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Articles

Evaluation of heavy metals and social behavior associated with water quality in Suches River, Puno, Peru

Evaluación de metales pesados y comportamiento social asociados a la calidad del agua en el río Suches, Puno, Perú

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Abstract

The purpose of this study is to evaluate the concentration of heavy metals in the Suches river and to analyze the social behavior of local agents on the quality of water related to mining activities in Cojata, Puno, Peru. Water and sediment samples were collected from the Suches river for the quantification of As, Cd, Cr, Pb, Cu, and Hg through inductive plasma mass spectrophotometry (ICP-MS). The research included the qualitative analysis of the social behavior of the communal agents of Cojata, based on the collection of representative testimonies. Average concentrations of metals in water are below the ECA-category 3 of Peru; however, As (11.52 mg kg^{-1}) and Cd (1.14 mg kg^{-1}) in the sediment samples exceed the limits recommended by the ISQG of Canada. The presence of these metals in the river is due to the discharges generated by excavations and drainage typical of mining activities, as well as the mineralogical composition and natural weathering of rocks in the study area, which would cause negative impacts on the quality of the river water. The social behavior of rejection of mining is based on the collective association of poor water quality related to its turbidity. The various sources of evidence suggest the need for the formalization of mining activities in Cojata, as well as the implementation of improvements in national environmental regulations.

Keywords: Water, social behavior, heavy metals, Suches river, sediments.

Resumen

El objetivo de este estudio es evaluar la concentración de metales pesados en el río Suches y analizar el comportamiento social de los actores locales sobre la calidad del agua relacionada con actividades mineras en Cojata, Puno, Perú. Se recolectaron muestras de agua y sedimentos del río Suches para la cuantificación de As, Cd, Cr, Pb, Cu y Hg mediante espectrofotometría de masas con plasma inductivo acoplado (ICP-MS). La investigación incluyó el análisis cualitativo del comportamiento social de los actores comunales de Cojata, con base en la recolección de testimonios representativos. Las concentraciones promedio de metales en agua se encuentran por debajo de los ECA-categoría 3 de Perú; sin embargo, el As (11.52 mg kg^{-1}) y Cd (1.14 mg kg^{-1}), en las muestras de sedimentos, superan los límites recomendados por la ISQG de Canadá. La presencia de estos metales en el río se debería a las descargas generadas por excavaciones y drenajes propios de las actividades mineras, así como a la composición mineralógica y meteorización natural de rocas en la zona de estudio, lo que causaría impactos negativos en la calidad del agua del río. El comportamiento social de rechazo a la minería se basa en la asociación colectiva de una mala calidad del agua relacionada con la turbidez de la misma. Las diversas fuentes de evidencia sugieren la necesidad de la formalización de las actividades mineras en Cojata, así como la implementación de mejoras en las normativas ambientales nacionales.

Palabras clave: agua, comportamiento social, metales pesados, río Suches, sedimentos.

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Introduction

Mining is one of the most important economical abstraction activities worldwide. Several river basins at the south of Peru are rich in highly commercial and industrial metal deposits (INGEMMET 2009), however, as time went by, the zones where these processes are being made have faced considerable changes, the exploitation sites as much as the surrounding areas, the environment became affected by the use of the terrain, location of dumping sites and the establishment of wide-spread camps (McIntyre, Bulovic, Cane, & McKenna, 2016).

The removal and sliding of great quantities of ground can contain heavy metals, considered as contaminating chemicals when they are found in high concentrations in any environmental bodies (Hodges, 1995; Rahim *et al*., 2019). Metals that are considered toxic are mostly As, Cd, Cu, Cr, Pb y Hg (OMS, 2006; Yi *et al*., 2020), these metals can significantly affect the hydrological resources in terms of availability of good quality water, and also generate potential impact in a great number of services from the ecosystem (Hodges, 1995; Liang *et al*., 2020).

The risk implied by the transference of metal through the trophic chain (Lu *et al*., 2019 and the damage that they represent for human health (Topalián, Castañé, Rovedatti, & Salibián, 1999) are highly relevant, especially in developed tows near mining activities (Islam, Ahmed, Raknuzzaman, Habibullah-Al-Mamun, & Islam, 2015), considering these occurrences can be extended beyond the mine's operative life and is considered that in many cases the social and environmental impact is bigger than the benefits from the project (Ural & Demirkol, 2008).

In Peru, minor scale mining activities represent a risk for environmental behavior. There are cases of legal mines with little scale activities covered by regulations that protect aquatic environments through quality water criteria (MINAM, 2017), this they take into account the use of the body of water depending on cataloging: First category (population and recreation); second category (extraction, farming and other marines, coastal and continental activities); third category (watering of crops and drinking for animals); fourth category (conservation of the aquatic environment) (ANA, 2018). However, the Peruvian government has not yet issued a guiding decree to set parameters of quality in sediments, that is the reason why several studies (Ali-Khan, Tobin, Paterson, Khan, & Warren, 2005; Chau & Kulikovsky-Cordeiro, 1995; Flores, Del-Angel, Frías, & Gómez, 2018; Zotou, Tsihrintzis, & Gikas, 2020) use international references, for example, Canadian ones (Canadian Council of Ministers of the Environment, 1995), which can be complemented using the guidelines for levels of probable effects recommended by MacDonald, Ingersoll and Berger (2000).

The intensive practice of mining along with other uses of the ground that affect the hydric system and the quality of the water at the basins also generates doubt and social arguments regarding the hydrological source of nearby communities (McIntyre *et al*., 2016). Numerous investigations emphasize the need for a complete diagnosis of the environmental quality of an ecosystem through the discussion between several groups of social actors that are part of the influence area of alternative states of and industrial activity (Chapin, Folke, & Kofinas, 2009; Sánchez-Infantas & Quinteros-Carlos, 2017). Other studies had suggested that there is an influence on the behavior of social actors, based on the observations about characteristics of environmental bodies and the risks that could compromise their health or productivity (Hilson, 2005; Paul, 2017b; Pengli, 2008).

Dogaru *et al*. (2009) demonstrate that the results associated with the experiences of the actors and measures of water quality at the Certej basin in Romania are convergent. These discoveries also suggest that the mining activities represent an obvious risk in superficial water, however, the quality of the water was not much predicted by the regression model and it does not seem to be related to mining as other explanatory factors related to mineralogy and hydrological dynamic. Is that how social behavior and the characteristics of environmental bodies give different types of evidence, by relating these they allow to set a base for better management of resources in a more accurate and transdisciplinary way (McIntyre *et al*., 2016; Morales *et al*., 2020).

The governments from countries that have gold artisanal mining insist that the solution to the conflicts between social actors and informal and illegal miners is the formalization of workers. On this line, Milanez and Puppim-de-Oliveira (2013) evaluated a case in which the formalization and agreed establishment of little groups or economic communal agents have contributed to the environmental improvement by the mining sector in the State of Paiauí (Brasil). The results suggest that some formalization of existing practices and appropriate politics have resulted in the innovation with some positive effects on the performance of artisanal mining.

On the other hand, in the Peruvian state, some failed and erratic series of actions have appeared in the process of formalization of illegal and informal mining. Valdés, Basombrío, and Vera (2014) indicate that factors related to economically-structural deficiencies (informal employment) lack of efficient public policies, and the instability of the government in face of pressures from the mining sector, explain why the objectives and goals were not reached in form and time.

The purpose of this study is to evaluate the concentration of heavy metals at the Suches river and to analyze the social behavior of local agents on the quality of water-related to the mining activities in Cojata, Puno.

Heavy metals as environmental contaminants

The presence of heavy metals in any type of environmental body it's a great concern due to biomagnifications that reach the highest trophic levels (Jain, Kapur, Labana, Banwari, & Sarma, 2005; Paul, 2017a).

The abnormal concentration of several metals and metalloids in ecosystems has awoken the need for further precise knowledge about its geochemical behavior in natural environments near mining areas, spillways, urban areas, and industrial centers (ATSDR, 2006), that's because these elements represent a high risk for human health (ATSDR, 2020). It's greatly known that if there is a high accumulation of metals in the organism, this can cause tumors, gastrointestinal; muscular; reproductive; neurological and hereditary disorders (Buxton *et al*., 2019; Genthe, Kapwata, Le-Roux, Chamier & Wright, 2018; Wang, Qin & Liu, 2019).

In Peru, several studies have reported about the presence and accumulation of heavy metals in the water and sediments in zones where extractive mining activities are developed (Himley, 2014). Donaires-Flores (2017) reported that the first part of the Suches river, starting from its origin point, shows a water pollution ratio of 0.20, considering it of acceptable quality with a low presence of microcontaminants, however, the middle and lower portions show greater deterioration of the river which can be due to high accumulation of heavy metals with a rate of pollution ratio of 0.70 and 0.50, respectively, also, Santos-Frances, Martinez-Grana, Alonso-Rojo and Garcia Sanchez (2017) determined that the rate of contamination produced by metals in Colquirrumi (a high altitude zone of the Western mountain range of the Andes) was high because of the high density of mining sites that work in the area. On the other hand, Pino *et al*. (2017) determinated the relation between geology, climate, and hydrology at Caplina basin (Tacna, Perú).

Their research concludes with the identification of three geomorphological units: Western Cordillera, Puna, and Flanco Disectado, where the influence of summer rains plays a high role in the circulation of the biggest percentage of superficial draining, that erodes andesitic and dacitic rocks, transporting sediments through water regularly, also, the biggest sources of influence on water quality had been recognized: arsenic (1.43 mg l^{-1}), lead (0.22 mg l^{-1}) and sodium (296.72 mg l^{-1}); which were beyond de standard levels of environmental quality of Peru (MINAM, 2017).

That is why, despite de fact that mining generates great economic benefits, it can also cause serious socio-environmental risks, such as modifications of several natural resources and lot social impact, in consequence, the evaluation of the concentration of these metals is essential for the benefit of the ecosystem and the communities in that zone.

Approach on the analysis on social behavior

For the analysis of the social behavior of communal agents around the contamination of water and sediments, we can appeal to the sociological theory of social action. This social action is guided, not by the structures or imposed rules as a way of repression on the subjects, but by feelings, ideas, and critical, reflexive, and comprehensible attitudes of the agents (Weber, 2002). Given this explanation, social action takes care of human behavior regarding the product of social interaction of the agents based on communicative action, where language plays a prominent role, accompanied by the interpretation for coordination and negotiation of the actions (Habermas, 1999; Lorenc, 2014); social action tries to understand how the individuals or people intertwine their actions to carry out a thing in common in a determinate place and time (Allones-Pérez, 2005).

Similarly, we are doing a reference to Giddens, Lutz (2010) who says that social action is a continuous process of reflection that the individual or subject maintains for the control of his body in his everyday life, that is to say, that the organization of daily life is the process from which every individual builds and rebuilds the social structure. This is the product of intentional behavior given thanks to the constant reflection of the agent.

On the other hand, from the point of view of the phenomenology of Schutz, one tries to find the comprehension of the subjective meaning of social action (Laffaye, 2013), because every experience is potentially significant, so, through a reflexive look it can be separated from the flow of experience and that way understand it's subjacent meaning. In that way, as López states (López, 1995), Schultz phenomenology centers its attention on social subjects, which behavior cannot be explained through causal blueprints, it has to be comprehended, which means that said conduct needs to be subjectively comprehended, this implies the knowledge of conscious functions of the agents because the subjectivity of the agents constitutes the objective world.

Finally, from the socio-phenomenology perspective, one tries to understand the social behavior of the agents by putting them into context with the world and life (Toledo, 2007), this forms the horizon of every form of reality that different social practices, lived and cognitive experiences can come to form.

Materials and methods

Study area

Suches river watershed, located between Peru and Bolivia (Rodriguez & Ulanowicz, 2015), has a length of 164 km(Iltis, Carmouze, & Lemoalle, 1991)and it flows until it turns into one of the main tributaries rivers of Lake Titicaca (Molina & Pouilly, 2016). At the headwater of this basin at the bank of Suches river, artisanal mining activities are developed (Villegas *et al*., 2012). In most of these the process of abstraction is open-casted (INGEMMET, 2009). In this study, we keep under observation the section of Suches lagoon, capital of Cojata district (

Figure ***1***), with a length of 33.8km. The sample points are described in Table 1.

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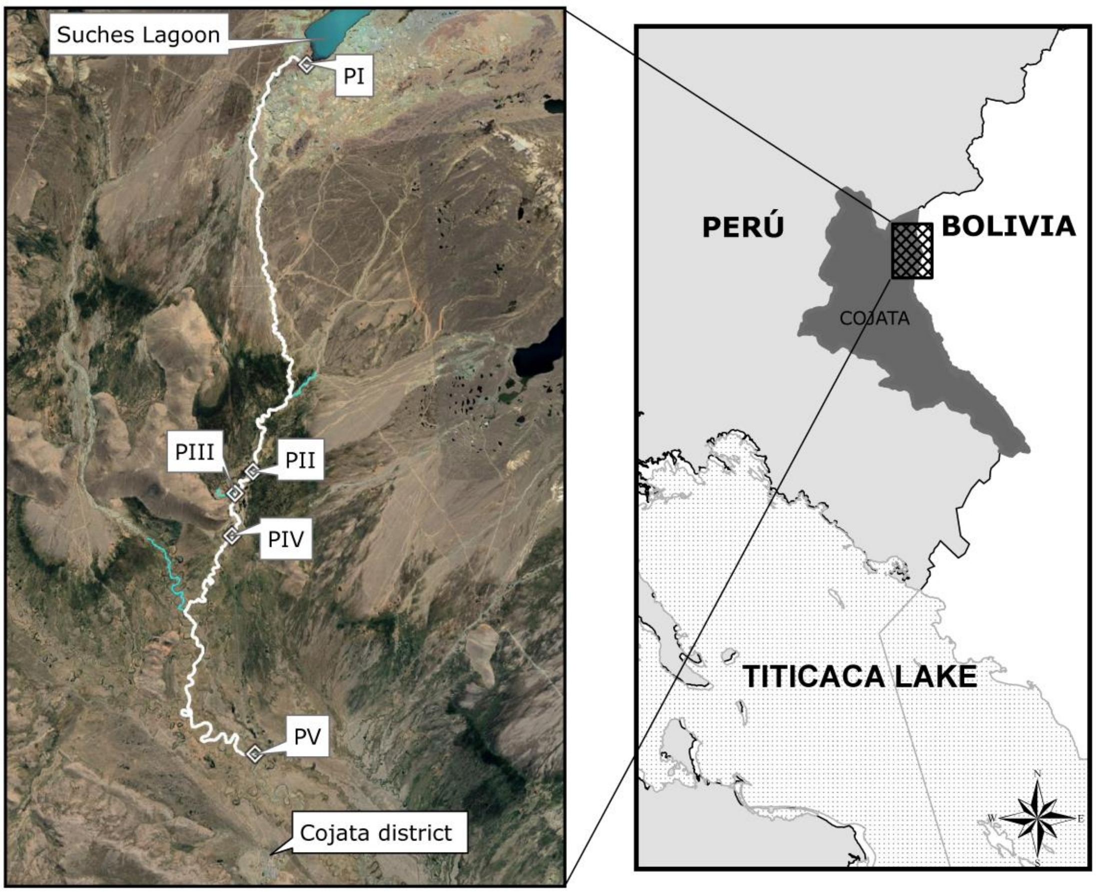

Figure 1. Location of the study area. Source: a self-made elaboration.

Table 1. Geolocation of sampling points.

Sampling Points	**South latitude**	**West longitude**	**Description**
PI	14° 47′ 44.57″	69° 20′ 24.85″	Effluent from Suches Lagoon

PII	14° 54′ 28.74″	69° 21′ 48.33″	Mining dumping collecting zone
PIII	14° 54′ 48.81″	69° 22′ 8.03″	Agriculture zone
PIV	14° 55′ 30.04″	69° 22′ 13.8″	Affluents catchment zone from the left bank
PV	14° 59′ 1.22″	69° 22′ 4.08″	Zone nearby Cojata district capital

Source: Self-made elaboration.

For the valuation of opinions on lived experiences of local agents regarding environmental pollution, we had in mind the participation of local people from Cojata district, which is located in Huancané province at 5000 M.A.S.L, in Puno department (Peru). This town is formed by 16 communities with a total of 769 households (INEI, 2017) and is the first district that receives water from the Suches river (DRA Puno,2016). Townspeople from Cojata work mostly with agriculture, using the closeness of the river for a freshwater supply (DRA Puno, 2016; Gonzáles & Aparicio, 2009; Huanca, Apaza, & Lazo, 2007).

Water and sediment sampling

Having in mind the National Protocol for monitoring of water quality of superficial hydric resources of Peru (ANA, 2016) five sampling points have been established, these are described in Table number 1. The samplings were done during the transition of dry to the rainy season in October and December 2019, also in January and February of 2020. At each point 50 ml of water were collected in a falcon kind polyethylene cone-shaped jar 10 cm below water, adding 1 ml of nitric acid, we also collected 250 grams of superficial sediment with a polycarbonate spoon the sediment was put in polyethylene bags with hermetic seal. The samples were kept at 4°C until their analysis at the lab (EPA, 1991)

Determination of physical-chemical parameters and heavy metals

Ph, electric conductivity (EC), oxidation-reduction potential (ORP), and temperature were determined in situ, using the multiparameter model HI9829 from the HANNA brand. Also, the field staff registered the turbidity of water in a qualitative form. The samples were quantified in an inductively coupled plasma mass spectrophotometer ICP-MS, Icap Q model Thermo Scientific brand. The concentration of six heavy metals was determined (EPA, 2014) and sediments (EPA, 1996; EPA, 2007): Arsenic (As), Cadmium (Cd), Chromium (Cr), Copper (Cu), Mercury (Hg) y lead (Pb). The concentrations of these metals were evaluated according to Peru's water quality standards- Category 3 (MINAM, 2017) and Canada's sediment quality index (Canadian Council of Ministers of the Environment, 1995).

Methodology for social behavior analysis

For the recollection of data in situ referring to subjectivity and inter-subjectivity of local agents about water quality concerning mining activities. Three qualitative techniques were used (Hernández, Fernández, & Baptista, 2014). In the first stage, we applied the semi-structured guide to 30 deputy governors (authorities from rural zones) that represent Suches river nearby zones (point of study) that allowed us to register the subjective experiences of the local agents. In the second stage, we applied the focal group guide to eight communal authorities and people in charge of the management of crops watering in Cojata District, who have more information about the problematics, this lets us identify and describe the inter-subjectivities of the social

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agents. Finally, the direct register observation file lets us analyze social actor's behavior about socio-environmental processes.

After all this, we carried out the processing and analysis of the data through qualitative data analysis software Atlas.ti 8, to systematize the data through identification and organization of the testimonies of the local agents in the function of sub-categories where we organized the categories of characterization and river's social problematic.

Results

Physico-chemical characterization

The PH values of water in the Suches river vary between 6.98 and 7.56, showing minimal variations over the study zone, the electrical conductivity values were between 84.6 and 126 uS/cm, the oxidation-reduction potential varies between 191 and 208 mV. It has been registered that in P1, the turbidity of water was clear and without visible variations, in parts 2 and 3 the turbid state of the river was evident,

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while in parts 4 and 5, the water looked semi-clear. The river's temperature fluctuates between 9.04 and 14.3 °C.

Determination of heavy metals in water and sediments.

Table 2 shows the concentration of metals in water, where we can see: As from 0.78 to 6.62 µg L^{-1}; Cr from 1.95 to 10.5 µg L^{-1}; Cu from 2.68 to 6.78 µg L^{-1}; Pb from 0.58 to 5.45 µg L^{-1}, while Cd and Hg are bellow detection levels. All the metals are below the environmental quality standards of water in Peru.

Table 2. The concentration of heavy metals in water.

Sampling points	As µg l^{-1}	Cd µg l^{-1}	Cr µg l^{-1}	Cu µg l^{-1}	Hg µg l^{-1}	Pb µg l^{-1}
PI	0.78 ±0.084	BDL	1.95 ±1.2	6.15 ±4.9	BDL	0.58 ±0.3
PII	5.86 ±4.61	BDL	10.5 ±6.7	6.02 ±4.7	BDL	5.45 ±3.9
PIII	6.62	BDL	6.24	6.78	BDL	4.92

	±3.25		±3.0	±3.2		±2.5
PIV	4.36 ±2.09	BDL	4.2 ±2.2	5.52 ±2.6	BDL	3.16 ±1.6
PV	2.44 ±2.13	BDL	3.1 ±2.2	2.68 ±2.4	BDL	1.95 ±2.1
Medium Value	4.01	---	5.2	5.43	---	3.21
DE [1σ]	2.4	---	3.4	1.6	---	2.0
Medium	4.36	---	4.2	6.02	---	3.16
Max.	6.62	---	10.5	6.78	---	5.45
Min.	0.8	---	1.95	2.68	---	0.58
ECA water (C-3)	100	10	---	200	1	50

Source: Self-made elaboration.

The concentration of these six heavy metals in sediments is shown in Table 3. Cd concentration showed a gap between 0.9 and 1.3 mg Kg^{-1} with a medium value of 1.14 mg Kg^{-1} and a homogenous distribution through the study zone that exceeds the ISQG limit of 0.6 mg Kg^{-1}; however, none of the zones present a concentration above the permissible exposure limit of 3.5 mg Kg^{-1} proposed by MacDonald *et al.* (2000). The concentration of As was between 3.6 and 15.5 mg Kg^{-1} with a medium value of 11.52 mg Kg^{-1}; the PI, PII, PIII, and Pv are over the ISQG limit of 5.9 mg Kg^{-1}, even though all the zones present a concentration below permissible exposure limit of 17 mg Kg^{-1} (MacDonald *et al*., 2000).

Table 2. The concentration of heavy metals in sediments.

Sampling points	**As mg kg^{-1}**	**Cd mg kg^{-1}**	**Cr mg kg^{-1}**	**Cu mg kg^{-1}**	**Hg mg kg^{-1}**	**Pb mg kg^{-1}**
PI	13.5 ± 0.4	1.2 ± 0.5	15.06 ± 1.7	10.48 ± 2.3	0.09 ± 0.07	11.88 ± 2.6
PII	12 ± 6.6	0.9 ± 0.4	13.98 ± 3.4	10.92 ± 3.1	0.12 ± 0.07	9.7 ± 2.2
PIII	13 ± 5.8	1.3 ± 0.6	15 ± 2.9	11.86 ± 3.4	0.1 ± 0.04	9.82 ± 1.4
PIV	3.6 ± 1.6	1 ± 0.4	13.38 ± 1.1	10.02 ± 2.6	< 0.02	9.7 ± 1.2
PV	15.5 ± 6.9	1.3 ± 0.6	13.66 ± 1.9	10.98 ± 2.3	0.11 ± 0.05	10.46 ± 2.5
Médium value	11.52	1.14	14.22	10.85	0.10	10.31
DE (1σ)	4.61	0.18	0.77	0.68	0.01	0.93
Medium	13	1.2	13.98	10.92	0.11	9.82
Max.	15.5	1.3	15.06	11.86	0.12	11.88
Min.	3.6	0.9	13.38	10.02	0.09	9.7
CEQG ISQG	5.9	0.6	37.3	35.7	0.17	35

PEL	17	3.5	90	197	0.49	91.3

Source: Self-made elaboration.

Social behavior of local agents

The representative testimonies of local agents based on the interviews processed by Atlas.ti 8 software are shown in Table 4, in which we present the expressions of agent's social behavior, grouped in 4 analysis sub-categories related to river water quality, cause, contaminating effects, and expectative about mining in Cojata.

Table 3. Testimony of local agents.

Analysis sub-categories	Representative quotes (testimonies)
River water, quality	1. The water from the river that we and the animals drink it's completely polluted, the color of the water is chocolate, and this leaves the Meadows full of mud and that's what our animals consume, causing them fever and diarrhea leading them to their deaths

	2. Contamination is in the water, there are different substances such as mercury, burnt oil, and turbid water that affect animals and human beings 3. I have no knowledge of which materials miners use; I just know that the water comes in turbid
Cause: Informal mining	1. The contaminants that miners use are mercury, burnt oil from heavy machinery, and plastic, they don't have plants that sediment mud or solid waste 2. The contaminants, like mercury, are in the water, in the earth, in the Grass, that is what alpacas eat and drink, and that is why alpacas are also contaminated 3. Informal miners are the ones that do this activity out of the regulatory frame, they say that communities' law protects them to make legal use of the Surface without considering the study of the environment or technical studies for gold extraction
Contaminating effects	1. Contamination affects different things, such as water, air, land, plants, and animals, all Suches river is contaminated because of informal mining,

	developed by our Bolivian brothers that work on the border performing different activities, such as machine washing and gold extraction 2. Contamination is in the water, there are different substances such as mercury, burnt oil, and turbid water that affect animals and human beings 3. The miners that work in the high part or border of Bolivia eliminate polluted water, they also perform commercial activities creating infectious focuses from tons of organic and inorganic waste 4. The water from the river that we and the animals drink it's completely polluted, the color of the water is chocolate, and this leaves the Meadows full of mud and that's what our animals consume, causing them fever and diarrhea leading them to their deaths
Expectative about mining in Cojata	1. The Good about mining is that it generates employment for the inhabitants that live near this sector, the cattle industry could not support family expenses that is why we search for other means to obtain income. For that, it would be Good that some Peruvian companies that work informally would legalize their procedures to extract minerals

	according to environmental norms 2. There are a lot of brothers in Cojata that work in mining because the production and breeding of alpacas do not do well economically, a lot of young people work in mining. For that, we only ask for these mining centers to not work at the bank of Suches river and to respect technical environmental norms 3. Mining Works irregularly, but if they legalize it could benefit the population, also, these mining companies are using new forms of extraction such as a process with cyanide that has more pressure to absorb gold 4. There is no expectation of improvement in Cojata District, each settle Works in what it's possible, there are no Jobs or support from institutions

Source: Self-made elaboration, based on interviews, focal group, and direct observation.

All the local agents that were interviewed and the people who participated in the focal group, by consensus, stand that informal mining that is developed at the top of the Suches river basin, generates environmental contamination in Cojata District. Faced with this situation, the agents express rejection of this type of mining, however, they stand that legalization and respect for the technical environmental norms could benefit mining activity and the population from the zone.

Discussion

The analysis of physical-chemical parameters of water in the Suches river indicates that, in general, the PH values, temperature, CE, and oxidation-reduction potential are in normal conditions considering this type of water body (Donaires-Flores, 2017; Iltis & Carmouze, 2003). The variations that gave place to reported values ranks can be because of fluvial precipitations related to monitoring time. The presence of turbid water seen in points 1 and 3 are associated with natural and anthropogenic causes, increasing the number of sediments in suspension.

Is important to emphasize that the tributary rivers and meadows located after point 2 determine the characteristics of the river in parts 3, 4, and 5.

The analyzed metals in the water showed the tendency Cu > Cr > As > Pb. Copper is the metal that shows the biggest concentration in almost every testing point, probably because of natural processes associated with weathering of rocks in the study zone, which mineralogical composition locally merges vulcanite (CuTe) covered by a chain of fluvial deposits, fluvial-glacier, and glaciers, the laters define the morphology of the zone (INGEMMET, 2009).

Due to the low possibility of Cu concentration in sediments, the results of Table 3 confirm that the presence of this metal could be due to natural causes. Favoring the homogeneity of this distribution in the study zone. Furthermore, the metals Cu and Cr tend to create strong complexes through the presence of organic matter (humic substances) in the sediments and then release from the degradation of organic compounds or oxidation of sulfur to sulfate (Botsou, Sungur, Kelepertzis, & Soylak, 2016; Kelepertzis, Botsou, Patinha, Argyraki, & Massas, 2018).

There are important variations regarding the concentrations of As, Cr, and Pb in water corresponding to point 1 and point 2 respectively. This would imply that before point 2 there is a collection of mining waste mostly made from the discharge of mine tailings, typical sterile materials that come from extraction activities, and even organic matter waste. These discharges can contain metal or metalloid particles soluble in water, that assist the stability and transportation depending on the composition of particles and environmental conditions (Langman, Behrens, & Moberly, 2020).

As is a metalloid commonly associated with metallic mineral deposits such as arsenopyrite (FeAsS) which has an abundant presence according to geological and mineralogical studies on the zone (MINAM

2014) As presents an important concentration charge in water starting in point 2, it is possible that its release in water could be related to extraction and processing of these minerals, that apply the wash and separation methods of the removed material to extract valuable metal (Mamani-Matamet & Marcos-Bonotto, 2019; Villegas *et al*., 2012).

In point 1, the concentration of pb es the lowest (0.58 µg l^{-1}). However, the average concentration in point 2 is 5.45 µg l^{-1}, and it decreases until 1.95 µg l^{-1} in PV, this concentration behavior may be due to the presence of Pb in the acid drainage of mines (Vieira, Rodriguez, de Paula, Braga & Simões, 2020). Due to its high density, Pb tends to deposit in sediments, quickly occupying the area surface of these particles (Eid & Zawia, 2016), so we can see a homogenous distribution pattern generated by a greater dragging forcé from water in times of flood and bigger superficial drains (Belizario, Capacoila, Huaquisto, Cornejo, & Chui, 2019).

The mixture of crystalline particles may be caused by the presence of Cd in the Suches river (MINAM, 2014). Donaires-Flores (2017) dismissed the cadmium values found for the determination of water quality in the water of Suches river, considering them insignificant. The presence of Hg in sediments may be due to the use of this element to amalgamate with gold as a technique of mineral recovery, however, in this study, the concentrations of mercury do not exceed the minimum concentrations considered by different normative. A previous study about the concentration of mercury in the Ramis River watershed, an important tributary of Lake Titicaca, concludes that residual exposure and accumulation of mercury in big extensions of water below historical mining zones, it's five times bigger than in adjacent zones impacted only by outdoor nature and atmospheric deposition (Gammons *et al*., 2006), this suggests that the disposition of this metal could also be in the lower part of Suches river water, precisely in point five, where the concentration of metals shows important variations being the biggest of the concentration points.

It's noticeable that the average concentration of all the analyzed metals is bigger in sediment than in water. The possible mechanisms of reduction of metals include the adsorption on clay and other or other solid surfaces, precipitation or co-precipitation of minerals, and biological absorption. It can be expected that a great portion of this mitigated metal charge is transported water down during events of high flow (Gammons *et al*., 2006).

Speaking about the social behavior of local agents, expressed on their feelings, ideas, attitudes, criticism, and reflection (Weber, 2002), They express the communicative action (Habermas, 1999), questioning the quality of water because they stand that there is contamination on water evidenced in its turbidity, in the deaths toll of alpacas and other problems with community health. This social behavior of communal agents gives into account the presence of heavy metals in the water of Suches river, and that its consumption is affecting human life, animals, and plants (Aliu, Aliu, Mustafi, & Kamberi, 2011; Chibuike & Obiora, 2014); it is also generating various sicknesses (Roman *et al*., 2013). According to Alvarez-Rodríguez, Rodríguez-Avelló, and Pantoja-Timarán (2005), the use of heavy metals, such as mercury for gold abstraction, inevitably generates contamination to rivers, the land, and even workers, because it does not count with safety measures. In this sense, Betancur-Corredor, Loaiza-Usuga, Denich, and Borgemeister (2018) confirm that gold extraction activities can generate more contamination and environmental degradation, which represents a threat to the natural ecosystems and the health of the communities that live near this zone.

This situation in Cojata is a result of informal mining activities in the process of gold exploitation done by the miners, both Bolivians, and Peruvians, what according to Salazar (2014) would be related to the idea of ancestral property and the right upon land and subsoil that the miners claim to possess, and because of this, they would have the right to exploit it freely, generating rejection attitudes and behaviors from the local agents towards informal and illegal mining. For Gonzalez-Rey (2019) this reality will strengthen the skepticism and mistrust from the community social agents because of an erratic response from the state, that has not found a way out of the incapacity to contribute to democracy deepening through the acknowledgment of subordinate social agents, not reaching the objectives and goals for the extension of deadlines that have to do with a formalization process of mining that guarantees better environmental practices (Valdés e*t al*., 2014).

Nevertheless, even though there is a feeling of rejection that the agents express, they also identify the positive side of the mining industry, because this activity generates jobs for some of the inhabitants of the zone, as said by Cusiyunca and Morante (2019). From one point, the expectative of life is focused on the continuity of superior education and migration to other cities, in other cases is focused on juvenile employability related or not to gold abstraction, as a previous mean to sustain their possible way to superior education and later settlement in a residence or household in a determined city. For that local agents in Cojata talk about the need for the formalization of mining activities and respect of environmental norms. Carmona-García, Cardona-Trujillo, and Restrepo-Tarquino (2017) stand that the tools for environmental management and a cleaner production would help to minimize the environmental impact during the cycle of mining activity.

Based on the analysis of social behavior and the characteristics of the study zone, there is a need for formalization of mining activities obeying the environmental norms. These changes may adjust bilaterally through the system of environmental management and the implementation of clean technologies that minimize the environmental impact of mining activities.

Conclusions

There is evidence of a considerable variation in the concentration of heavy metals in the water and sediments of the Suches river. The heavy metal concentrations decrease in function of the river course, being > Cr > As > Pb the ones below ECA-category 3 for water. In sediment, the concentration of heavy metals varies through the course of the river path, however, As and Cd are above ISQE in most of the points. The presence of metals can be attributed mostly to mining exploitation of secondary deposits of moraine origin where there is the use of traditional technologies for gold extraction and mineralogical composition and weathering of rocks in the study zone.

Based on the analysis of the social behavior of the local agents from Cojata, they associate the turbidity of water with the discharges from mining processes, blaming the bad quality of the water on the presence of mercury, which affects the animal, plant, and human life near the zone. In the context of local agent's testimonies', they express rejection towards informal and illegal mining in the zone, that is why they demand the formalization of mining operations and the fulfillment of normative that contribute to the reduction of environmental impact, however, they also stand that there is a positive point about mining, that is because this practice generates employment for some inhabitants of the district.

In general terms, the physical-chemical studies agree with the social behavior of the local agents of Cojata about the quality alteration of water in Suches river due to the presence of heavy metals, however, mercury is not the main cause of the impact generated by mining activities in Cojata, other metals like As, Cd, and Cu are to blame.

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