Promoting Responsible Recovery and Handling of Mercury from Contaminated Artisanal Gold Mining Tailings in Colombia

Laboratory Results of Tests of Mercury Recovery by Copper Plates
Report February 2020

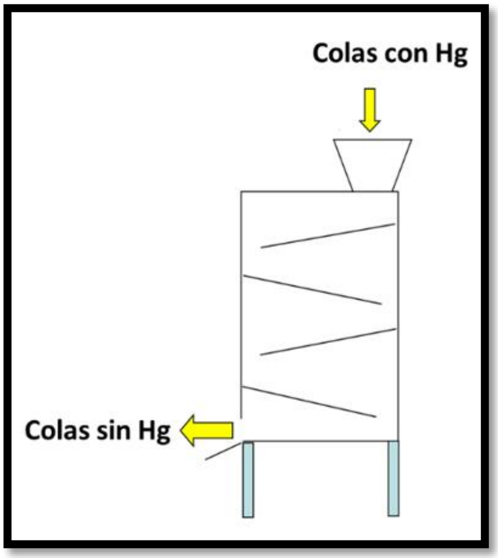

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Tabla de Contenido

1. Introduction

This document presents the results of laboratory-scale tests of one of the selected technologies for the recovery of mercury present in tailings generated by artisanal and small-scale gold mining (ASGM). These tests correspond to activities of the project entitled: "Promoting the recovery and responsible management of mercury in contaminated tailings from artisanal gold mining in Colombia," which is executed by Pure Earth and financed by the United States Department of State. This strategic have the technical support, by “National Center for Cleaner Production and Environmental Technologies (CNPMLTA)”, and for the initial part of the construction of the plates, the private company “Innovación Ambiental” -INNOVA S.AS E.S.P.

The tests took place in the laboratory of the Minerals Institute - CIMEX of the National University of Colombia, located in Medellin, and are considered as the previous step for the escalation to pilot tests in the plant; The proven technology corresponds to the Copper Plates.

2. Tailings Characterization.

2.1. Location and type of tailings

Since June 2019, a series of visits were made to different departments of the country in areas that report artisanal gold mining activity, with the suspicion of the use of mercury and the presence of contaminated tailings. Finally, tailings from four areas were collected, which due to their different characteristics allows a comparison of the effectiveness of the tests for each type of tailings selected. The selected tailings are:

Table 1. Tailings selected for laboratory tests.

Tailings	***Location***	***Kg***
San Roque	Antioquia	20
Soto Mayor	Nariño	15
Rio Quito	Choco	20
Rio Negua	Choco	20

Figure 1 shows the location of these tailings in the national territory.

Figure 1. Contaminated tailing's location

It is necessary to highlight that the selection of the sites for the evaluation of the tailings has a review of the country's mining exploration that must support the representativeness of the selected sites. According to the above, it is reported that the departments that concentrate the greatest extractive activity are Boyacá (18%), Antioquia (14%), Bolívar (10%) and Cundinamarca (10%), this information is reported by the mining report National, which shows that the department of Antioquia is the one with the highest percentage of extraction of metallic minerals with 34%, followed by Bolívar (28%), Chocó (12%) and Santander (6%). Northeast Antioquia is characterized by having the 3 of the oldest gold mining exploitation centers in the country in Cáceres, Remedios and Segovia. (Jiménez, 2019). San Roque is also a municipality in the northeast of Antioquia with a strong presence of artisanal mining and the use of mercury, but also important advances in the formalization process (Zapata, 2019). It is for this reason that it is particularly expected that the tailings located in San Roque comprise a representative composition of mercury (Hg) and Gold (Au) that allows a detailed evaluation of the recovery of Hg by the technology of the Copper Plates proposed in this report.

Table 2 describes the location of the tailings and their status at the time of collection, as well as the type of mining that generated the tailings.

Table 2. Tailings location description

Tailings	Área Description	Identified mining activity
San Roque – Antioquia	The Mining Units (UM) are located in 3 “veredas” of the Municipality of San Roque, which are Vda. The Awakening, Vda. The Carrilera and Vda El Basal. The area where the MUs are located corresponds to a rural area with proximity to inhabited homes, vegetated soils and water sources.	These are active artisan processing plants ("entable"), where gold is obtained through mercury amalgamation. Workers and people who live on these sidewalks and transit near the MUs are exposed to mercury by inhalation / ingestion. The processed rock comes from vein mining.
Andes – Nariño	La mina Gualconda está ubicada en el municipio de Los Andes, en el departamento de Nariño, en una zona montañosa y empinada. Se han depositado toneladas de relaves con mercurio en el sitio durante más de cuatro décadas. Si bien algunos de los relaves han sido contenidos en sacos, fracciones significativas se dispersan en pilas en un área sensible, muy cerca del arroyo Honda.	The Gualconda mine has been in use since 1975 and corresponds to vein-type mining.
Rio Quito – Choco	Rainforest area with evidence of environmental damage along the	The areas are affected by active illegal alluvial miners.

	riverbank, caused by illegal dredges that remain active.	
Rio Negua – Choco	Jungle area with evidence of environmental damage along the riverbank. Small-scale miners frequent the area using the barequeo technique, which uses sweeping to obtain residual gold.	The areas are affected by the illegal extraction of alluvial gold, but these operations are currently abandoned.

2.2. Tailings pretreatment

Taking into account the capabilities and limitations of the equipment used in the test set-up and in order to be able to carry out standardized tests for all tailings, these were previously treated in a 30 and 70 mesh screen. This allows the removal of particles from large size that can intervene in the efficiency of the tests because the particles that are retained in each one of the meshes are discarded and nothing else is worked with the through material. It is important to mention that at this stage of the process, a thorough washing of the materials to be discarded was carried out to ensure that no mercury losses were generated. Likewise, the tailings were concentrated by a vibrating table, for which it was possible to obtain two types of tailings for San Roque in which they were determined as concentrate and others as means, each of them had the same test processing protocol. The vibrating table classifies minerals according to their specific weight, in this way the heaviest materials such as sulfides, gold and mercury remain in concentrates. In the media are the materials whose specific weight is less than those of the concentrates. The table does not separate by size, however, it is important that the food on the table has a uniform size since, if a mineral has little specific weight, but is large, it can go into the concentrate stream and contaminate them. This is why a stage prior to concentration is classification as explained above.

It should be noted that mercury losses could have occurred in this screening process, for this reason this limitation will be evaluated at the time of carrying out the tests in the field and with more material.

Figure 2. Vibration Table for tailings concentration.
Source: https://www.911metallurgist.com/metalurgia/mesa-concentradora-para-oro/

The differentiated analysis of concentrates and fines is an important phase for tailings pretreatment. The reason is that the differentiated processing will be given by the type of tailings and as it is obtained from the tailings and directly from the site where they are present, for this reason, it will be established whether the concentrated or fine tailings have the same capacity to release mercury (Hg), into the tested copper plates. It is important to take this step into account when conducting pilot tests in the field.

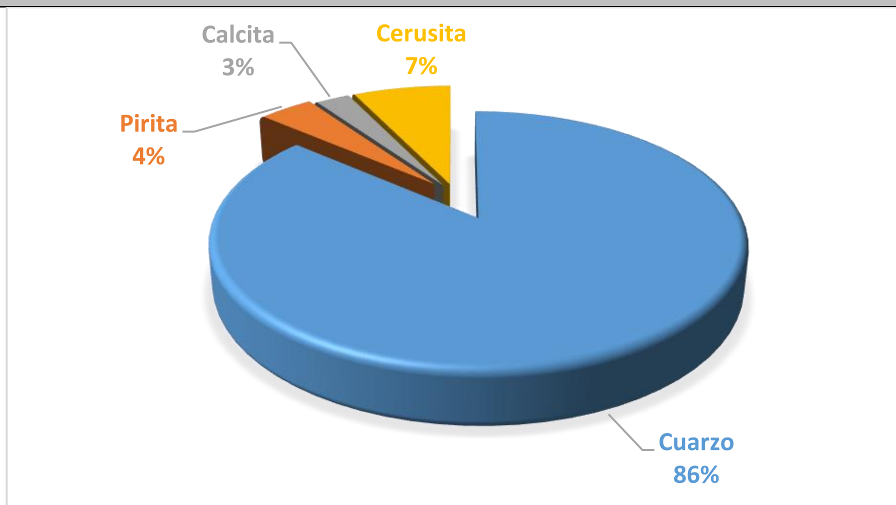
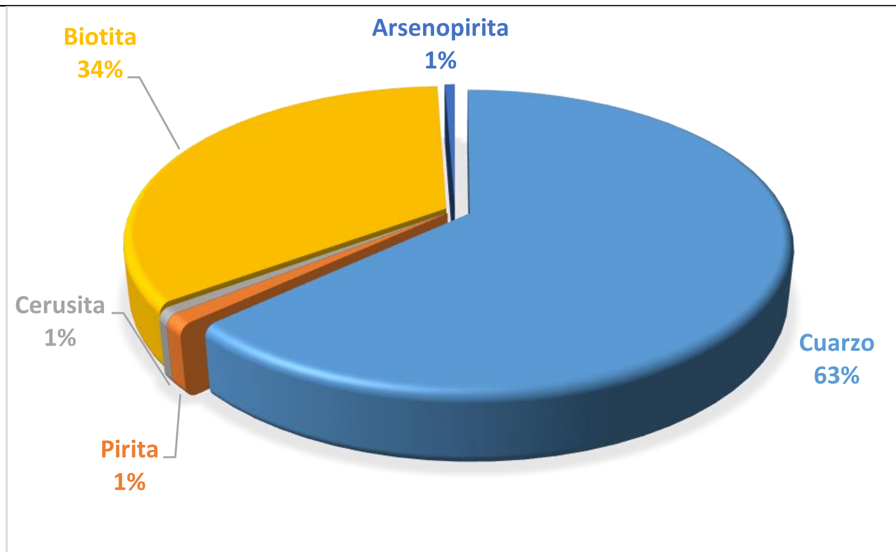
2.3. Mineralogical characterization.

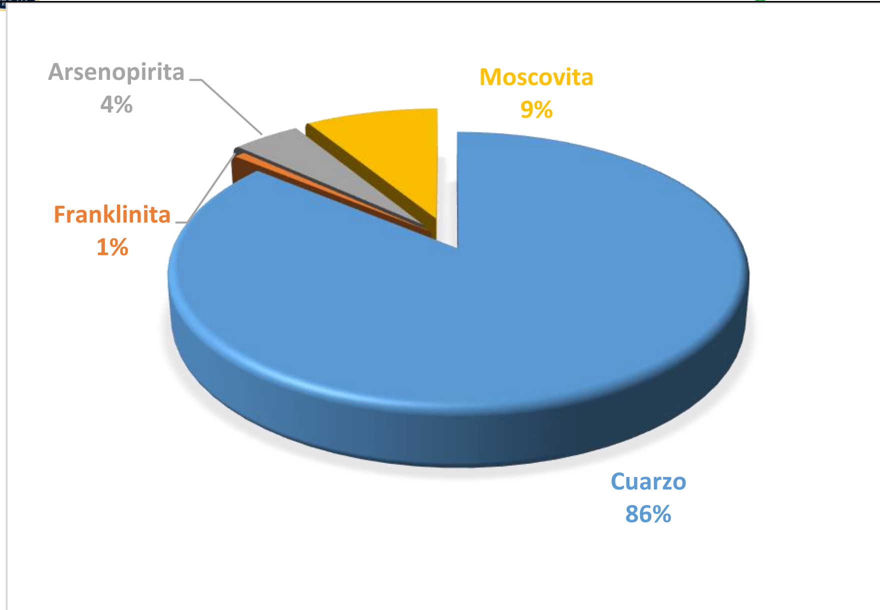
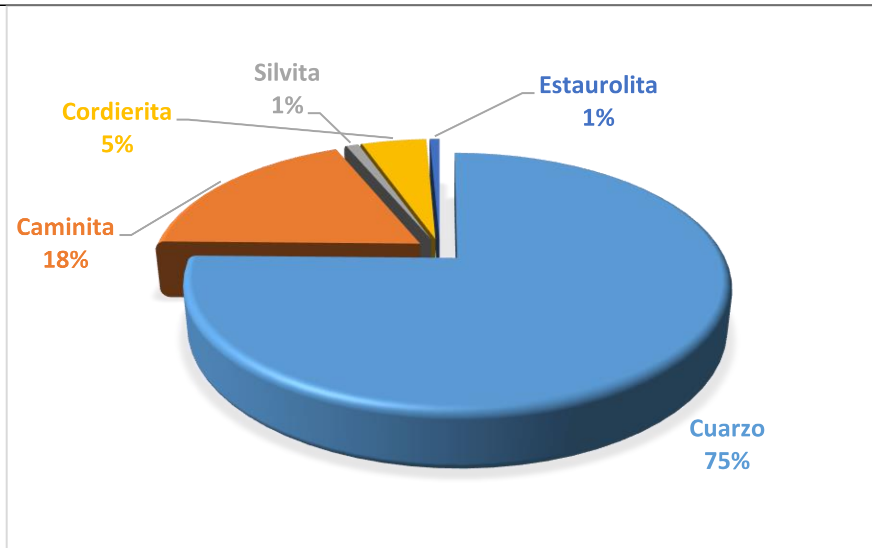
The mineralogy of the tailings was carried out by means of two tests, the first test consisting of an X-Ray Fluorescence (FRX) with the Epsilon 1 - Panalytical equipment, which reports the concentrations of the elements in percentage. The second test consists of an X-ray Diffraction (XRD) with the Aeris reference equipment, the purpose of which is to detect crystalline structures in the sample and to discover the minerals present in it. These two tests were developed by the Cecoltec laboratory.

The results obtained are percentages of a certain mineral in the sample. With the results of the analyzes, an idea can be formed about the composition of the materials with which they are working and many of the behaviors that they present in certain situations can be explained. Detailed reports can be found in Annexes A and B.

The Mineralogical composition of each of the tailings is shown in.Tabla 3. below

Tabla 3. Composición mineralógica de los relaves

Tailings	***Mineralogical composition***
San Roque - Concentrados	
San Roque – Finos	

Soto Mayor	
Rio Quito	

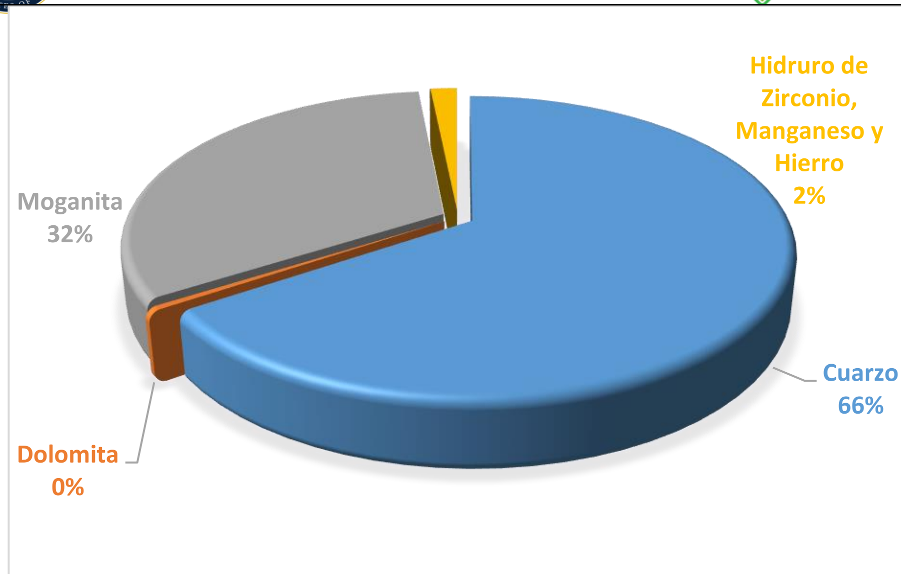
Rio Negua	

Table 4 describes each of the types of minerals found in the processed tailings.

Table 4. Mineralogical Description of tailings. (Cornelius, H, 1981) (Rosenqvist, T.1987) (Vásquez, M. H. 2005). (Vladimir Arias Arce, R. C.2005).

Mineral	***Important considerations***
Cuarzo	High hardness (7 on the Mohs scale) and high abrasiveness. Type of material with a high content of this mineral can deteriorate the amalgamating plates with greater speed, as well as crushing equipment and tanks.
Arsenopirita	Material with this type of mineral has the probability of storing associated gold, it is highly cyanicidal and a source of arsenic.
Pirita	Material with this type of mineral has the probability of storing associated gold and contributes sulfur in mining processes.
Dolomita	This mineral is a source of magnesium and provides carbon that can react with Mercury.

Calcita	This mineral is a source of calcium and provides carbon that can react with Mercury.
Cerusita	This mineral is a source of lead and provides carbon that can react with Mercury.

2.4. Chemical characterization of tailings

The chemical characterization of the tailings was carried out by two analytical methods, one corresponds to the determination of heavy metals by the Olympus brand Portable X-Ray Fluorescence Analyzer (XRF) and the other by the tests carried out on the samples by the Canadian laboratory Act Labs. .

It should be taken into account that an average of 12 readings were taken with the XRF for each of the tailings samples, the results obtained were averaged with the same number of readings. In contrast to the analyzes developed by Act Labs, the Fire Test for the determination of gold and analysis of Atomic Absorption (A.A) with cold steam for Mercury were developed. The detail of the results of results can be found in Annex C and D.

In addition, a measurement of mercury vapors was made for each of the tailings, taking advantage of the volatility of mercury due to its high vapor pressure (0.16 Pa) for metals, where around 300 grams of tailings were taken in a sealed bag, is kept closed for almost 20 min and then the mercury vapors are read with the HERMES equipment, which is used for the determination of mercury vapors at the occupational level, however, this test gives an indication of the presence of mercury in that sample.

Table 5 shows the results of mercury and gold concentrations of the tailings processed by the different methods.

Table 5. Au and Hg concentrations in the processed tailings

Tailings	***XFR Hg (ppm)***	***AA Hg (ppm)***	***P. Fire Au (g/ Ton)***	***HERMES Hg (ug/m^3)***
San Roque - Concentrados	58,3	100	53,8	8,6
San Roque – Finos	78,0	92,8	5,6	2,3
Soto Mayor	39,5	59,4	15,6	4,0

Rio Quito	0,0	0,8	0,29	7,0
Rio Negua	0,0	0,7	1,93	0,5

Although there is no correlation in the results obtained by each of the applied methods, a trend in the presence of metals can be evidenced according to the type of tailings processed. This is how the highest concentrations of these two metals are found in the San Roque and Soto mayor tailings, in the same way the tailings with the lowest reported value correspond to the tailings of Rio Quito and Rio Negua in Choco. Although it is too early to give a conclusion of this characterization if there is a direct relationship by the type of artisanal mining, while San Roque and Soto Mayor correspond to vein mining (tailings from inlets), the other two tailings correspond to alluvial mining , important consideration in decision making at the end of the tests carried out.

An important aspect is the precision offered by the laboratory according to the analysis method used, the Actlabs laboratory uses the Atomic Absorption (AA) method with cold steam and uses composite samples, which may offer a result more reliable than the XRF's average per-point reading method.

3. Copper Plates

3.1. Copper Plates Preparation

One of the critical processes in the pilot tests is the preparation of the copper plates, which are in charge of retaining the mercury that passes through them, for which it is required that these plates are covered with silver (Ag) with the in order that said metal can capture the elemental mercury present in the tailings.

The available literature on the manufacturing process of mercury extraction plates in artisanal mining is very limited, so the tests carried out are based on general electroplating processes, the initial experience of similar projects and knowledge of the team members. .

A total of 15 different tests were carried out for the preparation of the copper plates where the adjustment of the main variables involved in the process was considered, such as the concentration of Silver Nitrate, concentration of Sodium Cyanide, Voltage, current and residence time of electrolysis, among others. Of all the trials, the 2 most effective and that showed the best results in previous tests in the laboratory were selected. The tests in detail can be seen in Annex E.

Finally, two sets of copper plates were selected, some silver with electric current potential (Figure 3) and others without electric current potential, however, the preparation protocol for the two sets was the same and corresponds to:

- Copper Plate 20 x 20 cm
- Cleaning with 30% nitric acid
- Sanding with industrial grinding wheels to generate an irregular surface.
- Preparation of excess Silver Nitrate solution in distilled water from Sodium Cyanide and precipitation of Silver Chloride in distilled water for silver plates without potential electric current.

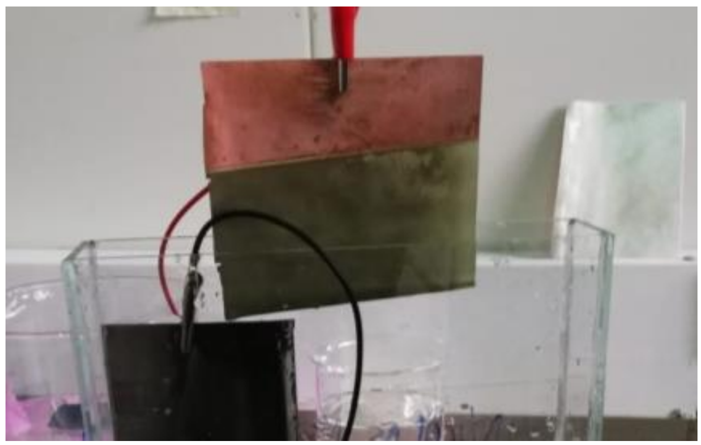
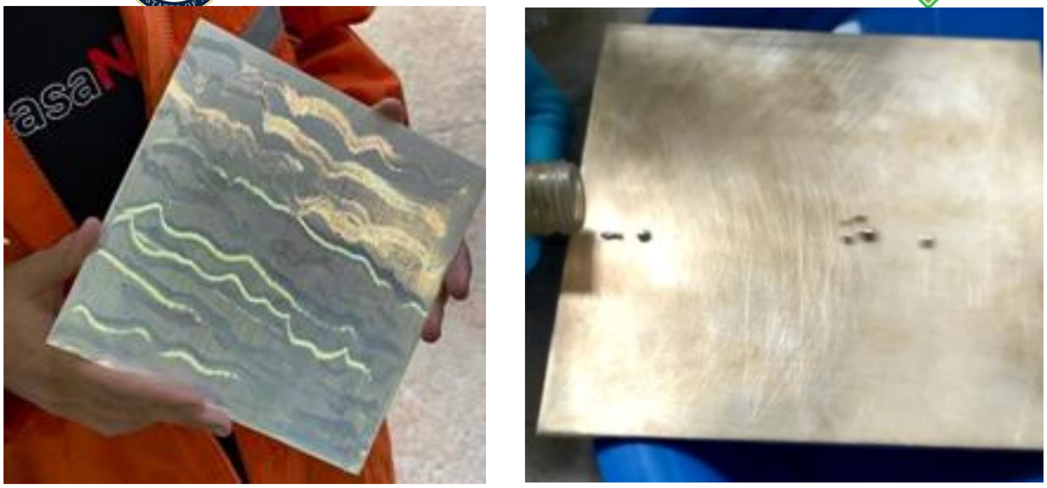


Figure 3. Silver plated copper plates with electric current potential.ateado

Within the tests carried out in the preparation of the copper plates, its effectiveness could be evidenced with an elemental mercury retention test in the laboratory and where the mercury droplets adhere perfectly to the processed plate. (Figure 4).



(a) (b)

Figure 4. (a) Silver plate with an irregular surface. (b) Retention of drops of mercury in processed plate.

The presence of electric current for the processing of the plates is an important variable, because this potential difference generates an affinity (Generation of an electrolytic cell) between silver and copper that allows Ag to adhere to the surface of the copper and that will allow to generate the affinity of silver and mercury under an electrochemical scenario of processing in copper plates (Gómez-Biedma, S., Soria, E., & Vivó, M., 2002). The electric current source used corresponds to a motorcycle battery, which has a voltage of 12 Volts and a current greater than 11 Amps. There is no accuracy in the current since the used ammeter could only measure up to 11 amps and this current was exceeded during the process.

3.2. Tailings test on copper plates

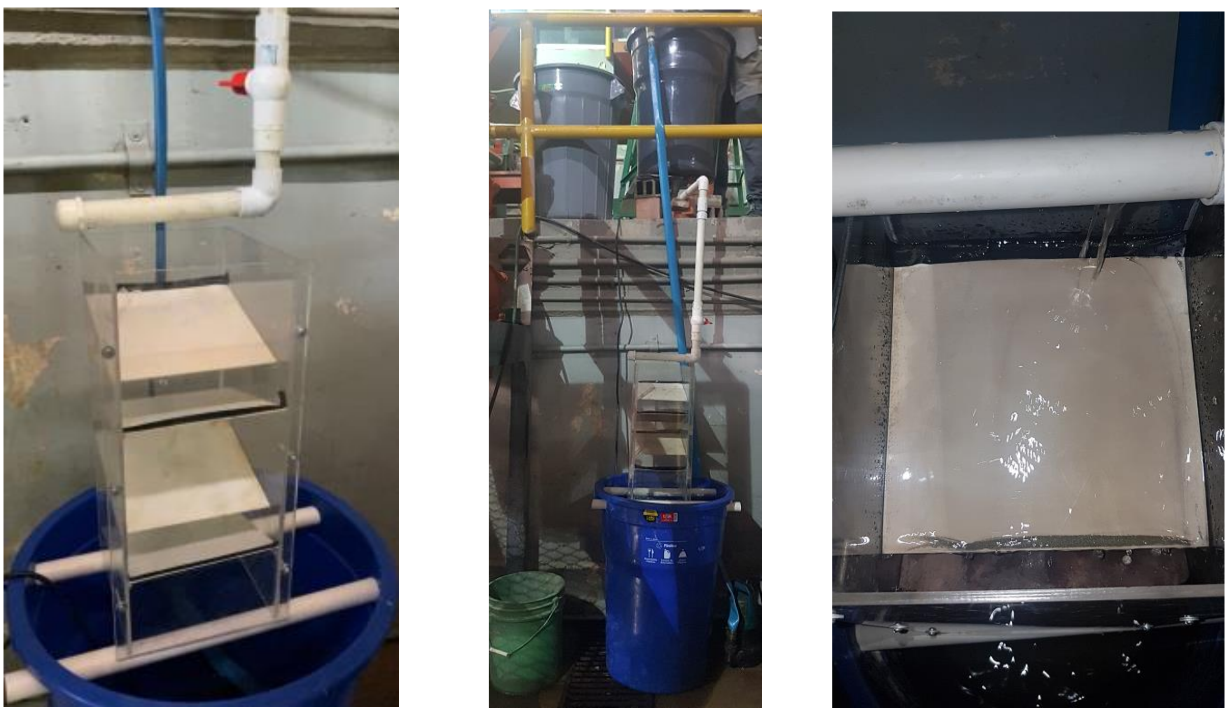
The tests carried out with the tailings on the copper plates can be seen in detail in Annex E, which were carried out according to the following protocol for each of the tailings:

- Positioning of 4 copper plates in a cascade, with an approximate slope of 20 °.
- Preparation solution of 45 gallons at 10% by weight of tailings solids. (Tail pulp)
- Passing of the tailings solution (Pulp) through the copper plates at a rate of 1.5 l / min.
- Recirculation of the tailings solution (Pulp) twice, in total three steps through the plate cascade.
- Settling of tailings for an average time of 5 hours.

- Extraction and filtration of the tailings and drying for an average time of 6 hours in a desiccator.
- Sampling for XRF, AA reading and determination of mercury vapors.

For each of the tests, a set of plates prepared in the same way was used, that is, a set with electric current potential and another set without electric current potential, which allows comparing the effectiveness for each type of plate.

Due to the amount of available tailings, it was possible to carry out the comparison test with the two types of plates (with potential and without electric current potential) only for the Soto Mayor tailings, the others only worked with powered plates. Figure 5 shows the assembly made and some illustrations of the process carried out.



(a) (b) (c)

Figure 5. (a) Positioning of cascade copper plates. (b) Installation of Test operation. (c) Passing the tailings solution through the plates.

3.3. Determination of Hg and Au after tailings processing.

After processing each of the selected tailings with the procedure described above, the same methodology was performed to determine the presence of mercury and gold as the initial samples before being processed. This involves measurements of mercury and other heavy metals with XRF, determination of elemental mercury by Atomic Absorption, mercury vapors, and fire testing for gold.

As an additional analysis to those previously described, the Leaching Toxicity Characterization (TCLP) test was carried out on each of the tailings in order to determine whether or not it could be considered a hazardous waste if classified within this category.

The results obtained and their corresponding discussion are presented in the results analysis section of this document.

3.4. Findings of the process

During the development of the tests, the following findings could be found, which should be taken into account in future processes and on larger scales. Among the most important are:

- On certain occasions there were blockages of the dispersion flutes of the tailing's solution, which was controlled with a 10% by weight solution of the tailings. This concentration can be much larger in field tests, since it is not a restriction parameter in the capture of mercury by plates.
- There is more retention of solid material in the plates when they have an irregular surface, which is recommended that you polish grooves on the plate surface before plating it.
- The mechanical retention of material occurs in the first plate, on the edge of the material falling to the next plate, from which it can be inferred that for this reason the first plates should retain more mercury than the other plates.
- At the end of each one of the tests, a reading of the XRF was made on the copper plate in order to show if there was a presence of mercury on the surface. Indeed, it was possible to show high concentrations on specific points on the plate and bright gray. (Figure 6).

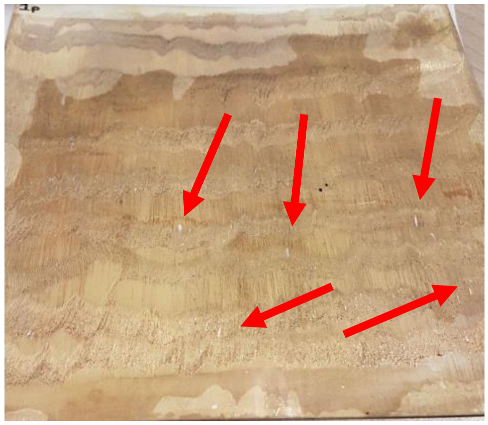
 

Figure 6. Mercury spots identified on the copper plates.

- After processing the tailings, a change in the color of the plate was evident. This can be due to the oxidation of another element or compound within the tailings, so it is important to take this parameter into account when applying field tests, since this determines whether a plate cleaning process should be carried out. (possibly with acetic acid) or repeat the silvering process of the plates during testing.
- It was not possible to remove the mercury captured by the plates, because due to the low concentrations it was amalgamated to the silver and not as extractable mercury.

4. Analysis of results

Next, an analysis is presented for each of the parameters measured during the tailings processing.

4.1. X-Ray Fluorescence Readings (XRF)

The data obtained by the XRF before and after processing are presented in Table 6.

Table 6. *Hg measurements by XRF - Olympus*

Tailing	Plate Type	Hg (ppm) - XRF		
		Before	after	% Reduction
San Roque - Concentrado	Potential	58,1	39,3	32,6
San Roque -Finos	Potential	78,0	27,3	65,1
Soto Mayor	Potential	39,5	8,3	78,9
Soto Mayor	No potential	39,5	34,6	12,4
Rio Quito	Potential	0,0	0,0	-
Rio Negua	Potential	0,0	0,0	-

Figure 7 shows that the highest percentage of mercury retention is reported for the Soto Mayor tailings with 78.9% and where it was processed with plates with electrical potential. It is possible that the electrical potential has favored the affinity between the copper (Cu) - silver (Ag) system of the plate and the mercury (Hg) of the tailings, generating high efficiency in the recovery of mercury from the Soto Mayor tailings. .

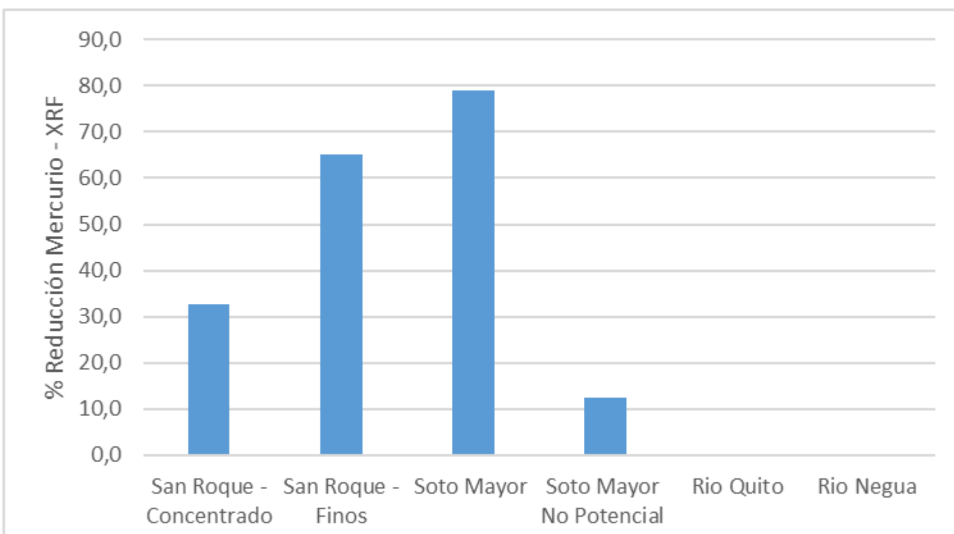


Figure 7. Hg Reduction Percentage determined by XRF.

4.2. Data by Atomic Absorption (AA)

Data obtained by Atomic Absorption by Act Labs laboratory before and after processing are presented in. Table 7.

Table 7. Results of Hg measurements by Atomic Absorption

Tailing	**Plate Type**	**Hg (ppm) - A.A.**		
		Before	**After**	**% Reduction**
San Roque - Concentrado	Potential	>100,0	86,6	13,4
San Roque -Finos	Potential	92,8	70,0	24,6
Soto Mayor	Potential	59,4	56,2	5,4
Soto Mayor	No Potential	59,4	62,6	-5,4
Rio Quito	Potential	0,87	1,2	-37,9
Rio Negua	Potential	0,78	1,4	-79,5

Figure 8 shows that the highest percentage of mercury retention is reported for the San Roque - Finos tailings, according to the analysis carried out by Atomic Absorption. However, for some tailings, such as those of Rio Quito and Rio Negua, it can be seen that there is no reduction of mercury in the processing, this possibly occurs due to interference in the method of analysis of the samples or by recirculation of the tailings with presence low initial mercury concentrations.

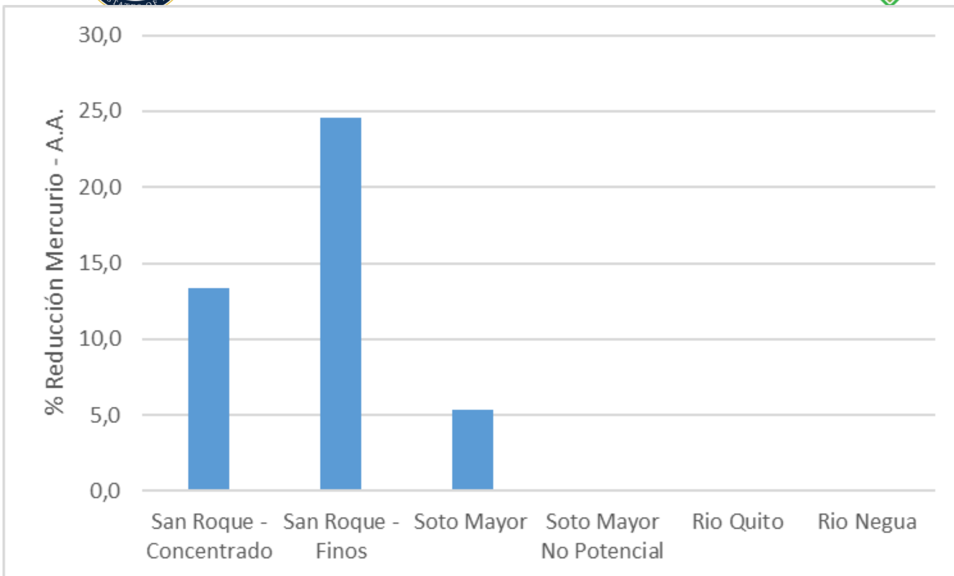


Figure 8. Percentage of Hg Reduction determined by Atomic Absorption .

4.3. Mercury vapors

The data obtained by HERMES from mercury vapors before and after processing are presented in Table 8.

Table 8. Comparación de vapores de mercurio en relaves.

Tailing	Plate Type	Hg Vapors (ug/m3) – HERMES		
		Before	After	% Reduction
San Roque - Concentrado	Potential	8,6	1,9	77,9
San Roque -Finos	Potential	2,3	1,5	34,8
Soto Mayor	Potential	4,0	1,0	75,0
Soto Mayor	No Potential	4,0	2,7	32,5
Rio Quito	Potential	7,0	3,3	52,9
Rio Negua	Potential	0,5	0,0	100,0

Figure 9 shows that the highest percentage of mercury retention is reported for the Rio Negua tailings with 100% retention. However, it should be noted that the initial value is very low (0.5 ug / m3) and that where a representative reduction is evidenced, it corresponds to the tailings of San Roque - concentrates and Soto Mayor with 77.9% and 75% reduction respectively and together tailings processed with potential plates.

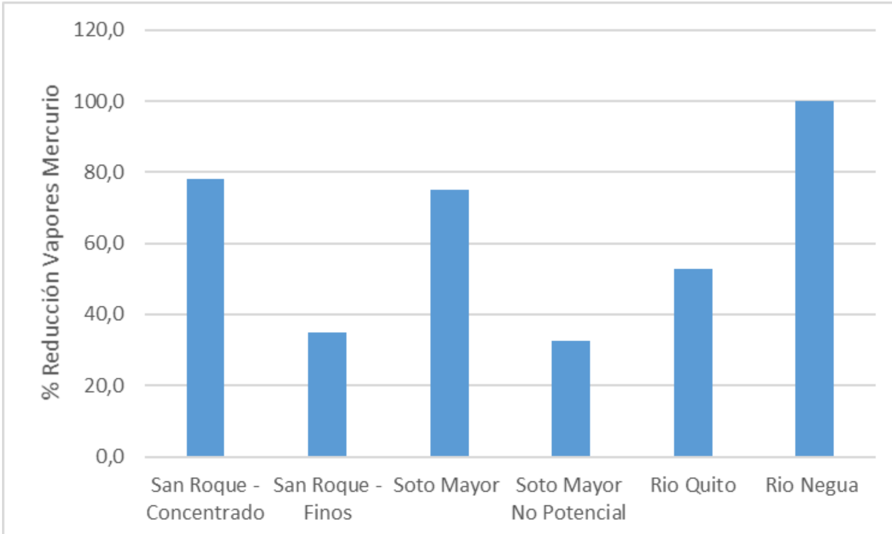


Figure 9. Hg Vapor Reduction Percentage

These percentages of mercury vapor (Hg) reduction may also be influenced by the characteristic volatility of Hg, therefore the reduction may be evident, but the actual proportion may decrease somewhat from that reported in the analyzes.

4.4. Gold Content

For each of the tailings, the amount of gold present was determined both before and after processing by the copper plates. Table 9 presents these results.

Table 9. Presencia de oro en relaves durante su procesamiento.

Tailing	Plate Type	Au (g/ton) - P. Fire	
		Before	After
San Roque - Concentrado	Potential	53,8	42,7
San Roque –Finos	Potential	5,6	14,6
Soto Mayor	Potential	15,6	16,9
Soto Mayor	No Potential	15,6	19,1
Rio Quito	Potential	0,29	0,57
Rio Negua	Potential	1,93	0,74

Figure 10 shows the presence of gold in each of the tailings before and after processing. It can be seen that there is no significant variation and that the reported reductions and increases are due to the tailings themselves.

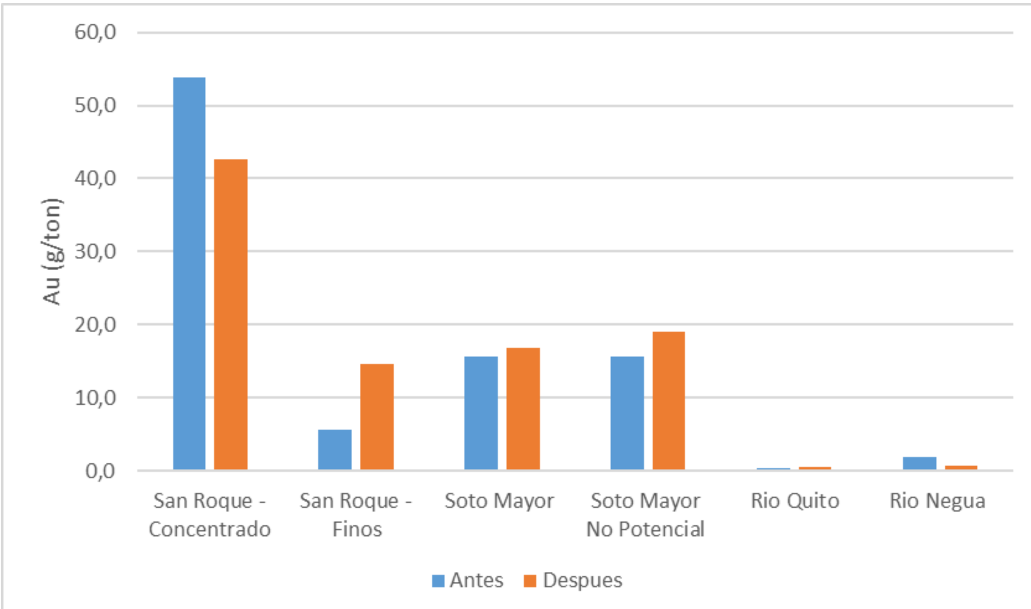


Figure 10. Presence of gold before and after tailings processing.

4.5. Presence of Cyanide

Table 10 shows the laboratory results of total cyanide (CN) in each of the tailings of the characterized sites.

Table 10 Presence of Total CN in the tailings processed

Tailing	***Plate Type***	***CN Total (ppm)***
San Roque - Concentrado	Potential	33,5
San Roque -Finos	Potential	144,0
Soto Mayor	Potential	10,0
Soto Mayor	No Potential	10,0
Rio Quito	Potential	0,843
Rio Negua	Potential	0,399

Figure 11 shows that in all the tailings that were used in the tests, the presence of cyanide is found in a higher concentration for tailings from vein mining, this evidences that the tailings have already been processed to obtain gold with the I use cyanide. The tailings with the highest amount of Cyanide correspond to those of San Roque, specifically the fine tailings with 144 ppm, while the Negua River presents the lowest concentration with 0.399 ppm.

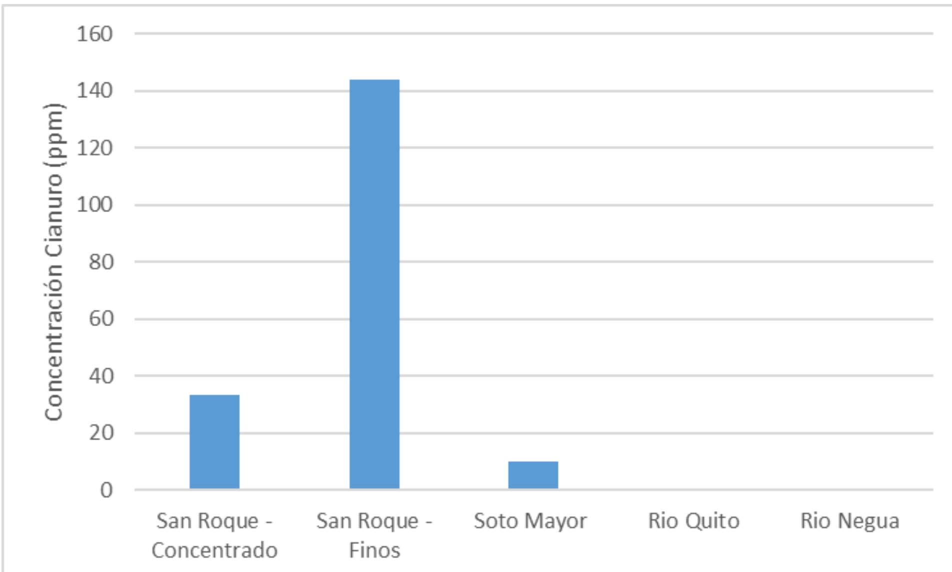


Figure 11 Presence of total cyanide (Cn) in processed tailings

4.6. Leaching Toxicity Test (TCLP)

One of the most important aspects to review in this project is the classification of tailings under the gaze of National regulation, especially the question: Are tailings from artisanal gold mining hazardous waste? In order to respond, it is necessary to refer to Decree 4741 of 2005, which establishes the maximum permitted limits of pollutants for the classification or not of a waste as a hazardous waste.

One of the most relevant tests to classify a material as dangerous corresponds to the Leaching with Dangerous Characteristics (TCLP) test. These tests were carried out on the tailings resulting from the process on the copper plates.

Table 11 shows the results obtained by the laboratory.

Table 11. Comparative of TCLP results with Colombian regulation.

Element	***Ag***	***As***	***B***	***Ba***	***Cd***	***Cr***	***Pb***	***Se***	***U***	***Hg***
Unit	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	ng/L
Detection limit	0,1	0,1	0,1	0,1	0,01	0,1	0,1	0,1	1	6
Legal Limit D. 1076 - 2015	***5***	***5***	***-***	***100***	***1***	***5***	***5***	***1***	***-***	***200***
San Roque Concentrados	< 0.1	< 0.1	< 0.1	0,3	0,09	< 0.1	0,3	< 0.1	< 1	< 6
San Roque Finos	< 0.1	< 0.1	< 0.1	0,4	0,18	< 0.1	0,3	< 0.1	< 1	10
Soto Mayor	< 0.1	7,9	< 0.1	< 0.1	0,03	< 0.1	< 0.1	< 0.1	< 1	21
Soto Mayor No Potential	< 0.1	0,6	< 0.1	< 0.1	0,03	< 0.1	< 0.1	< 0.1	< 1	9
Rio Quito	< 0.1	0,1	< 0.1	0,6	< 0.01	< 0.1	0,1	< 0.1	< 1	< 6
Rio Negua	0,2	< 0.1	< 0.1	0,4	< 0.01	< 0.1	0,1	< 0.1	< 1	31600

According to the results obtained, only the tailings from Rio Negua did not comply with the permissible limits established in the current national regulation. On the other hand, the other tailings did not report toxic leaching hazard, however, it is necessary to complement the criteria of the current regulations, including the parameters commonly known under the acronym CRRETIB. Table 12 shows a description from a technical and regulatory point of view, however, a more in-depth study may be required to validate its danger with further duly accredited laboratory analysis.

Table 12. CRRETIB Analysis Technical-Regulatory

Parameter	Regulatory requirement *	Analysis
C-Corrosivity	pH>2 y pH<12,5	During the laboratory tests, capto analyzes were performed under the colorimetric tape technique to determine pH. The results reported values close to 7 or neutral.

R - Reactivity	It generates toxic gases, vapors, and fumes. Cyanides, sulfides, organic peroxides that, by reaction, release toxic gases, vapors, or fumes. Explosive or detonating reaction endothermic or exothermic reaction on contact with air, water or another element or substance Provoke or promote combustion.	Tailings are generally waste or material in process that experience indicates that they are very stable under normal conditions of temperature, pressure and exposure to the elements. It is unlikely that exothermic or endothermic reactions will occur due to the fact that within its components there is no presence of materials with these capacities. Mineralogical analysis rules out substances classified as strong oxidizers or oxidizers.
R - Radioactivity	Elements or isotopes, with a radioactive activity per unit mass greater than 70 K Bq / Kg (seventy kilo becquerels per kilogram)	This type of danger is typical of sectors such as nuclear energy, diagnostic images such as X-rays in the health sector, and places with close proximity or a history of operations or manufacture of nuclear weapons (Petrangeli, 2006). Mercury-contaminated sites do not exhibit any of these characteristics.
E-Explosivity	Forms potentially explosive mixtures with water; Easily produces a detonating or explosive reaction or decomposition at a temperature of 25 ° C and a pressure of 1.0 atmosphere Being a substance manufactured in order to produce an explosion or pyrotechnic effect.	
I - Flammability	• Be a flammable gas • Be a flammable liquid • Solid with the capacity under conditions of temperature of 25 ° C and pressure of 1.0 atmosphere, to produce fire by friction, absorption of humidity or spontaneous chemical	The tailings do not meet these hazardous characteristics since they are solid with a high presence of moisture and do not have materials considered flammable among their constituents.

	alterations and burning vigorously and persistently making it difficult to extinguish the fire • Being an oxidant that can release oxygen and, as a result, stimulate combustion and increase the intensity of fire in other material.	
B - Biological or infectious risk	Pathogens: pathogens are microorganisms (such as bacteria, parasites, viruses, rickets and fungi) and other agents such as prions, with sufficient virulence and concentration to cause disease in humans or animals.	This type of waste is typical of places where health procedures are performed or places where bodies have been disposed of due to pandemic diseases. The sites where the tailings are located do not have any of these characteristics.

* Decree 4741 of 2005 annex III.

5. Conclusions

After developing laboratory-scale pilot tests of the technology called copper plates, it can be concluded:

- The mineralogical composition of the tailings is not a fundamental factor in applying the copper plate mercury retention technique. However, it is an important parameter to identify in which type of mineral the present gold can be found and at the same time be able to review the gold extraction processes that are being used in the area where the tailings belong.
- The mineralogical characterization allows supporting and validating that the mines where these tailings originate are indeed of a metallic type, that is, characteristics with high gold (Au) contents.
- Having used different analysis methods and techniques in determining the mercury concentration in the tailings, confirms the reliability of the data being analyzed.
- In most of the tests carried out on copper plates, a reduction of mercury is reported in the processed tailings, however when the tailings report a very small amount of mercury concentration, they are reporting an increase due to possible measurement interferences with Atomic Absorption and with XRF readings.

- Copper plates prepared with electrical potential report a greater reduction in mercury in tailings than those that were prepared without electrical potential, because they facilitate the electrochemical affinity between the metals present (Cu, Ag) and the processed ones (Hg, Au).
- It is possible to increase the retention of mercury on copper plates taking into account observations such as: (i) the plates must have a fairly rough surface that aids in the capture of mercury, (ii) the flow of the tailings solution does not need to be of laminar flow, the more turbulence is generated, the more possibility of capturing mercury on the plate.
- It is important to carry out a detailed review of each of the findings found during the laboratory pilot tests in order to minimize the risks that may arise when scaling the tests to the laboratory.
- The characteristic volatility of mercury can generate a small variance in the results of reducing mercury vapors in the tests carried out, which although if they report a percentage reduction, the value may be slightly less than that reported in this report.
- The untreated tailings evaluated in the tests contain levels that exceed the limits allowed by the Colombian regulation for mercury, this suggests that they should be treated as hazardous waste.
- There is no interference of the copper plates with the amount of gold present in the tailings, since there is no significant variation in the concentration of gold in the tailings during the copper plate process.
- The results of the TCLP tests carried out on the tailings already processed by the copper plates, show that for five of the six samples taken, the levels of toxicity stipulated by Colombian regulations are not exceeded. However, it is necessary to develop a more detailed complementary analysis that involves the other parameters considered under the regulation of hazardous waste to confirm whether or not they should be classified as hazardous waste.
- The process of removal of mercury captured by copper plates should be reviewed in more detail, because during the tests carried out, the capture of mercury occurred at very low concentrations, which amalgamed the silver coating and not mercury. metallic as expected initially. It is hoped that with field concentrations this part of the process can be optimized.

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ANNEX

Annex A – Reportes Laboratorio Cecoltec
Annex B - Reporte Mineralógico de Relaves
Annex C – Detalle Lecturas XRF
Annex D – Reporte Laboratorio Act Labs
Annex E - Bitácora de Ensayos Placas de Cobre y Procesos