Monitoring and PH Analysis of Tailings from the Effluents of the Cerro De Pasco Mining Company in the Years 2017-2021

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Abstract. Currently, mining operations in Peru, such as in the province of Pasco, require water consumption for metallurgical mining processes, supply for personnel, among other operations. The purpose of this study is to determine whether the mining company located in Cerro de Pasco has reduced its pH values over the years and whether they are within the Maximum Permissible Limits established by Peru. The impacts of mining activities cause damage to water bodies and the health of the population, so water monitoring is carried out at certain discharge points called cell1, cell2 and cell3, where pH measurements were taken. The results of the monitoring, with respect to the tailings from the mine, are acidic pH values containing suspended solids as well as high concentrations of sulphates and metals. The contributions of the study, which is carried out in the city of Cerro de Pasco located at 4338 m.a.s.l., show practical results as they are used for a diagnosis and analysis for the years 2017-2021 with respect to the mine tailings.

1 Introduction

Environmental pollution is defined as the act of soiling or contaminating the environment (1), resulting from anthropogenic actions. In the present investigation, we will be informed about the contamination of water bodies (2). Water pollution is generated by a variety of human activities (3). The pollution problem in the city of Cerro de Pasco is caused by untreated effluents from mining activities (4). Since the early 1900s, several mining companies have carried out metal extraction activities in Cerro de Pasco, these companies sell and buy the productive and economic units and exploit these territories without any precautionary measures or reparation for the various breaches of national regulations on discharge and environmental protection (5). In 1981, the Yanamate lagoon located in the district of Chaupimarca was declared of public necessity and utility, and the following year the continuous discharge of acidic water from the mine tailings began (6). In 1987 the water bodies reached their maximum level, endangering the central road. The increase in acidic water was neutralised by the type of rock in the area (massifs) and the limestone-rich soil (7).

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However, as time went by, these rocks lost their effect due to the decrease of their physical and chemical characteristics as a consequence of the high concentration of acidic water (8). This is the biggest problem in the rivers as a result of mine tailings discharges (9). An environmental hydrogeological assessment was carried out on the water bodies in the area due to acid water discharges (10). Heavy metals were found in rivers, which are of great concern because of their toxic characteristics, their ability to cause cancer through exposure and their persistence in the environment (11). The purpose of this research is to carry out pH monitoring studies carried out at the mine at three points which are from the effluent discharges of mining activities, these monitoring points were called cell 1, cell 2 and cell 3. Finally, the analysed data were compared with the Maximum Permissible Limits (MPL) for the discharge of liquid effluents from mining and metallurgical activities established by the Peruvian Supreme Decree No. 010-2010-MINAM.

2 Methodology

2.1 Place of study

The city of Cerro de Pasco is the capital of the Chaupimarca district in the department of Pasco, located in the centre of Peru. It is one of the most difficult places to live, both for physical reasons (climate and altitude) and for anthropic reasons linked to environmental pollution. The city of Cerro de Pasco is located approximately 190 km northeast of Lima on the Andean plateau, at an average altitude of 4338 m above sea level (12) with coordinates 362200E and 8819400N based on the UTM system (WGS 1984) as shown in Fig. 1.

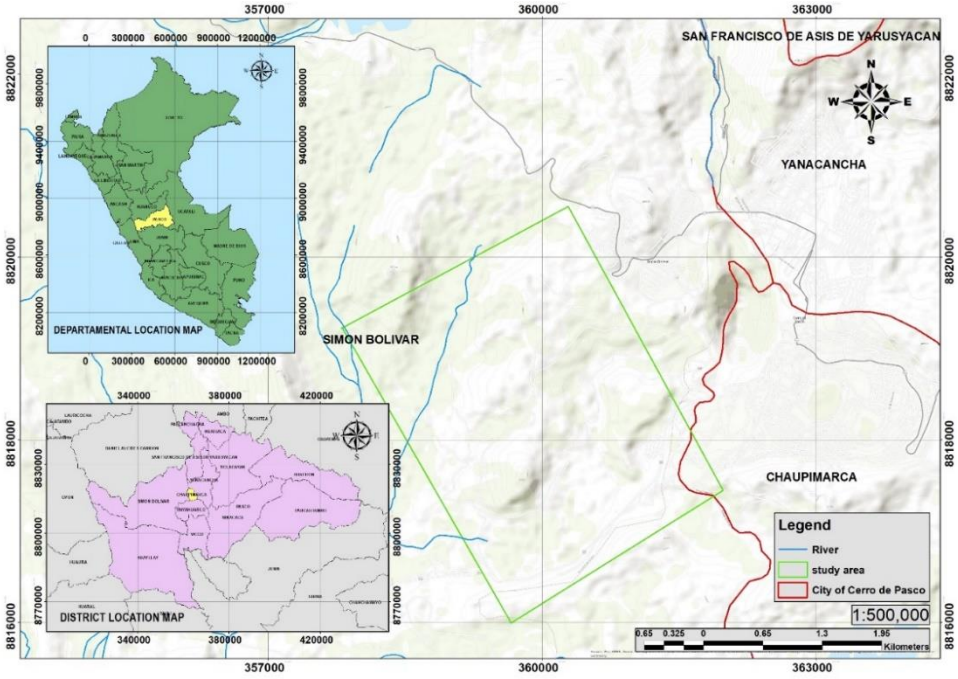

Fig. 1. Map of the Geographical Location of Mining.

2.2 Sampling method

The pH monitoring was carried out in the three cells during the morning hours, from April 2017 to August 2021. To carry out the pH monitoring in the cells, the Surface Water Resources Quality Monitoring manual was used, by means of simple and punctual sampling where a sample sector is taken at a fixed point to be analysed individually (13). In addition, materials such as small bottles, transparent plastic buckets, disposable gloves, tampers and equipment such as GPS and hydrographic bottles were used. Once the sample was obtained, the containers were labelled with adhesive labels where the code of the sampling point and the date were placed (14).

2.3 Statistical analysis

The sample was taken from the mine tailings located in the monitoring points called cell 1, cell 2 and cell 3. Different data were obtained and synthesised using statistical graphs, bars and standard error using the Excel programme. Focusing on the pH of each cell and the filtration they have towards the river, a comparison of the pH taken from each day is made by placing the annual averages and a total average with the upper limits of the tailings water level. Following the calculations of the standard error, which determines the range within the result, the true value of the parameter is located with a confidence level of 95%.

2.4 pH class and description

Tailings drainage from mining activities mostly have a low pH and contain suspended solids with a high concentration of sulphates and metals (Fe, Mn, Cu, Pb, Ni, Cd, Hg, Zn, Al) [15]. As a consequence, high concentrations of these elements are harmful to biological life and pollute water bodies, causing a deficit in the use of this resource for the population of Cerro de Pasco in livestock and agricultural activities. Table 1 below describes the classification of drainage according to pH.

Table 1. Drainage classification according to pH and acidity/alkalinity potential of minerals [15].

Class	Font	Description
Acid	<6	Acidity generated by oxidation of minerals, especially sulphides, associated with metal mines, coal and pyrites.
Alkaline	> 9 o 10	High alkalinity generated by dissolution of oxides, hydroxides and some silicates.
Almost neutron	6-9 o 10	Depending on the presence of minerals in certain periods are acidic or alkaline, concentrations of dissolved metals some may exceed toxic levels.
Other	Irrelevant	It can affect the concentration of metals. It is associated with non-metallic mining such as: salts, borates, bentonites, gravels.

2.5 Maximum Permissible Limits for the Discharge of Liquid Effluents from Mining and Metallurgical Activities

Mining and metallurgical activities carried out within the national territory of Peru, present conditions of bioavailability and biotoxicity for those elements present in the liquid effluents

that are discharged into the environment and these in turn directly affect ecosystems and human health. Therefore, the Ministry of Energy and Mines and the Ministry of Environment have established through the supreme decree Nº 010-2010-MINAM approving the Maximum Permissible Limits (MPL) applicable to those mining-metallurgical activities that develop the discharge of mining liquid effluents, are described in table 2 (15).

Table 2. Maximum Permissible Limits for discharge of mining liquid effluents.

Parameter	Unit	Limit in at any time	Limit for the annual average
pH		6 -9	6 -9
Total Solids in Suspension	**mg/L**	50	25
Oils and fats	**mg/L**	20	16

3 Results

The statistical relationship in table 3 shows that the data are significant and the sum of squares is 18.508, with a degree of freedom of 14 observations that can vary when estimating parameters.

Table 3. Analysis of variance of factor tables (ANOVA) of the river in Cerro Pasco.

Origin of the variations	Sum of squares	Degrees of freedom	Average of the squares	F	Probability	Critical value for F
Rowa	10.87984	4	2.7199	6.950286	0.010237	3.837853
Columns	4.49817333	2	2.2490866	5.747068	0.028362	4.458970
Error	3.13076	8	0.3913			
Total	18.5087733	14				

3.1 Annual average pH result for the years 2017-2021.

In figure 2 the results of the annual averages of pH according to the drainage classification based on pH and acidity/alkalinity potential of minerals from table 1 the acid values are considered >6, alkaline values are considered < 9 and neutral values from 6 to 9. With respect to the year 2017 the cells have values from 7.49 to 8.43, in the year 2018 the cells have the values from 7.28 to 8.35, in the year 2019 with values from 6.68 to 8.96, in the year 2020 with values from 6 to 7.82 and in the year 2021 only in cell 1 with a value of 6.8 shows that the tailings are neutral class. On the other hand, with respect to the year 2021 in cells 2 and 3 their values respectively are 5.32 and 5.2, showing that the tailings are of acid class.

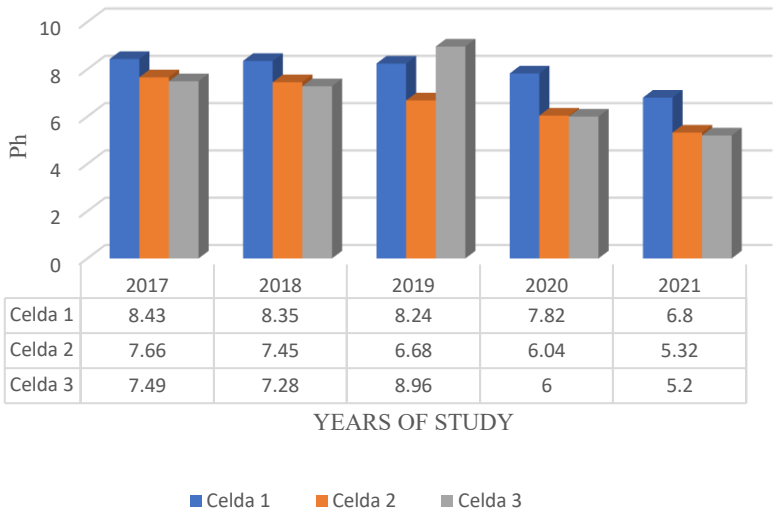

Fig. 2. pH sample from cell 1, cell 2 and cell 3, year 2017-2021.

3.2 Analysis of annual pH values with MPLs for effluent discharge

The analysis in Fig. 3 according to the Maximum Permissible Limits for mine tailings discharge with respect to pH its limit for the annual average is within the range 6-9, showing from the year 2017 to 2020 the values of the three cells are within the range. With respect to the year 2021 it is observed that the value of cell 1 remains within the established range unlike cell 2 and 3 that does not exceed the minimum range.

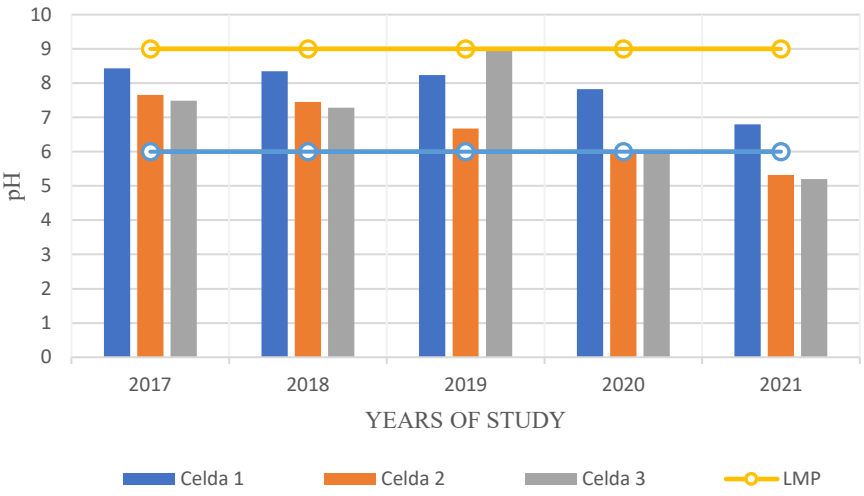

Fig. 3. Annual pH analysis using the LMP for discharge of effluents from mining activities.

4 Discussion of results

4.1 Annual average pH result for the years 2017-2021

The annual average pH data for each cell for the study years 2017 to 2020 show that the minimum value is 6 and the maximum value is 8.96 considered neutral tailings as they are within the pH classification range. The values for the year 2021 show that there are two classes of pH with respect to the tailings, since in cell 1 its value is 6.8 considered within the neutral range, unlike cells 2 and 3 whose values are 5.32 and 5.2 respectively, considered as acid tailings (16), the formation of these tailings is caused by chemical oxidation of sulphides, due to acceleration by bacterial activity. On the contrary, in the case of alkaline tailings, it happens as a result of the dissolution of oxides, hydroxides and silicates (17).

4.2 Analysis of annual pH values with MPLs for effluent discharge

For the development of revision with respect to the parameters of environmental pollution towards water resources, based on the objective of maintaining the quality levels, the principle of graduality is used, enabling progressive adjustments to these levels for ongoing mining activities. The pH data are within the MPL parameters from the year 2017 to 2020 unlike the year 2021 in cells 2 and 3 the pH value is not within the MPL parameters established in the Supreme Decree N°010-2010-MINAM, meaning that the mining company did not perform adequate treatment in their mine tailings, which would indicate an acidic pH (18).

5 Conclusion

In the investigation of pH monitoring of tailings effluents from mining production activities located in the city of Cerro de Pasco, it was possible to determine annual averages of pH of the three study cells. These data were obtained for the years 2017-2021, and a comparison was made to analyse whether there is a variation in pH over the years for which measurement data were obtained. These data were compared with the LMPs provided by Peruvian law, the comparison was made on an annual basis where it can be analysed that in the years 2017 2020 annual pH values have remained within the LMP, however in the year 2021 in cell 2 and cell 3 pH values did not meet what the standard established so that acid pH values were obtained, understanding that this year the mine did not perform the correct treatments to maintain the pH within the LMPs established by Peruvian law.

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