From the SWOT analysis it can be inferred that the proposal to improve waste management and its implementation represents a strength that will allow the company to opt for legalization and association with groups and cooperatives in the sector and take advantage of the benefits of international organizations to companies that implement sustainable production processes; since precisely the breach of legal regulations and an extraction process that causes affection to the environment are its main weaknesses. Similarly, staff training in environmental protection and sustainable practices helps to improve the image of the company and the artisanal mining sector in the eyes of local, regional and national public opinion.

The observation made allowed us to make the description of the artisanal gold mining, starting with the explanation of the production process, where the stages of the same will be presented with their inputs, outputs, residues and the quantities of each one. The process of artisanal gold mining begins

with the extraction of thesands of the determined place to be taken to the feeding of the gutters (a small company can extract up to 200Kg / h, therefore that was our calculation base), where the washing will be done, with water (6000L / h) from the same river where the sand is extracted, using a motor pump. In the gutters the sands are washed and screened according to their density and size, the largest fall from the carcass (192 kg) and the thinnest (8kg) are deposited at the bottom of the carcass, in a carpet or rubber located under the grid, to which 1 kg of mercury has previously been added. This process is done per charge, investing 1 hour in each charge, so 7 charges are made per day.

Next, the fine sand trapped in thecarpet is washed with agitation in plastic containers and the surface is removed, leaving only the heaviest that goes to the bottom, which is taken to a plastic raft where an additional 200g of mercury has been deposited, and the sand is barequeo to improve separation. This sand is removed from the raft and only the amalgam of gold with mercury is left, which is subsequently passed through a filter cloth to remove the residual mercury which is recovered by 30%. Once the amalgam balls of a day's work have been obtained, they are taken to a metal container, where they are subjected to heating by direct flame of the stove; where mercury vapors are released into the atmosphere and the gold remains in the container free of impurities, achieving approximately 1 kg / day.

Also, a summary of the information obtained in the different interviews is presented in Table 2.

**Table 2.** Interview with artisanal miners

| No. | Response Summary |
|---|---|
| 1 | He is an artisanal miner, an inhabitant of the community, who learned the trade from his father since childhood. It is not legalized, it knows that mining pollutes the environment and chemicals are dangerous, but it has no other way of income to support the family. |
| 2 | It is about a woman who practices artisanal mining, an inhabitant of the community, who learned the trade from her husband. It is not legalized, it knows that mining pollutes the environment and chemicals are dangerous, but it has no other way of income to support the family. |
| 3 | This interviewee is an inhabitant of the community, learned to mine with his neighbors, is not legalized, knows that mining pollutes the environment and chemicals are dangerous, but has not found another job. |
| 4 | It is about a teenager, who studies some days and other days helps his parents to mine, from whom he is learning the trade. He doesn't know that mining pollutes the environment, nor that chemicals are dangerous. |
| 5 | This is the case of an artisanal miner who moves from one community to another community to mine to bring sustenance to his home. He knows that there are laws and that mining causes damage to the environment. |

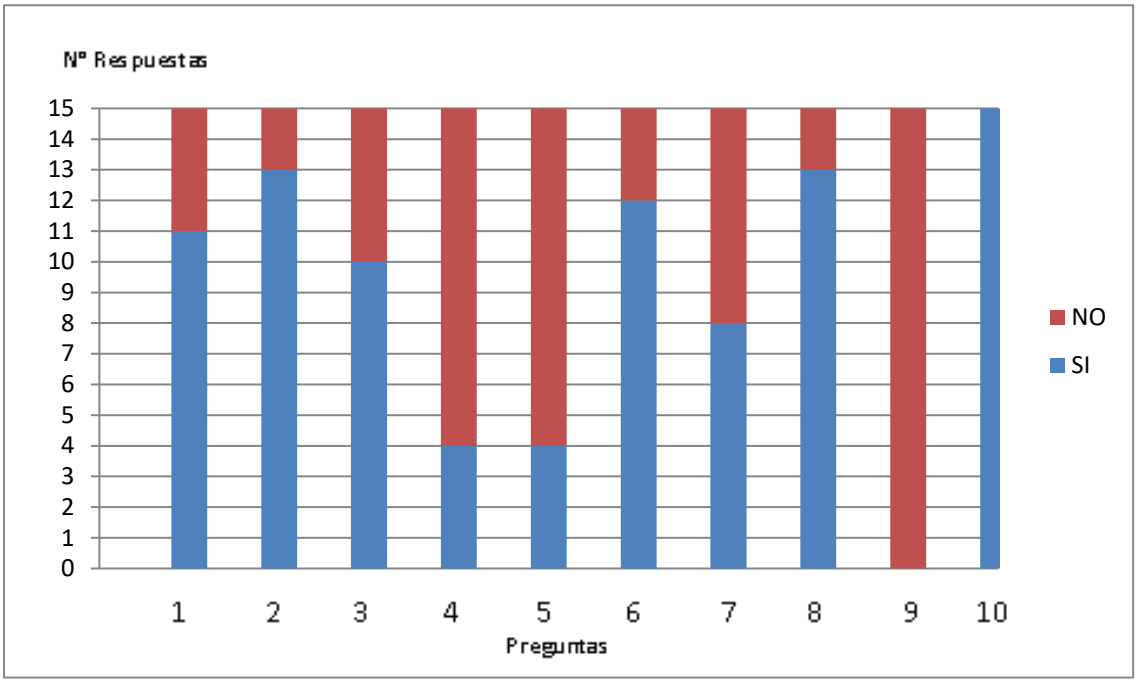
Table 3 and Figure 2 present the answers to each question.

**Table 3.** ***Responses to the survey of miners***

| No. | Question | YES | NO | Don't know/ Not responding |
|---|---|---|---|---|
| 1 | Are you an inhabitant of the place? | 11 | 4 | 0 |
| 2 | Do you work in artisanal gold mining? | 13 | 2 | 0 |
| 3 | Did you learn mining with your family? | 10 | 5 | 0 |
| 4 | Do you know how dangerous mining is? | 4 | 11 | 0 |

| | | | | |
|---|---|---|---|---|
| 5 | Do you know the damage caused by artisanal mining to the environment? | 4 | 11 | 0 |
| 6 | Do you agree with gold mining in the area? | 12 | 3 | 0 |
| 7 | Do you know that there are laws that regulate mining? | 8 | 7 | 0 |
| 8 | Do you know that it is important to take care of the environment? | 13 | 2 | 0 |
| 9 | Have you received training on how to take care of the environment? | 0 | 15 | 0 |
| 10 | Would you like to receive training? | 15 | 0 | 0 |

**Figure 2.** *Survey responses to miners*




According to the results obtained to the questions, it can be observed that most of the artisanal miners are inhabitants of the nearby communities, however, there are some who live in another community and only come to work in mining extraction; 13 work in artisanal gold mining and 2 of them answered no, because they work in mining extraction, but not artisanal but for a company; that 10 learned to mine gold by hand with their family, that is, that this trade has been the means of income to the family for years, and that only 5 learned the trade with other sources.

Similarly, it is observed that only 4 answered knowing that artisanal mining is a dangerous activity, and 11 state that they were unaware of the danger that this activity brings; Only 4 respondents respond to be aware that the activity of artisanal gold extraction causes environmental damage, and 11 say they do not know this, claiming that they only use shovels and rafts in the activity and that 12 respondents say they agree with artisanal gold mining, because this is an activity that their ancestors did and does not cause damage to the environment, and 3 say they do not agree with this activity, but it is their only source of income. In addition, it is observed that 8, of 15 respondents express knowledge that there are laws that regulate artisanal gold mining, while 7, express that they do not know these laws and that 13 miners know and understand that it is important to take care of the environment, and only 2 say they do not know the importance of caring for the environment. Regarding training in environmental care, the total of respondents respond that they have never received training, but that they are interested in receiving it.

Finally, applying the methodology for the diagnosis of the current situation of artisanal mining in this region, and analyzing the information obtained through the application of on-site observation,

interviews and surveys, it can be said that, currently in the company under study, Solid Waste Management is totally deficient and inadequate. because the solid waste generated during the process, are disposed next to the banks of the river without any prior treatment, and that the people dedicated to this activity do not know the importance of carrying out an adequate management of solid waste, of legalizing artisanal mining, of knowing the danger involved in the use of chemicals and the need to make this activity sustainable and friendly to the environment, therefore, a proposal to improve Solid Waste Management for artisanal gold mining is made below .

After carrying out and analyzing the diagnosis of solid waste management in artisanal gold mining in the Province of Napo, Table 4 presents a proposal for improving management that can be extrapolated to artisanal gold mining developed in the country, basing it on the stages of the pyramid hierarchy of solid waste management shown in Figure 3. , applied to artisanal gold mining. Subsequently, each of the proposed improvements will be described, detailing the resources, those responsible for each one and the time necessary for their implementation.

**Table 4.** Proposal to improve Solid Waste Management

| Stage | Proposed improvement |
|---|---|
| **Reduce** | • Training of personnel in environmental protection.<br>• Change of technology.<br>• Legalization of the company.<br>• Partnership with other companies and organizations in the sector. |
| **Recycle** | • Recovery of waste when selling it to another company. |
| **Treatment** | • Develop a plan for the proper closure of the operation. |
| **Final provision** | • Develop a plan for the proper disposal of waste. |

**Figure 3.** *Waste Management Hierarchy*


Source http://www.ptolomeo.unam.mx

**Description of the Stages**

**Stage: Reduce**

- **Training of the staff in environmentalprotection:** it is proposed to dictate courses and / or training and awareness workshops for staff, which include topics such as the importance of environmental care and natural resources, sustainable mining technologies, legal regulations of artisanal gold mining, for which experts in each of the topics will be invited.
- **Change of technology: since the waste** generated in artisanal gold mining has a high mercury content, it is imminent to change the extraction process to a method that does not use this chemical contaminant, and in this way the impact of the waste on the environment and human health is reduced.
- **Legalization of companies:** ensuring that mining companies comply with all mining legal regulations and register as such with the respective entities will result in benefits such as obtaining permits, requesting credits and training from government and international organizations and associating with each other.
- **Partnership between companies and organizations in the sector**: establishingrelationships between companies in the sector will allow the exchange of experiences and knowledge, program training plans together, request social benefits for the community and labor benefits for workers.

**Stage: Recycle**

- **Recovery of waste when selling it to another company: in view of** the fact that the screening and washing process applied in the company does not allow a longer contact time of the extracted material with mercury for a complete amalgamation, the waste generated can be recovered by being sold to other companies of greater capacity that have processes and equipment that allow a longer contact time and thus obtain an extra economic income.

**Stage: Treatment**

- **Develop a plan for the proper closure of the exploitation:** thisstage refers to the procedures to be carried out once the mineral is exhausted in the place where the mining is carried out, for the closure of the same, that is, that equipment and facilities will be removed from the place, as the removed vegetation will be restored, how the affected cause will be corrected, among other activities.

**Stage: Final disposition**

- Draw up a plan for the proper disposal of the waste: it will draw up a plan for the final disposal of the waste into the environment, in which it will be analysed to determine its level of contamination and the correct place for its location will be evaluated so that it does not affect the vegetation or the natural course of the river, Preferably the waste should be returned to its original place.

Table 5 presents the metrics or indicators established **to** control the development of proposals to improve solid waste management of artisanal gold in Ecuador.

**Table 5.** Matrix of Control Mechanisms

| Proposed improvement | Metric |
|---|---|
| Training of personnel in environmental protection. | Knowledge assessment at the end of each session |
| Change of technology. | Getting a quote |
| Legalization of the company. | Progress in required documentation |
| Partnership with other companies and organizations in the sector. | Approaches made |
| Recovery of waste when selling it to another company. | Waste sold |
| Develop a plan for the proper closure of the operation. | Progress of the plan |
| Develop a plan for the proper disposal of waste. | Progress of the plan |

## CONCLUSIONS

From the dayi a g nóstico de la a ct u al g e sti o n d e residuo s in artisanal gold mining in Ecuador, taking as reference the Province of Napo, it was determined that the way waste is managed is inefficient; in addition, Data were obtained to determine the amount and type of solid waste, the training needs of miners and thus design a proposal for management improvement.

In order to protect the environment from the consequences of this extractive practice, a pr o pue s t a d e better ofl s istem a d e g e stion d e r was designed esiduos for artisanal gold mining companies in Ecuador, where the actions to be followed for the implementation of the same and so on are presented. In a matrix, the monitoring and control mechanisms of the designed proposal that were established from the proposal were presented.

## RECOMMENDATIONS

- Perform mercury content analysis of the waste generated in the mining operation and thus be able to infer the level of impact on the environment and people.
- Keep a strict record of all daily entries and exits to the mining extraction process that allows a correct recovery of waste.
- Prepare a proposal for Integral Waste Management that includes the management of liquid waste and gaseous emissions.

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