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SOCIO-FAMILY MANAGEMENT OF OCCUPATIONAL AND ENVIRONMENTAL RISKS DUE TO MERCURY EXPOSURE IN FAMILIES OF BAREQUEROS IN THE LOWER CUENCIA DEL RÍO SAN JORGE. (AYAPEL, COLOMBIA, 2025)

María Alejandra Doria-Carmona[1*], Luz Dary Ripoll García[2], Concepción Elena Amador-Ahumada[3]

[1]Universidad de Córdoba, Montería, Colombia, mdoriacarmona@correo.unicordoba.edu.co https://orcid.org/0009-0004-9177-1122
[2]Universidad de Córdoba, Colombia, lripoll@correo.unicordoba.edu.co https://orcid.org/0000-0002-4761-905X
[3]Universidad de Córdoba, Colombia, concepcionamador@correo.unicordoba.edu.co https://orcid.org/0009-0000-7497-7808

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Corresponding Author: María Alejandra Doria-Carmona (mdoriacarmona@correo.unicordoba.edu.co)

ABSTRACT

In the riparian areas of areas where mining activities are carried out, for gold exploitation, a high level of mercury has been demonstrated among residents. To analyze the effect of the practices used by the barequeros and their families residing in the lower basin of the San Jorge River, which they have adopted for the management of risks to personal, family and environmental health. This is a descriptive, cut-off study with a qualitative approach from the constructivist perspective in social research, seeking a respectful understanding of the intentionality of the practices that families carry out in order to reduce the risk of mercury poisoning or contamination; The informants were 14 barequeros with their respective families, information was collected through interviews, focus groups until the saturation point was reached. The results of the systematization of the findings, although they reveal the perceptions, commitments and attitudes of the families in the face of the environmental, family and health risks of mining activity, the management of the associated risks is being managed with a precarious and informal approach that is not appropriate for the toxicological risk condition that is particular to mercury. Conceptually, the perception of "contamination" is assimilated by the barequeros with the meaning of "clean", proof of this is that detergent soaps are used in order to decontaminate the skin and clothing, the same concept is applied in terms of the "decontamination" of the water used. Families in the Lower San Jorge River Basin, aware of the need, have created informal prevention systems that do not allow reducing exposure to mercury, although without formal intervention or more advanced technologies. However, their responsiveness is constrained by structural and contextual factors that impede the implementation of more effective practices.

KEYWORDS: Practices, Decontamination, Barequeros, Families.

1. INTRODUCTION

In nature there are heavy metals such as mercury (Hg); this metal is considered very toxic (Cano, 2012), and is the only element that remains in a liquid state at a temperature of 0ºC; this metal is not degradable and accumulates in living beings (Barzola, 2017), which it enters through various routes Posada-Posada & Arroyave-Maya, 2017); Four important access routes have been demonstrated, the main one being inhalation, which occurs when inhaling mercury vapors, through this route it enters the respiratory system. This is the one that represents the greatest occupational risk among miners (Rodríguez, 2017; Camasi, 2012).

There are also other routes of entry such as direct contact with the skin (Fernández, 2019) which it accesses through adsorption or through wounds or lacerations of the tissue, it can also penetrate through the eyes (Morales & Reyes, 2023), especially when they are not protected (Fernández, 2019), a situation that can occur in the person who swims or bathes in the river because they are not performing any activity with occupational hazards. Mercury or its form of methylmercury usually enters the body through the consumption of contaminated foods such as fish, this being the route of the digestive tract (Milhomem et al, 2019).

This is one of the main ways in which a person can become contaminated even if they do not belong to the mining guild; since human activities near rivers and other aquifers have generalized cases of exposure (Cano, 2012; Gaioli et al, 2012; Díaz et al. 2020); in such a way that the frequent consumption of fish or shellfish (Raiman et al, 2014) can contaminate people located at long distances from gold mining centers. Older and larger fish have been shown to contain higher levels of mercury Mancera-Rodríguez & Alvarez-Leon, 2006; Llop et al, 2013; González-Estecha et al, 2014); another form of inadvertent contamination can occur when drinking or ingesting mercury-contaminated water, which is an infrequent cause of acute poisoning (Echeverry et al, 2015; Díaz Arriaga, 2014) but which can influence chronic poisoning due to the non-biodegradable nature of mercury. Families living on the banks of rivers that receive tributaries from mining areas (Echavarría-Rentería & Hinestrosa-Cuesta, 2001).

This situation is replicated in the riparian areas of the areas in which mining activities are carried out for gold exploitation, where a high level of mercury has been demonstrated in residents near the swamp (Ripoll et al, 2024), even among domestic animals (Argumedo et al, 2013). Ignorance of pollution and its dangers can lead to exposure to risks through occupational practices (Muñoz-Vallejo et al, 2012) or family activities such as bathing, swimming or consuming water from these rivers, inadvertently exposing oneself to the risk of ingestion, absorption through the skin leading to mercury poisoning. Mercury can cause serious health problems, acute or chronic poisoning, fetal malformations in both short and long term periods, showing its adverse effects on human and environmental health including flora and fauna.

In this sense, it is important to study not only the evidence of mercury exposure, but also the way in which families living in riparian areas intend to reduce the potential risk to their health and the biotic environment (PAHO-WHO, 2006; Vesgas, 2018). Mercury, among humans, exerts activity similar to that of a neurotoxin, after its progressive accumulation in an individual being harmful to all animal and plant life, in particular its effects due to biomagnification are more severe for those at the top of the food chain in humans generates long-term neurological and renal degeneration (UN, n.d.).

In Colombia, gold mining known as Artisanal and Small-Scale Mining (ASM) applies to mining activity that is carried out with intensive use of labor, low technification, and low production margins per deposit (Colombia, 2013); with occupational practices that favor pollution reaches wild fauna and flora in aquatic and terrestrial environments (Rocha-Román et al, n.d.), due to biomagnification, the impacts of pollution affect people's lives, both family members who are directly involved in mining activities and those who live in the vicinity (Español, 2012).

It is recognized that soils in Artisanal and Small-Scale Mining (ASM) areas have been measured to have high concentrations of mercury (Hg), ranging from 723 to 2067 times higher than those of control soils. In the study by Ssenku, et al (2023), soils showed moderate to high contamination; the values of the geoaccumulation index (Igeo) were between 1.16 and 3.31; it was also identified that both crops and wild plants accumulated Hg levels above the permissible limit of 20 ng/g (0.02 ppm), in food crop samples 47% of these exceeded the permissible limit of mercury established by the FAO/WHO at 0.5µg/g (Ssenku, et al, 2023).

Since 2013, the use of mercury in ASM has been banned throughout the territory; through Law 1658 of 2013 (Ministry of the Environment, 2013), the National Government assumed the transitional challenge of eliminating this chemical element in gold mining in 5 years, (a period that covers the years 2013 to 2018) in which the Government promoted

mercury-free gold mining and demonstrated that such activities The economic conditions can be achieved through the use of clean technologies, through gravimetric concentration of mercury-free minerals, which has been developed since 2005.

In Artisanal and Small-Scale Mining (ASM), labor activities are carried out by human beings who reside in conditions of generalized poverty, vulnerability due to social exclusion in the regions, in addition to the severe environmental impacts that affect both the ecosystem and human health. In 2007, the United Nations Environment Programme (UNEP) states that "[...] It is estimated that between 10 and 15 million miners are involved in artisanal and small-scale gold mining, of which 4.5 million are women and 1 million are children [...]". Due to the conditions of poverty in this type of mining, informality predominates and depending on this, empiricism, and improvisation.

Likewise, studying the management of families and communities exposed to mercury will allow the identification of hazards, risks and prevention measures aimed at decision-making in relation to the need to reduce environmental pollutants and their effects on riverside populations. Therefore, these results reveal the need for constant monitoring to promote the use of effective strategies to be used by the barequeros and their families to reduce the presence of mercury in this affected region or the bad practices to mercury exposure.

Since 2000, the United Nations Environment Programme (UNEP) has drawn attention to the need to understand and quantify human actions in relation to exposure to mercury releases. That is why in this article, the effect of the daily practices used by the families of barequeros residing in the lower basin of the San Jorge River is analyzed, focusing on the effectiveness of the strategies that they have adopted in order to mitigate the individual exposure to mercury by the barequeros. as well as the practices used to (in their concept) manage risks to the health of the family and the environment immersed in social, economic, political, and cultural contexts.

From a public health perspective, the relevance of this study lies in its ability to integrate a socio-family element into the comprehensive vision of the problem of the use and disposal of residual mercury in response to the call of the United Nations Environment Program, addressing the analysis of daily practices from the meaning and effect of the same in the communities of barequeros have implemented to mitigate the impact of the use of residual mercury. mercury in their occupational environment and family. Likewise, these results are in line with the Public Health Impact Program of Córdoba, which defines the strategic guidelines that prioritize environmental health and risk management in the region due to the constant threat of environmental deterioration Colombia, Ministry of Health, 2019; Vesgas, 2018).

2. METHODOLOGY

2.1. Type of Study

This descriptive study, carried out with a qualitative approach from the constructivist perspective in social research, seeks a respectful understanding of the intentionality of the practices that families carry out in order to reduce the risk of mercury poisoning or contamination.

Abstract research analyzed from the constructivist perspective in social research in order to understand the meaning that actors give to the daily practices they carry out in the contexts where their occupational and family activities are carried out in relation to the perception of control of mercury exposure (Pérez, 2025).

2.2. Study Scenario

Centered in the Department of Córdoba which is located in the northwest of Colombia on its Atlantic Coast with a geographical area of 23,980 km2. It is divided into two regions, one of flat lands in which the valleys of the Sinú River, the San Jorge River and a large part of the municipalities are located, with livestock and agriculture being the main economic activities. To the south of the department is the other region, with mountainous relief, in which the mountains of Ayapel, San Jerónimo and Abibe are located. It is home to a great wealth of fauna and flora native to South America, where the Sinú River and the San Jorge River are born.

The department of Córdoba is made up of 30 municipalities, the municipality of Ayapel with its villages and townships is located in the basin of the San Jorge River. The San Jorge River is born in the municipality of Ituango (Antioquia), in the Alto Yolombó its basin is distributed among the departments of Antioquia, Bolívar, Córdoba and Sucre (La Mojana Region), with a population of approximately 1,752,284 inhabitants residing in its entire extension that is close to 368 km in length. In the department of Córdoba, the San Jorge River begins its course in the Lindero and Santa Bárbara streams and ends its course in the Amarillo and Caño Viejo streams. This river irrigates the Ciénaga de Ayapel and leaves Córdoba through the township of Cecilia, municipality of Ayapel (Aguilera-Díaz, 2009).

In the San Jorge River basin, agricultural activities,

artisanal gold mining have been carried out for more than fifty years using techniques such as chiseling, hydraulic milling, barequeo and the use of mercury (Sánchez-López, 2022). This is reflected in evidence of mercury contamination in humans and fish (Gracia et al, 2009).

Techniques such as direct observations, interviews and records in field diaries were used to capture the information, in order to understand the activities with which the barequeros and their families manage the risks associated with exposure to mercury before, during and after the activities of artisanal mining, focusing on the analysis of the probable effect of the preventive actions adopted within the framework of their perception of risk.

2.3. Informants

The key actors were located, who, after the presentation of the project, its aims, scope and methods, allowed the identification and access to 14 barequeros and their families. Participants were selected through non-probabilistic sampling, for convenience and according to representativeness criteria, considering voluntary and informed participation as a primary criterion; the key informants had to be 1) residents in the lower basin of the San Jorge River, 2) located in the municipality of Ayapel, 3) economic activity related to artisanal mining, these being the representative criteria of the target population. 11 women who live with gold miners and 14 gold miners aged between 19 and 37 years were interviewed, with at least 2 years of residence in the gold mining zone and 8 months of gold mining occupation. Of these 14 families, it is identified that in three of them the entire family goes to the extraction sites at least once a month.

During the fieldwork, the gradual immersion was carried out through a series of visits on a weekly basis, in which contacts were made with the barequeros and their families; data capture was maintained until reaching the saturation point, so qualitative data collection was classified as progressive, as it was appropriate to the time availability of the participants (Guber, 2004).

2.4. Information Processing

The recordings obtained with the consent of the informants were transcribed for reading and rereading in favor of the organization of the emerging categories. In total, 1233 sentences were obtained with content related to the socio-family management of occupational and environmental risks related to the handling of mercury. From the organization of these four categories of practices emerged: 1) related to personal decontamination; 2) practices related to occupational protection against toxic hazards; 3) practices aimed at controlling the risk of family contamination and 4) practices aimed at the conservation of the environment.

Each emerging category was formulated with the addition of semantic phrases with content related to it; subsequently, for confirmatory purposes, the intentionality of the community-managed measures was contrasted in focus groups and the effectiveness (real impact) of these practices was qualitatively estimated. It was considered that with respect to the practices there was an empirical management process, since the set of practices has in common an interpretative axis that implies the existence of an objective, planning, execution, evaluation and control activities; which could be verified and contrasted in focus group sessions of a maximum of 4 subjects.

3. RESULTS

To understand the effectiveness of risk management carried out by the barequeros and their families who live in the lower basin of the San Jorge River in the municipality of Ayapel, with the purpose or intention of mitigating the risks of exposure or poisoning by mercury derived from their mining activities, it is necessary to briefly know the steps of the gold extraction process. Mercury is used in gold mining to separate gold from its source (water, gravel, or rock), which is separated by forming an amalgam (mixture of mercury and gold) that is visible. This amalgam, after forming, is collected and heated so that mercury evaporates and disperses as vapor and in this way pure gold (known as gold sponge) is obtained.

In this process, the barequero's labor consists of collecting the material to be processed, handling the mercury and transporting the mixtures to the indicated site for mercury vaporization. According to the expressions "when the mercury is thrown everyone goes home, to bathe, to eat, there are only the owners of that or the person in charge"; this being an important source of environmental pollution due to the vaporization of mercury released into the environment with risks to human and environmental health.

The results of the systematization of the findings, although they reveal the perceptions, commitments and attitudes of the families in the face of the environmental, family and health risks of mining activity, the management of the associated risks is being managed with a precarious and informal approach that is not appropriate for the toxicological

risk condition that is particular to mercury. The findings presented explore the expected and real effect of the daily and social dynamics of the exposed community, which is in a context of vulnerability due to living conditions. The findings are presented below, organized into emerging categories.

Practices aimed at personal decontamination. Conceptually, the perception of "pollution" is assimilated by the barequeros with the meaning of "clean", proof of this is that detergent soaps are used in order to decontaminate the skin and clothing. The substances used for body decontamination are a complex mixture of compounds containing surfactants , surfactants, brighteners, enzymes, water softening agents and fragrances that exert their activity by effectively dissolving dirt and impurities in water.

It is this sense of cleanliness that is the basis of the decontamination practices carried out by the barequeros "wash their hands with Fa' (detergent)" and then bathe"; in the same sense they express that we "drown" the dirt by rinsing dirty clothes in the waters of the San Jorge River. According to the semantic expressions of significance of these practices, it is common to indicate that after cleaning "that" does not remain in them and consequently, according to their accounts, the traces of mercury "do not go to the houses".

This practice, which is intended to be in situ decontamination, is in no way effective for the expected meaning or expectation of this practice, which is to eliminate traces of mercury in the person's body; although some of them change their clothes, this does not limit exposure because dirty clothes, it is loaded to be taken to the house, where it is deposited "outside".

Table 1: Meaning and Effectiveness of the Practices Used to Control Toxic Risk.

Internship	Description and meaning of practice	Management effectiveness
Practices aimed at personal decontamination.	The barequeros wash their hands with detergents (or any soap) and bathe.	Ineffective Soaps and detergents do not decontaminate fabrics or surfaces that contain mercury
Practices aimed at occupational protection against toxic hazards.	The barequeros feel safe because they wear exclusive clothing for work activity (clothing made of normal fabrics). They do not wear gloves or face masks. When the mercury is heated, they move away from the area and disperse to their homes	The practice, although well-intentioned is ineffective, mercury can adhere to clothing and washing does not decontaminate, as it is in the separation zone of the amalgam of gold and mercury; Being in the zone where gold separates from mercury, mercury can be inhaled or absorbed through the skin
Practices aimed at controlling the risk of family contamination	Mercury is kept outside (the house) in a closed jar They change their clothes in the mine; They leave work clothes outside the house. They wear the same footwear inside and outside the mine Some rinse their work clothes in the river (to "drown that"). The barequero's work clothes are hand washed separately (but in the same courtyard and family laundry room)	There is ineffectiveness in these practices, despite the intention of not contaminating the family environment Mercury is transported to homes and surrounding land areas in shoes, dirty clothes, and washing them results in the dispersion of mercury on the surface of the house. The practice of "drowning" mercury by immersing contaminated clothing in river water can contaminate the water source.
Practices aimed at environmental conservation.	They reuse water so as not to contaminate it, in this sense they clarify the water, clean it of solid waste They filter water with mercury through double filtering using "holes" in the ground until it is "not seen"	There is inefficiency in these practices, the impact differs from what was expected because mercury after filtration and/or decantation not only contaminates water, but also terrestrial space.
Source: interpretation of the consolidated semantic expressions		

It is of interest to identify the differences between dirt and pollution; the first being the presence of matter or solid waste, while the second is the introduction of substances that can be harmful in and for the environment because they have the potential to generate disorders and instability that affect living beings and biotic ecosystems.

Although there is a common ground that dirt due to the accumulation of solid waste can be a major source of pollution (e.g. garbage that contaminates the soil), solid waste is visible to the naked eye, while pollution usually occurs without the pollutant being visible, as is the case with chemical pollutants that are present in the soil. air or water.

The contextual analysis of the informants' expressions reaffirms in various ways that the concept of "dirt" is equated with "contamination", with other expressions such as "we do not pollute, the

water we use is clear [transparent]".

Practices aimed at occupational protection against toxic hazards In terms of occupational protection practices, the barequeros and their wives rely on clothing to be an efficient Personal Protection Element (PPE) that protects them against mercury hazards. In this sense, phrases such as "they use appropriate clothes for them to work" were issued, they consider that there is no exposure to risk and that their situation inside the mine is "normal because we do put on work clothes"; the pattern of daily clothing being "a pair of pants, a longer shirt, a bus, that kind of thing." Results that show that the barequeros believe it is sufficient to apply in gold mining, the same PPE indications, which are recommended for the management of other types of toxic substances such as agrochemicals or agricultural toxics, expressed with phrases such as "appropriate clothing for them to work".

Of special interest is that they frequently use the pronoun "that" to designate mercury, which is understood and assumed by the barequeros and their families as an inanimate element; it is identified in phrases such as "to work that", "the owners of that or the person in charge", "to wash or lower that"; From this perspective, the expression of the pronoun grants the perception of closeness of the element assumed to be inanimate or lifeless, it is assumed to have no life, no movement of its own. In this sense, the interpretation of the use of the neutral pronoun when referring to mercury represents, in addition to the confidence in this chemical element, that it is assumed to have no capacity to cause harm.

Likewise, the barequeros consider that a form of occupational protection is to move away from the area after the mercury is applied to form the amalgam or when it is boiled to extract the gold, an aspect illustrated by phrases such as "when the mercury is made everyone goes home, to bathe, to eat"; ignoring the potential of inhaled mercury for their health, and of the microparticulate form for the biotic systems present in the habitat in which the mining exploitation is located. This may be because mercury vapor is not irritating or odorless, and its inhalation may go unnoticed.

Practices aimed at controlling the risk of family contamination. Although the contextual analysis shows the ineffectiveness of daily practices to address the risks of mercury exposure, the responses show that, if the risks are recognized, and that there is an awareness of the need to adopt measures adopted to systematically reduce exposure.

In families, special care is taken with the risks posed by the clothing used by the barequero in the mine with expressions such as "their clothes, their shoes, I have to leave them aside and let them, and wash them apart", "those clothes from there in the mine, that are out here"; Similarly, families consider "dirty" to be equivalent to "contaminated", in families it is customary for the barequeros to "wash by hand, to get rid of the dirty", leave it outside the house and then "wash it in the morning separating the clothes" with the significance of protecting the family from the risks of mercury; From this perspective, it is considered that the practices enunciated are fundamental for the reduction of the exposure of family members.

The informants are unaware that mercury also accumulates on the earth's surface, that breeding animals and that particulate dust material has the same potential to affect the individual and the environment included in the peri-domiciliary space; the family also inappropriately perceives the joint risk with phrases such as "we are all going to the mine", "wife, husband, children"; It goes without saying that the toxic effect of mercury remains in the mine, which is self-limited to the compound, since it is even stated that "mercury is stored outside the house", "it remains in a special jar".

Families and barequeros assume as a fact that clothing and cleanliness, as well as personal hygiene, play an important role in reducing exposure to mercury. Indications for mercury-contaminated clothing indicate that it should be discarded.

These practices aimed at personal, occupational and family protection, although structured, do not meet the proposed goals, also denote the commitment that the families of those who work in the Ayapel gold mines with the need for risk mitigation; These practices, which are assumed on a daily basis rather than rudimentary, are precarious that reveal the situation of informality, poverty and ignorance despite their high vulnerability to pollution.

Practices aimed at environmental conservation. It is highlighted in this analysis that the damage to the environment and natural resources remains a constant concern for the barequeros of Ayapel. Regarding the need to actively participate in the conservation of environmental health and biodiversity, the gold miners of the gold mines of the Lower San Jorge River Basin critically perceive the need to conserve the natural environment.

They recognize that there is contamination of the San Jorge River as a source of natural water that requires their active participation in its care; however, the practices they carry out with all environmental awareness (and little knowledge) are

oriented towards the reuse and recycling of water. For this expected effect, recycling consists of cleaning, sedimenting or clarifying the water they have used, phrases such as "from the same hole where the earth was removed, there the same water is poured; from that hole it falls into another hole and thus the water comes out filtered,"

For the barequeros, the recycling of water consists of both its cleaning (decantation) and its reuse thus: "in the same hole and in the same water that you are pouring, you are recycling it", "we are working with the same water, we are not polluting"; they recognize as true that this form of filtering generates that the fragmented mercury is deposited on the ground "that is, that is left there" and they assume that in this way the water is not being affected, but they are transferring significant loads of mercury to the terrestrial space on the banks of the San Jorge River; It is illustrated with the story "(...) the water and mercury remain in that hole, the claritic water comes out on top."

Reiterating the aspect mentioned above regarding the concept of the barequeros in terms of dirt being equivalent to pollution, it has been stated that the practice used of filtration and recycling of water, for them is effective when they say "we discard it, it goes to the water and you do not see it"; For them , it is a conservation practice to make the water look cleaner, ignoring or ignoring that it still contains hazardous chemical residues.

4. DISCUSSION

The findings regarding practices aimed at the risk of family contamination and the on-site environmental conservation of the exploitation confirm the postulates of the United Nations Environment Program (2002) in which artisanal and small-scale gold mining is expressed as the primary source of deliberate release of mercury. since it is carried out even under conservationist assumptions and protection of the family environment; The results of this study indicate that during the management of the risk of mercury contamination, the effect that is located is counterproductive, since loads of mercury that have been released in the mine are transferred to the spaces in which the barequeros and their families reside.

These findings allow us to identify that certain practices of the barequeros have an impact on the fact that the soils in the artisanal and small-scale mining areas (ASM) studied have high concentrations of mercury (Hg), between 723 and 2067 times higher than those obtained in the control soils. In Sseku's study, soils showed contamination at moderate to high levels, cataloged according to the values of the geoaccumulation index (Igeo), which range between 1.16 and 3.31. The results of the study showed that food crops as well as wild plants accumulated Hg levels above the permissible limit of 20 ng/g (0.02 ppm). This study revealed relatively high levels of Hg in the aerial parts of plants and that 47% of food crop samples exceeded the permissible limit (0.5 µg/g) of mercury set by the FAO/WHO (Ssenku et al, 2023).

Regarding occupational protection measures, Muñoz et al (2012) agree in the study in relation to the scarce use of protective measures against exposure to mercury, as well as in the present study in which the use of masks and gloves, recommended when handling mercury or amalgam, is not used. this in order to avoid absorption through the air and through the skin; they are the ones that cause the increase in the consequences on the health of those in charge of the workforce (Muñoz et al, 2012).

The practices reported by the barequeros and relatives of the Lower Basin of the San Jorge River are aimed at reducing the visibility of the river in the water and in the soil; unaware that mercury, being a liquid metal, fragments very small when it falls and disperses in microdroplets. The proper washing and identification of mercury that has been suggested involves spreading sulfur dust, which will change color upon contact with mercury, and should be carefully collected to be packaged in a ziplock plastic bag for final disposal by a company that treats the polluting waste.

The effect of L-Cysteine amino acid as a chelating agent of heavy metals through its thiol group has been documented, evidence shows that it is possible to use it in soils or on riverbanks; this being a low-cost alternative with potential for in-situ use in the remediation of mercury-contaminated sediments by increasing the non-mobile mercury species by more than double those originally present, only after placing the amino acid in contact with the contaminated water (Acosta et al, n.d). The decontamination of water bodies contaminated with mercury through the decantation and clarification of the waters, as the barequeros do in their daily practices, does not have any type of efficacy, efficiency or effectiveness, since the metal is mainly stored in sediments (Randall & Chattopadhyay, 2013); and its treatment requires the use of different proven remediation techniques that remove, isolate and reduce the recirculation of the metal, such as dredging, capping, and phytoremediation or chemical immobilization, respectively (Randall & Chattopadhyay, 2013)

In this regard, no form of soap or detergent that can be used by barequeros in hand washing, bathing, or washing clothes has properties to neutralize mercury; it is recognized with scientific evidence that selenium neutralizes mercury and, in particular, the organic mercury called methylmercury; mercury when poured or spilled is difficult to clean, especially when it is introduced into cracks and crevices, or on fabric or other porous material, which is why the cleaning practices that are carried out for decontamination purposes at the mine site, at home and water recycling are unproductive practices, whose impact is negative in all the areas analyzed.

Regarding the use of mercury (banned in Colombia since 2013), the indications indicate that if the amount of mercury is greater than 3 grams, it must be a trained professional who will be responsible for carrying out the decontamination; Regarding the in-situ treatment of contaminated ecosystems, it is recommended to use powdered sulfur since mercury is a highly chalcophilic element (i.e., it has an affinity with sulfur) and therefore, mercury binds strongly to compounds containing a thiol group even in the simultaneous presence of other heavy metals with equivalent molar concentration (Bansal et al., 2018; Matlock et al., 2003) recently forming HgS (Jagtap et al., 2011).

In daily practice, miners are still using mercury, and although they understand the risks, they do not have training or accessible and economical options to carry out artisanal mining for clean work; These occupational exposures as well as the repeated use of mercury are motivated by the need for subsistence of the barequeros, given the lack of other sources of income in the area, consequently confidence in the risk is generated and there is a tendency to normalize risk within daily routines.

Due to the ability of mercury to bioaccumulate and bio-magnify when it is released into the environment, and consequently to the filtration practices of the wastewater obtained after working with mercury, it would be expected that, in the exploitation area, as well as in the places of residence of the barequeros, food plants and others are carrying out mercury absorption related to a high level of contamination; in this regard, Marrugo-Negrete et al. (2015) have confirmed that the accumulation of mercury occurs in a greater proportion in the roots than in the aerial parts of the plants; this is explained by situations such as those found in this case, in which mercury is buried when filtering the water, consequently when the roots of the plants are directly exposed to the mercury present in the soil, they absorb a large amount of the metal in their roots to avoid the toxic effects, in the upper parts of the plant (Wang & Greger, 2004).

Solutions must go beyond simple prohibition and move towards the provision of environmental alternatives that replace mercury in gold exploitation, addressing direct actions that intervene in the causes of vulnerability, such as lack of access to economic resources, lack of education and lack of basic services. Risk mitigation strategies must incorporate a comprehensive approach that considers both environmental and health aspects as well as social and economic aspects, with the aim of ensuring a healthier and more sustainable future for the families of Ayapel.

The findings coincide with Camacho et al (2016), who have considered that the perception of risk of mercury toxicity is low in the community, mainly in situations in which mining is the only economic activity.

5. CONCLUSION

Families in the Lower San Jorge River Basin, aware of the need, have created informal prevention systems that do not allow reducing exposure to mercury, although without formal intervention or more advanced technologies. However, their responsiveness is constrained by structural and contextual factors that impede the implementation of more effective practices.

This study highlights the capacity of families in the municipality of Ayapel, located in the Lower Basin of the San Jorge River, to develop adaptive practices and cultural strategies in the face of the risks associated with mercury contamination derived from artisanal mining.

The perception of risk associated with mercury is mediated by cultural, social, and economic factors, which influences how families prioritize their mitigation actions. Conditions of vulnerability, such as lack of access to basic services, education, and health care, limit the ability of families to implement more effective mitigation strategies. The daily practices described, such as washing clothes and bathing after working in the mine, are evidence of the perception of risk, but they also show the limitations in the face of available resources.

The results obtained in this study complement previous research documenting the socio-environmental impacts of artisanal mining in vulnerable regions. However, this work differs by focusing on the cultural and everyday strategies that families develop to mitigate these risks.

In addition, the findings underscore the need for interdisciplinary approaches that combine scientific

knowledge with traditional knowledge to address complex problems such as mercury pollution. This implies recognizing communities as co-creators of solutions and not only as recipients of external measures.

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