Environmental Impact of Mining Tailings in the Middle Basin of the Rimac River in Peru

Salazar-Torres Carlos, Carbajal-Kam Itziar, Ponce-Ruiz Genesis, Lazo-Vilela Jeniffer, Alva-Baltazar Edgar, Master of Engineering and Tirado-Mendoza Gabriel, Master of Engineering
Universidad Privada del Norte, Peru, N00141236@upn.pe,N00059718@upn.pe,N00125674@upn.pe,N00098790@upn.pe, edgar.alva@upn.pe, gabriel.tirado@upn.edu.pe

Abstract*– For many years, mining activity has been the main source of work and economy in the province of Huarochirí, where San Mateo de Huanchor is located, it should be noted that during the development of this activity there are a series of impacts that put the environment and population health at risk. 60% of the contamination of the Rímac River comes from mining activity, which is extremely harmful, where basically its concentrations are carried out in the upper basins of the rivers, where the real problem is. According to the purpose of the research, the nature of the problems and the objective set will be a non-experimental descriptive documentary research, since various investigations of the last 3 years were reviewed where it was possible to obtain as results that there are 190 mining environmental liabilities and hydrocarbons without remedy, which cause surface and underground contamination causing the deterioration of water resources, which can also lead to social conflicts. This province has high levels of pollution, where these liabilities can be filtered into the Rímac River, generating irreversible damage to surface waters and with this it would also harm the city of Lima, since it would be left out of this resource due to the high concentration of pollutants.

Keywords*-- Mining activity, hydrocarbons, environmental liabilities, deterioration and pollutants.

Digital Object Identifier (DOI):
http://dx.doi.org/10.18687/LACCEI2021.1.1.103
ISBN: 978-958-52071-8-9 ISSN: 2414-6390

Environmental Impact of Mining Tailings in the Middle Basin of the Rimac River in Peru

Salazar-Torres Carlos, Carbajal-Kam Itziar, Ponce-Ruiz Genesis, Lazo-Vilela Jeniffer, Alva-Baltazar Edgar, Master of Engineering and Tirado-Mendoza Gabriel, Master of Engineering
Universidad Privada del Norte, Peru, N00141236@upn.pe,N00059718@upn.pe,N00125674@upn.pe,N00098790@upn.pe, edgar.alva@upn.pe, gabriel.tirado@upn.edu.pe

Abstract*– For many years, mining activity has been the main source of work and economy in the province of Huarochirí, where San Mateo de Huanchor is located, it should be noted that during the development of this activity there are a series of impacts that put the environment and population health at risk. 60% of the contamination of the Rímac River comes from mining activity, which is extremely harmful, where basically its concentrations are carried out in the upper basins of the rivers, where the real problem is. According to the purpose of the research, the nature of the problems and the objective set will be a non-experimental descriptive documentary research, since various investigations of the last 3 years were reviewed where it was possible to obtain as results that there are 190 mining environmental liabilities and hydrocarbons without remedy, which cause surface and underground contamination causing the deterioration of water resources, which can also lead to social conflicts. This province has high levels of pollution, where these liabilities can be filtered into the Rímac River, generating irreversible damage to surface waters and with this it would also harm the city of Lima, since it would be left out of this resource due to the high concentration of pollutants.

Keywords*-- Mining activity, hydrocarbons, environmental liabilities, deterioration and pollutants.

I. INTRODUCTION

The mining activity starts with the stages of prospection and exploration followed by the exploitation in order to get all the benefits from the minerals found. It is known that this activity generates hazardous chemical effluents that contaminate and damage our environment modifying it's relief and geomorphology generating a negative impact in different ecosystems. "The extraction activities of mineral resources, their benefits and concentrations, have led to environmental problems, better-known as environmental liabilities affecting air, soil and water altering its quality and disrupting ecosystems, bad practices were developed before the current environmental regulation that began in Peru in 1990" [1]

One of the problems related to the impact of illegal mining is the contamination of surface waters, especially due to the inappropriate disposal of effluents, wastewaters, acidic waters that do directly to the sewers, and construction/demolition wastes. The impacts on the quality and quantity of water are one of the aspects that caused the most controversy in the development of mining projects. It has been estimated that each year of mining and metallurgy activity releases 13,000 Mm3 of effluents into Peruvian waterways [2]. It should be noted that the concentrations of mining activities basically occur in the upper basins of the rivers. A mismanagement of mining could generate an impact on the physical environment such as water pollution. Tamboraque is a dangerous mining tailings deposit containing toxic waste for more than ten years and it is at risk of falling into the Rimac river basin.

The impacts generated depend on the environmental liabilities found in the water bodies and types of landmines, depending on this, one will be able to identify the risk factors of metals and metalloids for contamination. After the prospection and exploration stage, the exploitation process begins where different types of sulfides are released when exposed to air and humidity generating an oxidation that produces sulfuric acid forming the well-known drainage of acid water which dissolves toxic elements that are transported to the surface of water bodies, then these waters are used for daily or commercial use exposing the population to contamination by toxic elements. As a consequence, the presence of mining environmental liabilities in the water not only affects the quality of the environment itself but also the health of surrounding communities. Next, the location map and the location points of the mining liabilities in the San Mateo district are presented, as shown in Fig. 1.

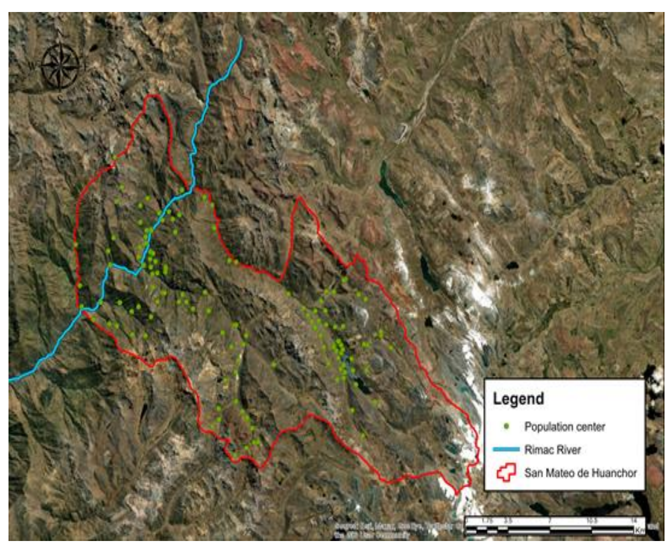

Fig.1 San Mateo district and populated areas. Source: Own elaboration.

This research is focused in the middle basin of the Rimac river, specifically to the part in which the district of San Mateo de Huanchor is located, this is one of the thirty-two districts that belong to Huarochiri province in Lima region, it is located at an altitude that starts from 3 185 meter above the sea level and has an area of 425.60 km2, where five peasant communities are located: San Miguel de Viso, San Mateo de Huanchor, San José de Parac, San Antonio and Yuracmayo. San Mateo de Huanchor has 5 280 inhabitants [7]. That is why, due to the problems described above, the analysis and interpretation of the current situation of the water quality in the section of the Rimac river basin in the district of San Mateo, which is our scope of study. The objective of the research is to identify the impact generated on the water resource by mining tailings in San Mateo.

How do mining tailings generate an environmental impact in the middle basin of the Rimac river? Mining production generates multiple contaminating residues such as copper, lead, zinc, iron, arsenic and cadmium causing harmful effects in the concentration of metals, various reagents, oils, lubricants and diesel and solids in suspension; therefore there are several studies on the impact of mining on ecosystems and health of the population , in our specific case in the middle basin of the Rimac river.

"Inventory and Evaluation of Natural Resources in the Marcapomacocha Project Area" [4], is the first study that evaluates natural resources of the Rimac river basins, Chillon and Lurin, this first study has limitations in the territorial area it covers, since it consists of 3 basins and results with little detailed and dispersed information, but it gives us an approximation of the natural resources potential.

"Control of Torrents in the Rímac River Hydrographic Basin" [5] from 1984 carried out by the General Directorate of Waters, Soils and Irrigation, takes as a basis the research mentioned above, but focuses more on the upper basin of the Rímac river. A more specific study, since it occurs in the upper basin, was "Environmental contamination in the middle and lower basin of the Rímac River"[6], which bases its information on the General Water Law, in which they mention the deterioration of the quality of waters from the source of the Santa Eulalia and San Mateo sub-basin.

It developed another investigation of "Contamination of the Rímac River by heavy metals from the mining industry", carrying out an intensive water sampling between 12 and 24 hours sampling every 2 hours, which focuses on two points of the upper area of the Rímac River, specifically the sources of the San Mateo River. [7]

In conclusion, according to the aforementioned studies, both the waters of the San Mateo River and the Parac stream transport significant amounts of lead and zinc, and that their waters suffer notable increases of these elements when passing through certain areas where there is no type of visual contribution, so it is not possible to justify the balance with discharges except for contributions of another nature [8].

In 2000, the Environmental Health Directorate of the Ministry of Health DIGESA developed two studies, one regarding water quality and the other regarding health, with the objective of determining population's health surrounding the Mayoc tailings field in San Mateo de Huanchor. They showed that contamination is affecting the health of the residents of Mayoc and Daza [9].

II.METHODOLOGY

A. *Research design*

This is a type of qualitative research, given that it will be sought to analyze the problem in order to propose solution alternatives and also non-experimental descriptive documentary based on different sources for the development. Due to the characteristics mentioned, the research is divided into three stages:

1. Cabinet stage
2. Field stage
3. Information processing stage

B. *Population*

The population in which this research is carried out is the populated center of San Mateo de Huanchor, in Huarochirí province, Lima, Peru. Is located at km 92 of the central road between the coordinates 11° 45' latitude and 76° 20' long with an altitude of 3100 to 5000 m.s.n.m. The populated center of San Mateo has 5280 townsfolk. [7]

C. *Techniques, materials or instruments:*

For the purpose of executing this research work, an in depth review of diverse documents was performed including a thesis with a maximum age of 4 years in which everything necessary could be extracted to be able to answer our research question covering the objectives set.

Environmental Inventory 2019 of the National Institute of Statistics and Informatics: This document details the results of physicochemical and biological parameters carried out in the Rímac watershed before and after mining activities between 2009-2018 in the Tamboraque area [10].

DIGESA water quality monitoring report: This was done to determine water quality and the presence of heavy metals, arsenic and cadmium mainly [11].

Identification of mining environmental liabilities, water quality monitoring and estimation of environmental risk: Information was compiled from different thesis to obtain the results of the monitoring of the Rímac river water and mining environmental liabilities and estimation of environmental risk of the liabilities.

Soil sampling: Samples were taken from 10 monitoring points in the area of the San Mateo de Huanchor population center by digging pits at the selected points. Samples were taken at a depth of 10 centimeters following the soil monitoring protocol and then taken to a certified laboratory for analysis and identification of the presence of chemical elements. This was done to determine the quality of the soils and the presence of heavy metals, mainly arsenic and cadmium. Identification and cartographic location of environmental liabilities: This will allow us to represent the maps of the soil quality situation, locate and describe the sampling points to analyze the main components of the local physical environment of the study area.

D. Procedure:

This article leads to a series of investigations that allowed to rescue definitions and fundamental characteristics related to the objective of the research. The research question defined to correctly follow the methodological development is: In what way do mining tailings generate an environmental impact in the middle basin of the Rimac River? Next, the procedures followed for the selection and exclusion of information will be described. Five articles and two thesis were studied, of which one article and two thesis were selected because they provided the necessary information to answer our research question.

Subsequently, for the analysis of the article "Peru Environmental statistics yearbook" conducted by National Statistics and Computing Institute (INEI) [3], information was collected on water monitoring conducted in the Rimac River, being the sampling point in Tamboraque taking only data from 2017 to 2018. In addition, a thesis from the Universidad Mayor de San Marcos was analyzed, where information was compiled on the contamination of the ecosystem in San Mateo as a result of mining environmental liabilities and the impact it can have on the health of the inhabitants. Similarly, a thesis from the University César Vallejo was analyzed where information was collected on the monitoring of the Rimac River in 2017 downstream of the dumping of the mining company called Nyrstar Coricancha and upstream at the confluence with the Mayo River.

For the search of the articles it was necessary to use keywords such as "Environmental impact in the middle basin of the Rimac River", "environmental pollution in San Mateo" "Mining and its impact on the water resources of the Rimac River basin", this was used to be able to obtain accurate information in relation to our objective. Filters were used to obtain more detailed information delimiting our study area and the environmental impact generated in the last 4 years by mining on water resources.

III.RESULTS

In this research, we gathered information for the topic of study that was carried out by following a line of processes. The corresponding filter was made through a deep analysis, among which the area of study and the objective was set for the research work to stand out, obtaining as a result 1 article and 2 thesis. In this way, we worked with this information based on guidelines such as compiling and analyzing recent information from 2017 to 2018 for the case of the thesis on the monitoring carried out downstream and upstream of the Coricancha mining dump and likewise from the Environmental Statistics Yearbook comparing with the Environmental quality standard ECA 2017; however, for the other thesis in which talks about the environmental impacts and effects on the inhabitants of San Mateo, information from 4 years ago was compiled. This was obtained:

A. Water monitoring

According to the article called "Peru Environmental statistics yearbook" by [3] tells us that the results of the water monitoring were collected from 2009 to 2018. However, for this research work, information was only collected from 2017 to 2018 comparing it with the ECA 2017 for water by [15] obtaining the following:

In the Table 1, it compared the result of water monitoring before and after mining activities in Rimac River by arsenic with ECA 2017, as shown to continue:

Table 1. Result of water monitoring before and after mining activities in Rimac River by arsenic. Source: National Statistics and Computing Institute (INEI).

Years	Before	After	ECA 2017
2017	0.034	0.041	0.01
2018	0.024	0.028	

In the Table 2, it compared the result of water monitoring before and after mining activities in Rimac River by arsenic with cyanide 2017:

Table 2. Result of water monitoring before and after mining activities in Rimac River by Cyanide. Source: National Statistics and Computing Institute (INEI).

Years	Before	After	ECA 2017
2017	0.001	0.003	0.2
2018	0.001	0.002	

Also, it compared the result of water monitoring before and after mining activities in Rimac River by zinc with ECA 2017, as shown in Table 3.

Table 3. Result of water monitoring before and after mining activities in Rimac River by Zinc. Source: National Statistics and Computing Institute (INEI).

Years	Before	After	ECA 2017
2017	0.959	1.265	5

2018	0.815	1.235

Finally, it compared the result of water monitoring before and after mining activities in Rimac River by lead with ECA 2017, as shown in Table 4.

Table 4. Result of water monitoring in Rimac River by lead. Source: National Statistics and Computing Institute (INEI).

Years	Before	After	ECA 2017
2017	0.018	0.019	0.05
2018	0.015	0.022	

B. Mining Environmental Liabilities

While, in a study conducted by Diaz, W [8] says that, "The study area San Mateo de Huanchor is a district with a large mining activity and due to it 22 mining environmental liabilities have been identified, as specified in the Ministerial Resolution N°102-2015 MEM/DM [12], there are in the category of mining work 11 pitheads, 01 chimney, 01 trench, and in the category of waste type there are 9 mine clearings, those responsible for the liabilities have not been identified; being the holders of the mining rights the following companies and individuals: Compañía Minera San Juan S.A., Esperada SAC, Gestiones y Recuperación de Activos S.A., Valderrama Saaveedra, Juan Orlando Wiese Sudameris Leasing S.A., Sociedad Minera Aruri SAC, Sociedad Minera Austria Duvaz SAC, Minera Lizandro Proaño S.A., Larizbeascoa & Zapata SAC. In San Mateo de Huanchor, former mining has left these environmental mining liabilities without any treatment or safety measures, putting the environment, safety and health of the district's inhabitants at risk. The presence of mining and hydrocarbon environmental liabilities tend to produce a negative perception among the population regarding the development of extractive activities due to the deterioration of water resources, which can also lead to social conflicts.

All existing liabilities in the district of San Mateo de Huanchor, which have been produced mainly by mineshafts, are classified as high risk for the population due to the accidents they can cause if a resident is near them, the mineshafts show deterioration due to the time of abandonment, there is contamination of surface and groundwater because the water runs superficially and manages to infiltrate into the interior of the workplaces that have not had the corresponding closure inside mines causing leaching of metals and dragging of sediments.

Likewise, another study conducted by J. Cervantes and S. Quito [13] indicates that 176 mining environmental liabilities were found in the district of San Mateo de Huanchor. Meanwhile, in the community called San Miguel de Viso in the district of San Mateo, according to Ministry of Energy and Mines MINEM [14] tells us that 46 liabilities were identified, of which in the study conducted in the field trip 20 of them were identified, of which 4 of them presented the following risks, as shown in Table 5:

Table 5. Mining liabilities identified with drainage. Source: J. Cervantes and S. Quito.

Mining Liabilities	Coordinates UTM		Description
	East	North	
PAS-1	8694527	354470	Ore hopper
PAS-8	8693841	356789	Relavera
PAS-14	8693744	356935	Pit-head
PAS-16	8693963	357116	Pit-head

Also, according to Peruvian law RM N° 238-2020-MINEM/DM [14] tell us that nowadays there are 182 mining environmental liabilities.

In addition, a map of the mining liabilities with drainage was made, which are close to the populated centers. This map allows us to have a vision of the risk that mining liabilities could represent as they are at a very short distance from the populated centers, affecting the health of the population, as shown in Fig. 2:

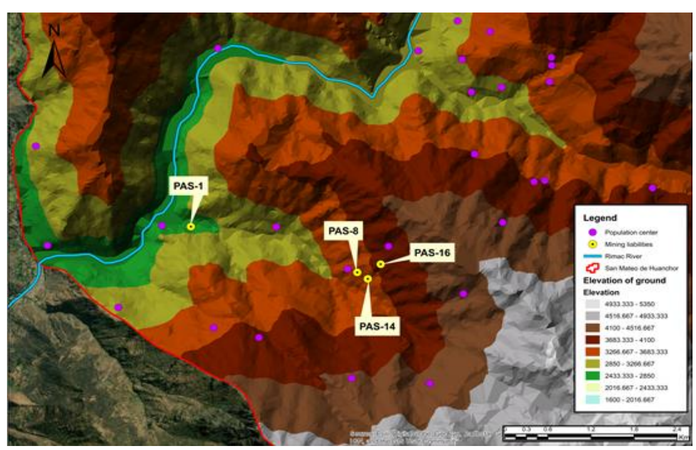

Fig.2 Map of mining liabilities identified with drainage. Source: Own Elaboration

C. Environmental risk estimation

Also, in a study conducted by J. Cervantes and S. Quito [13]. They monitored water for mining liabilities with drainage comparing with ECA for water according by [15].

In the Fig. 3, we can observe the result of the concentration by cadmium on mining liabilities with drainage and the ECA for water according by [15] for compare them.

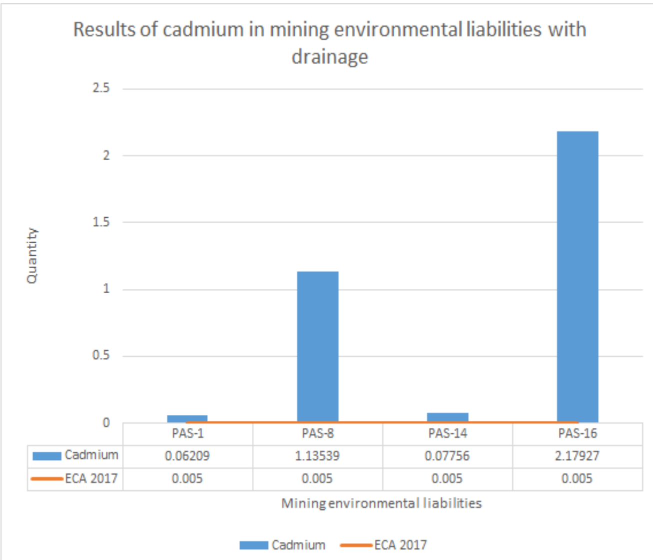

Fig. 3 Results of cadmium in mining environmental liabilities with drainage. Source: J. Cervantes and S. Quito.

As shown in the Fig. 3, the concentration by cadmium exceed the ECA for water in all of them.

Likewise, the results for mercury were the following and it compared with the ECA for water according by [15], as shown in the Fig. 4:

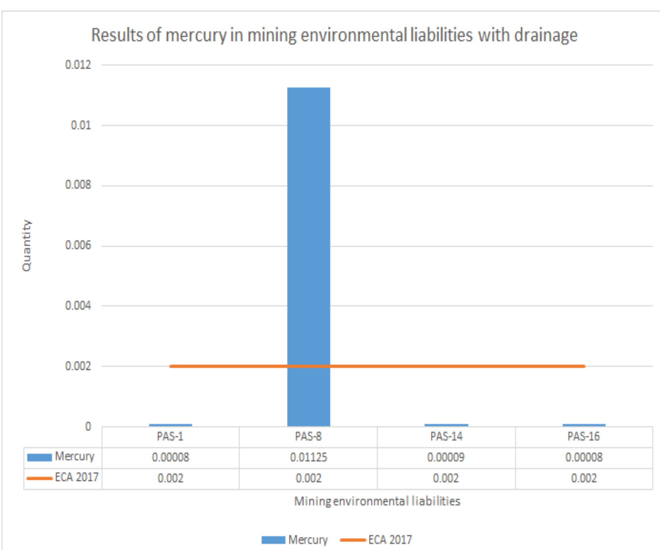

Fig. 4 Results of mercury in mining environmental liabilities with drainage. Source: J. Cervantes and S. Quito.

As shown in Fig. 4, the concentration by mercury in PAS-8 exceed the ECA for water. However, the rest of liabilities don't exceed the ECA for water.

Also, it obtained the results by arsenic from the monitoring of water in mining environmental liabilities were compiled and it compared with the ECA for water by [15].

As shown in Fig. 5, the PAS-8, PAS-14 and PAS-16 exceed the ECA for water.

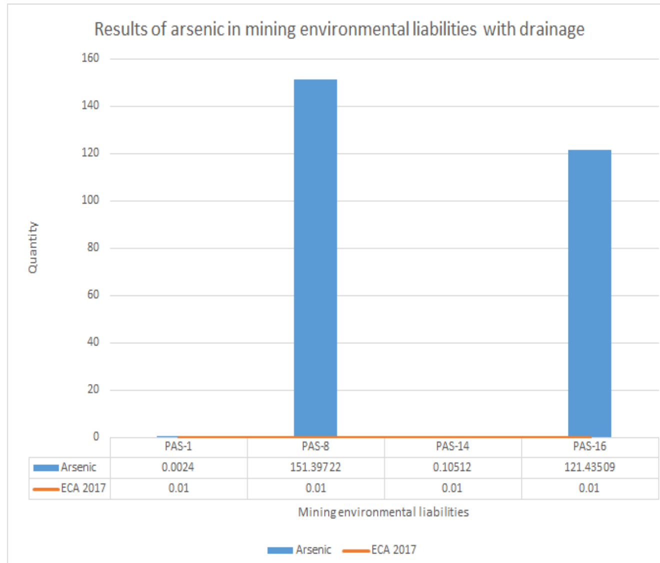

Fig. 5 Results of arsenic in mining environmental liabilities with drainage. Source: J. Cervantes and S. Quito.

Finally, the results by lead from the monitoring of water in mining environmental liabilities were compiled and it compared with ECA for water by [15], with most of the liabilities exceeding the ECA for water, which can be observed in the Fig. 6:

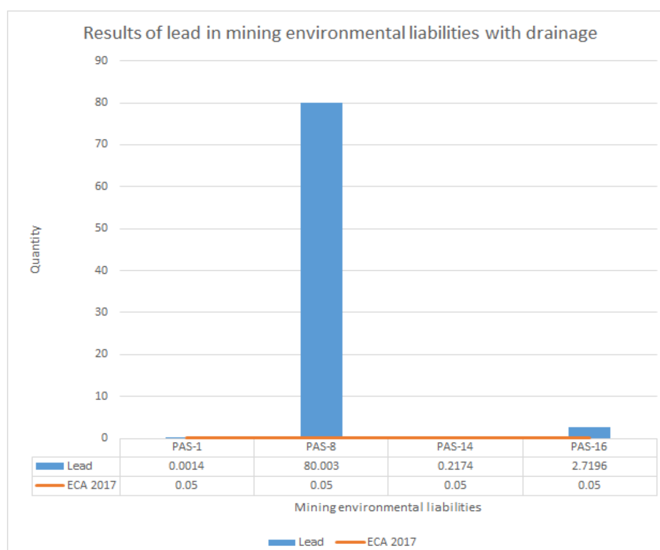

Fig. 6 Results of lead in mining environmental liabilities with drainage. Source: J. Cervantes and S. Quito.

In addition, once the results of the water monitoring in the mining environmental liabilities were obtained, the environmental risk estimate was calculated resulting for PAS-8 and PAS-16 a risk significant, as shown in Table 6:

Table 6. Environmental Risk Estimation. Source: J. Cervantes and S. Quito.

Liabilities	ID	Liability risk	Risk level
Ore hopper	PAS-1	42	Moderate
Relavera	PAS-8	69	Significant
Pit-head	PAS-14	55	Moderate
Pit-head	PAS-16	69	Significant

D. *Soil monitoring*

1) *Arsenic in the soil*

According to the study conducted by [8] it was compared the results of arsenic in the soil with the ECA for soil according by [16], indicate that, in 6 samples, the ECAs of soils for the Residential Use and Parks category are slightly exceeded, while in another 4 samples they are below the established national standard. The results of the sampling conducted, as shown in Fig.7:

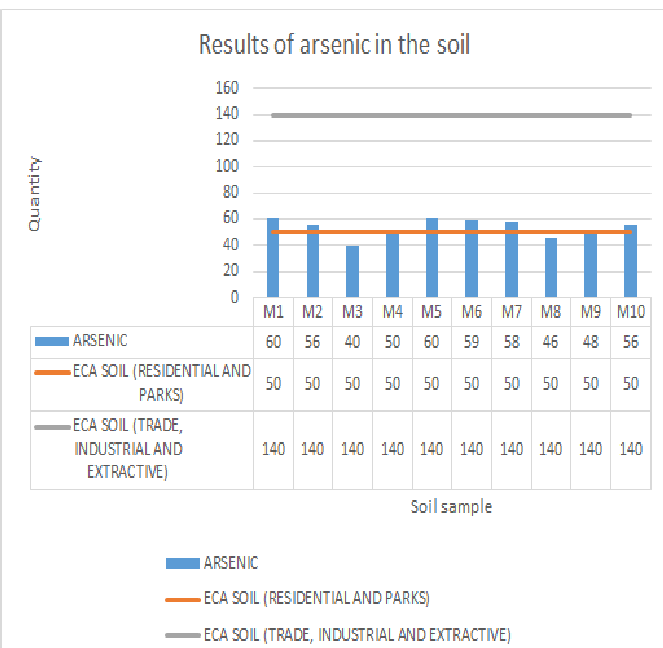

Fig.7 Results of arsenic in the soil. Source: J. Cervantes and S. Quito.

2) *Cadmium in the soil*

According to [8] it was compared the results of cadmium in the soil with the ECA for soil according by [16], it indicated that all the samples obtained present results below the ECA of soils for both Residential and Park Use as well as for Industrial and Extractive Commercial Use, this is due to alkaline soil with a pH of 8, 2 has caused the precipitation of cadmium, so it is not a contaminant in the soil at this time. In Fig.8, we can see the results of cadmium in the soil:

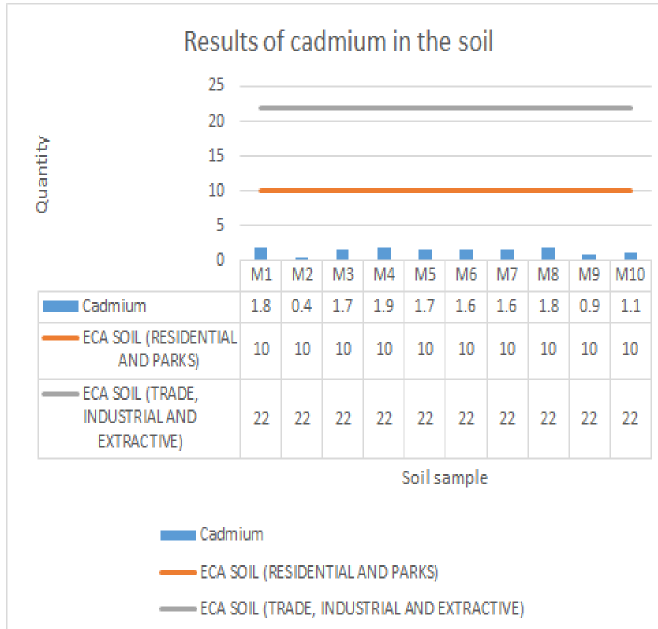

Fig.8 Results of cadmium in the soil. Source: W. Diaz.

E. *Water quality index*

According to Chillón Rímac, Lurín Water Observatory [4] tells us that the observed trend shows gradual decrease in the ICA-PE as one descends to the lower basin. This means a degradation of river water quality, which is strongly influenced by the presence of higher density of human settlements.

F. *Water erosion*

Water erosion, according [4] tells us that, increases its flow in times of flooding with the consequent dragging of material that acts as an erosive agent on its banks. This occurs mostly in areas of higher flow velocity, meanders and areas with the presence of rocks of lower resistance. In addition, in a study conducted by The National Weather and Hydrologic service SENAMHI- Water Services of City of Lima SEDAPAL determined that the districts with the highest risk of erosion are located in the upper basin, due to its high slope and low vegetation cover, are the following:

- San Buenaventura
- Laraos
- Lachaqui
- Arahuay
- Santiago de Surco

- Matucana
- San Bartolome
- Huachupampa
- Santiago de Tuna
- San Andres de Tupicocha
- Chilca

According to [4] maps and models of physical susceptibility have been developed by various stakeholders in the watershed. It is generally observed that the middle and upper zones of the watersheds are the most susceptible to soil degradation or loss. This is why it is important to highlight the importance of green infrastructure interventions that can be developed in these areas, since they generate soil stability and better vegetation cover as a means to contribute to strengthening susceptible areas and improve water regulation in the basins.

G. *Susceptibility of Natural Infrastructure*

According to [4] wetlands are ecosystems with a fundamental role in water regulation, as they allow extending the period in which the ecosystem provides water to the 55 populations by means of puquiales, which are sources of water emerging from the ground, or direct filtrations to rivers and streams. A total of 1,217 wetland units were identified, covering a total area of 5,397 ha. The largest number of wetlands are found in the Rimac River basin, with a total of 3,386.43 ha. In addition, the Rimac river basin is also affected with a high and very high degree of physical susceptibility, mainly from its middle part to the headwaters. A total of 3,349 ha of wetlands were identified with high physical susceptibility, as a result of the extraction of champas (set of roots with soil that form a compact mass) and/or overgrazing by cattle, sheep and Andean camelids. In addition, 2,500 ha of natural pastures were identified with high physical susceptibility due to the topography of the area and the low vegetation cover.

IV.DISCUSSIONS AND CONCLUSIONS

The parameters identified in the water monitoring made by the National Statistics and Computing Institute (INEI) in the Rimac River basin and conducted by J. Cervantes and S. Quito on mining environmental liabilities involving an affectation to the health of the inhabitants of the district of San Mateo de Huanchor which generates a direct relationship with what has been said by different authors in the background. One of them, according to [8] tells us that "both the waters of the San Mateo river and the Parac creek carry significant amounts of lead and zinc, and that their waters suffer notable increases of these elements when passing through certain areas where there is no visual contribution, so it is not possible to justify the balance with the discharges except that there are contributions of another nature".

Therefore, there is a relationship between the background and the results obtained.

Another finding are the mining environmental liabilities identified with drainage, therefore, the monitoring of these 4 identified liabilities was carried out. In addition, J. Cervantes and S. Quito indicated that "of the 20 liabilities identified within the study area, 09 of them were not registered within the MINEM liabilities inventory"[13]. One of the implications is found in the results found with the confusing identification of mining environmental liabilities [8], since according to the inventory of mining liabilities indicates that a total of 176 were found in the district of San Mateo de Huanchor. It should be noted that the studies that were conducted are compiled from the M.S. thesis. In addition, in the methodology used, information was collected from the thesis, but not from public entities, making it difficult to obtain the data.

Also, it is necessary to carry out water monitoring studies in the Rimac River basin in the district of San Mateo, water erosion, environmental quality index, among others. The limitation of this study was the lack of information. Also, it should be enabled by public entities to access information on studies conducted in the district of San Mateo. These monitoring and research conducted will help for future research and subsequent analysis.

The water quality of the Rimac River in the San Mateo district is regular and very poor during low water levels and floods. This is due to mining wastewater discharges in the area and seepage from environmental mining liabilities identified in the various communities.

The 182 environmental mining liabilities identified by MINAM in an updated inventory of this name is a potential environmental risk to the health of people and the ecosystem in the San Mateo district. This district has high levels of contamination due to the number of identified liabilities, and one of the studies compiled shows that the risk is moderate and significant. These liabilities could be filtered into the Rimac River, causing irreversible damage to surface water and thus to the city of Lima, which would be deprived of this resource due to the high concentration of contaminants for health and the ecosystem.

The results of the soil monitoring show that 6 of the 10 samples exceed the ECA for arsenic, causing seepage and volatilization in close communities, which would affect their health. The middle and upper basin of the Rimac River is at risk due to physical susceptibility. This is due to water erosion due to high slopes and low vegetation cover, as well as the extraction of wetlands without any control by the authorities.

REFERENCES

[1] APGEP-SENREM. "*Convention USAID-CONAM Community Participation in Monitoring Mining Activities: The cases of Vicos and San Mateo de Huanchor*". Research on Environmental Policy and Legislation. Systematization Document. Educational Graphic Association Task, Lima, Peru. 2019.

[2] National Water Authority (ANA). "*Water policy and national strategy of Peru*", 2009, [online]. Available: https://www.ana.gob.pe/sites/default/files/default_images/politica_y_estrategia_nacional_de_recursos_hidricos_ana.pdf

[3] National Statistics and Computing Institute (INEI), "*Peru Environmental statistics yearbook*", 2019, [online]. Available: : https://www.inei.gob.pe/media/MenuRecursivo/publicaciones_digitales/Est/Lib1704/libro.pdf . [28 January 2021]

[4] Chillón Rímac Lurín Water Observatory, "*Initial Diagnostic for the Resource Management Plan Water from Chillón, Rímac, Lurín and Chilca*". National Water Autority, 2019 [online]. Available: http://observatoriochirilu.ana.gob.pe/sites/default/files/Archivos/Diagnostico%20Inicial%2027082019.pdf . [Accesed: January 28, 2021]

[5] National Water Authority (1983), "in" *Control of torrents in the Rimac river basin*. Lima: Volume II.

[6] MINAGRI. "Ministry of agricultural development and irrigation", 2015. [Online]. Available: https://www.minagri.gob.pe/portal/54-sector-agrario/cuencas-e-hidrografia . [Accesed: June 3, 2021]

[7] H. Calla. "Pollution of the Rímac River by Heavy Metals from the Mining Industry", *Revista del Instituto de Investigación de la Facultad de Ingeniería Geológica, Minera, Metalúrgica y Geográfica*, vol. 13, no. 25, pp. 87-94, 2010. Available: https://revistasinvestigacion.unmsm.edu.pe/index.php/iigeo/article/view/399 . [Accesed: January 28, 2021]

[8] W. Díaz, "*Pollution of the ecosystem in San Mateo de Huanchor by liabilities mining environmental metallurgical and their impact on the health of the habitants*". M.S. Thesis, National University of San Marcos, Lima, Peru, 2016.

[9] A. Corzo, "*Impact of the mining environmental liabilities in the water resource of the Microcuenca Quebrada Parac neighborhood of San Mateo de Huanchor*," M.S. Thesis, Pontificia Universidad Católica del Peru, Lima, Peru, 2015

[10] J. Paucar. "Tamboraque: The dangerous mine tailings deposit that threatens Lima" *Lamula.pe*, 2017. [Online]. Available: https://redaccion.lamula.pe/2017/04/10/mineria-peru-lima-contaminacion-revales-cerro-tamboraque-huarochiri-carretera-central-rio-rimac/jorgepaucar/. [Accessed: January 28, 2021]

[11] C. Cabrera, "*Contamination of the ecosystem in San Mateo de Huanchor by mining metallurgical environmental liabilities and their impact on the health of the inhabitants*," M.S. Thesis, National University of San Marcos, Lima, Peru, 2016.

[12] *Updating the initial inventory of mining environmental liabilities*, Ministerial Resolution N° 102-2015-MINEM/DM [Online]. 2015. Available: http://www.minem.gob.pe/minem/archivos/file/Mineria/LEGISLACION/2015/marzo/RM%20102-2014-MEM-DM.pdf . [Accesed: January 28, 2021]

[13] J. Cervantes. & S. Quito. "*Evaluation of the environmental risk generated by mining liabilities in surface water quality*," M.S. Thesis, La Molina National Agrarian University, Lima, Peru, 2019.

[14] *Approve updating of the initial inventory of mining environmental liabilities*, Ministerial Resolution N° 238-2020-MINEM/DM [Online]. Available : http://www.minem.gob.pe/minem/archivos/file/Mineria/REGISTROS/PASIVOS/RM%20238-2020-MNEM-DM.pdf . [Accesed: January 28, 2021]

[15] *Approve environmental quality standard (ECA) for water and establish supplementary provision*, DS N° 004-2017-MINAM [Online]. Available : https://www.minam.gob.pe/wp-content/uploads/2017/06/DS-004-2017-MINAM.pdf . [Accesed: January 28, 2021]

[16] Approve environmental quality standard (ECA) for soil, DS N° 011-2017-MINAM [Online]. Available : https://www.minam.gob.pe/wp-content/uploads/2017/12/DS_011-2017-MINAM.pdf . [Accesed: January 28, 2021]