Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

Identification of Contaminants in the Upper Basin of the Santa River: Implications for the Ecosystem

Fray Masias Cruz - Reyes[1], Miguel Comeca - Chuquipul[2], Angel Aronés - Cisneros[3], Roselyn Chacon - Gonzales[4], Sigrid Cruz - Ledesma[5], Nolberto Comeca - Ramirez[6]

Abstract

The study aimed to identify the main pollutants in the upper basin of the Santa (Ancash – Perú) River and evaluate their relationship with mining tailings and other sources of contamination. Physical-chemical, inorganic, microbiological and parasitological parameters were analyzed at eight sampling points between the Negro River and Catac, using data from the National Water Authority (ANA) and comparing with the Environmental Quality Standards (ECA). The results revealed high levels of iron and aluminum at point 1, arsenic and chlorides at point 2, and bacteria such as Coliforms and E. coli at points 2 and 4, which implies a risk to public health and the ecosystem. It is concluded that constant monitoring and remediation measures are necessary in critical areas to protect water quality.

Keywords: *Pollution, Critical Parameters, Environmental Monitoring, Mining.*

Introduction

The presence of mine tailings in water bodies is an issue of great environmental relevance, especially in regions where mining activity is intense (Menéndez and Muñoz, 2021). In the Ancash region, the Santa River is a vital source of water resources for local communities, agriculture, and power generation. However, the development of mining in the basin has raised concerns about water contamination from waste from extractive operations, known as tailings. This problem not only affects water quality, but also the health of populations and ecosystems along the river (Peña and Araya, 2021).

Mine tailings contain heavy metals and other toxic elements that, if not properly managed, can seep into and contaminate water sources. In the case of the Santa River, which crosses important mining areas, the relationship between water quality and the presence of this waste has been the subject of numerous studies (Benavente et al., 2022). However, there are still significant gaps in knowledge about pollution levels, the transport mechanisms of these pollutants, and the direct and indirect impacts on human activities and biodiversity (Gamboa, 2021).

The main objective of this research is to analyze the water quality of the Santa River at different points along its course, particularly in the areas near the mine tailings deposits. It also seeks to identify which heavy metals are present in the water and in what concentrations, in order to evaluate their relationship with mining operations in the region. This analysis will determine the degree of impact on the river and the possible consequences for public health and the environment (Escalante, 2023).

To carry out this study, various water quality monitoring methodologies will be used, including physical-chemical analysis and the identification of heavy metals such as lead, arsenic, and mercury (Cornejo and Pacheco, 2009). In addition, sediment samples will be taken in areas near the tailings to establish a

[1] Universidad Nacional Mayor de San Marcos (Lima – Perú), Escuela Académica de Geografía, 0000-0003-3359-1727, Email: fcruzr@unmsm.edu.pe
[2] Universidad Nacional Mayor de San Marcos (Perú), 0000-0001-9305-8428, Email: mcomecac@unmsm.edu.pe
[3] Instituto de Investigación Geográfico Andino Rural (Perú), 0000-0002-5064-7027, Email: a.aronescisneros@gmail.com
[4] Universidad Nacional Mayor de San Marcos (Lima – Perú), ORCID: https://orcid.org/0009-0005-4739-9244, Email: roselyn.chacon@unmsm.edu.pe
[5] Universidad Privada del Norte, (Lima - Perú), ORCIID: 0009-0007-3043-4191, Email: sigrid.cruz@upn.pe
[6] Universidad Nacional Mayor de San Marcos (Lima – Perú), ORCID: 0009-0005-6721-7030, Email: nolberto.comeca@unmsm.edu.pe

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606
comprehensive diagnosis of contamination. Data collection will be complemented with historical information on mining activity in the basin and previous studies carried out by government entities and environmental organizations (Araya et al., 2021).

One of the challenges faced by this study is access to accurate and up-to-date information on mining companies' tailings management plans (Gagnon, 2019). Although there are regulations for the disposal of this waste, the implementation of these regulations may vary, generating gaps in the effective protection of water bodies. Cooperation with local communities will be key to obtaining additional data and understanding the impact perceived by inhabitants (Cacciuttolo and Valenzuela, 2022).

The results of this research have significant implications for the environmental management of the Santa River basin. It is hoped that the findings can be used to propose improvements in mining waste management policies and in the mechanisms for monitoring and overseeing water quality. In addition, the study will contribute to raising awareness of the risks of mining to the environment and human health, driving a more informed dialogue between authorities, mining companies and affected communities (Adiansyah et al.,2015).

Research into the presence of mine tailings and their relationship to water quality in the Santa River is essential to protect this critical water resource. Given the importance of the river in the economic and social life of the region, it is imperative that effective measures are implemented to mitigate pollution and preserve water quality for future generations. This research seeks to provide a solid scientific basis to guide these actions (Carneiro & Fourie, 2019).

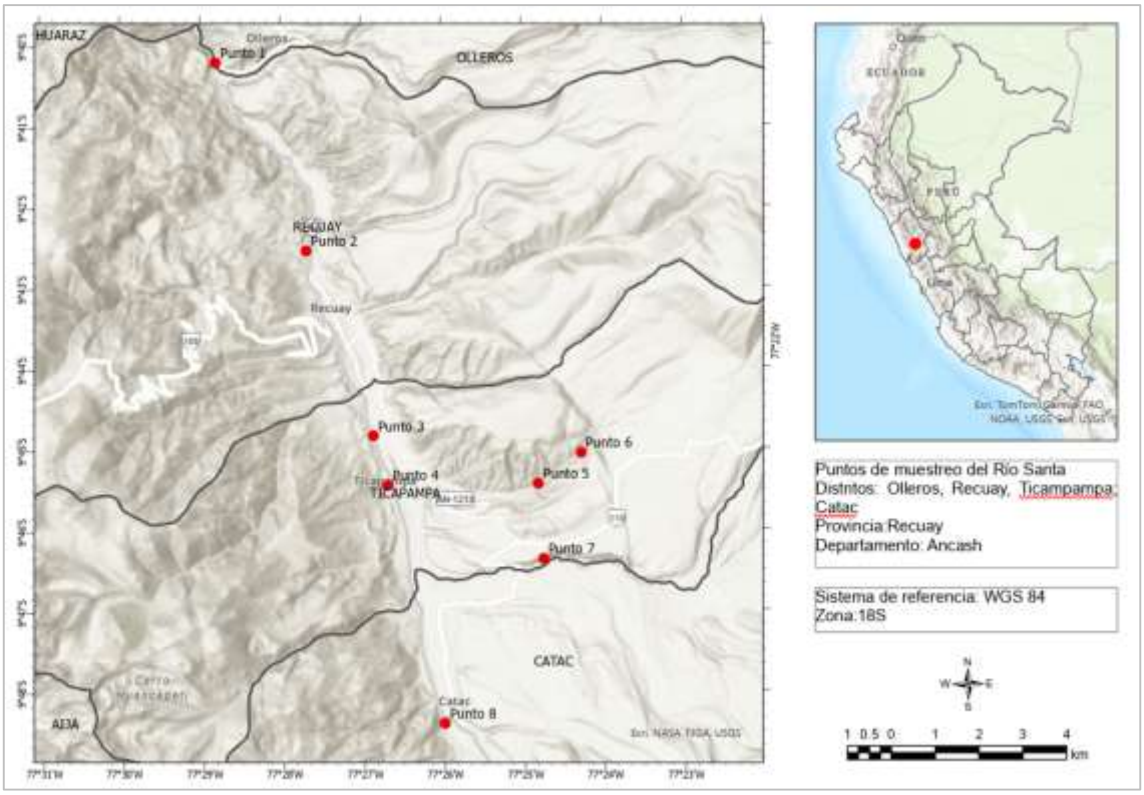
The need for integrated management of water resources in mining areas is underlined, involving all social actors and promoting sustainable practices in the exploitation of natural resources, with a view to guaranteeing the environmental health of the Santa River basin and the well-being of its riparian populations (Watts et al., 2023).

Methodology

The study area was located in the upper basin of the Santa River, in the department of Ancash, province of Recuay, covering the districts of Olleros, Recuay, Ticapampa and Catac. This territory was selected due to the importance of analyzing water quality in a region that is home to several communities and cultivation areas, which could influence the pollution of the river.

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

Figure 1. Study Area



An exhaustive analysis of three types of parameters was carried out: physical-chemical, inorganic and microbiological-parasitological along a specific stretch of the Santa River. The sampling began in the tributary of the Negro River, identified as point 1, and ended in the district of Catac, point 8. These points were strategically chosen to provide a broad view of water quality in different parts of the river.

The values of the parameters used in the study were obtained from the official website of the National Water Authority (ANA) for the year 2020. This source was selected for its relevance and credibility in terms of the management and monitoring of water resources in the country, which ensured that the data used were reliable and up-to-date.

For the analysis of the data, the Environmental Quality Standards (ECA) for Water, established by Supreme Decree No. 004-2017-MINAM, were used. These standards provided a clear reference to determine whether the levels of the different contaminants detected in the water met the permitted limits for human, agricultural or industrial use, thus facilitating the interpretation of the results.

Finally, the results of the eight sampling points were analyzed in relation to the concentrations of pollutants and their possible impact on local populations and nearby ecosystems. This analysis identified contamination hotspots and suggested possible sources that could be affecting water quality in the upper Santa River basin.

Results and Discussion

Table 1 presents the detailed results of the physical-chemical parameters obtained at the eight sampling points along the Santa River, ranging from the district of Recuay to Cátac. These data make it possible to assess the quality of the water in different sections of the upper basin and detect possible sources of pollution. Each point provides a representative overview of water conditions in relation to the concentration of dissolved chemical elements and their variability along the course of the river. The analysis of these parameters is crucial, as it provides key information on the composition of water and allows the

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

identification of significant alterations that could have an impact on both the aquatic ecosystem and the human populations that depend on this resource. Changes in concentrations of certain metals, nutrients, and dissolved organic compounds may be indicative of anthropogenic contamination or natural processes that affect water quality.

Table 1. Physical-Chemical Parameters of the Upper Basin of the Santa River

Parameters	Measure	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Item 7	Point 8
Oils and Fats	mg/L	0.4	0.4	0.4	0.4	0.4	0.204	0.4	0.4
Ammonia-N	mg/L	0.044	0,189	0.044	0.05	0.026	0.087	0.01	0.052
Chlorides	mg/L	8.389	25.272	7.787	8.86	0.295	0.112	0.381	8.936
Conductivity	(µS/cm)	431	----	191.6	183.2	94	23	59.6	----
Dissolved iron	mg/L	8.1523	0.5768	0.3222	0.405	0.5533	----	0.014	0.475
Nitrates (NO3-)	mg/L	0.159	0.091	0.131	0.097	0.069	0.009	0.56	0.188
pH	pH Unit	3.42	----	7.57	7.89	7.3	6.78	7.44	----
Sulphates	mg/L	110.74	37.19	32.14	40.08	24.39	1.886	0.0019	32.61
Temperature	°C	13.2	----	17.6	15.5	11.7	10.1	9.8	----

Fountain. Based on ANA reports (2020)

In all the points evaluated (1 to 8), the value of oils and fats remains constant at 0.4 mg/L, except in point 6, where it drops to 0.204 mg/L. This parameter is essential to assess the presence of hydrocarbons and organic pollutants in water. The values are low and within what is expected for waters that are not highly polluted, which is favorable for water quality.

Ammonia levels vary significantly between points, with point 2 standing out with a high value of 0.189 mg/L, indicating the presence of organic waste or nearby agricultural activity that contributes to the elevation of this parameter. In the rest of the points, the levels are lower, with a minimum at point 7 (0.01 mg/L), which indicates a good level of oxygenation and low presence of decomposing organic matter.

In relation to chlorides, they present significant fluctuations, especially in point 2, with a high value of 25,272 mg/L. This could be related to sources of industrial or agricultural pollution, as well as saline water infiltration. At the other points, the values are significantly lower, as at point 6 with 0.112 mg/L. Chlorides, in excess, can affect the taste of water and its use in irrigation, so control of polluting sources would be necessary.

Conductivity reflects the amount of salts dissolved in the water, being an indicator of salinity. Point 1 shows a high value of 431 µS/cm, possibly due to the presence of dissolved minerals from the source of the river. Along points 3 to 7, the values are lower, between 23 and 191.6 µS/cm, indicating a lower concentration of ions in solution. However, the lower value at point 6 (23 µS/cm) may suggest purer waters in that specific area.

Dissolved iron stands out in point 1 with a high value of 8.1523 mg/L, which could be due to natural sources such as erosion of iron minerals or anthropogenic contamination. As we move towards the other points, the values decrease drastically, reaching 0.014 mg/L at point 7, which is a positive sign of less presence of this metal in the water.

Nitrates, derived from agricultural activities and waste, have a peak at point 7 with 0.56 mg/L. This value is considerably higher than at other points, which could be indicative of a source of fertilizer contamination

Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606
in this area. In contrast, in point 6 the lowest value is observed, of 0.009 mg/L, which suggests a lower influence of these activities in this section.

The pH value varies between 6.78 (point 6) and 7.89 (point 4), which is suitable for natural waters, remaining in ranges close to neutrality. A proper pH is crucial for aquatic life and nutrient availability. Although there are slight variations between points, the values are within the optimal range for most aquatic organisms.

Sulfates vary significantly, with point 2 standing out with 37.19 mg/L and point 7 with 0.0019 mg/L, which could reflect differences in local geology or sources of point pollution. As for the temperature, it remains in adequate ranges for the conditions of the river, with the warmest point being at point 1 with 13.2 °C and the coldest at point 7 with 9.8 °C. This suggests altitudinal variations and proximity to glaciers as possible tributaries that modify water temperature.

From the results obtained, it is possible to identify several critical points that require monitoring due to the presence of abnormal values in the physicochemical parameters measured. Firstly, point 2 stands out with several parameters that are not expected, starting with the high levels of ammonia (0.189 mg/L) and chlorides (25.272 mg/L), which indicate the possible presence of sources of agricultural or industrial pollution, such as the excessive use of fertilisers or infiltration of contaminated water. These levels are significantly higher than those observed elsewhere, making it an important focus for future research and control measures.

Likewise, point 1 also presents a worrying situation, with a high conductivity (431 µS/cm) and a high concentration of dissolved iron (8.1523 mg/L). These values could be due to natural erosion processes or sources of mining pollution, suggesting that this area should be carefully monitored to prevent possible negative impacts on water quality and the aquatic species that depend on it. These findings coincide with what was reported by Novoa et al. (2022), who also detected high concentrations of metals, such as iron and manganese, in water samples near mining activities, exceeding environmental quality standards. Although the iron levels in our study are lower compared to those reported by Novoa et al., they are still concerning and could affect both water quality and aquatic biodiversity, especially as it pertains to species that depend on these ecosystems.

Point 7 is another critical point, due to the high levels of nitrates (0.56 mg/L), which suggest possible contamination by fertilizers, probably related to nearby agricultural activities. This increase can affect the eutrophication of the water, which would compromise the ecological balance of the river in this area. Coinciding with what was pointed out by Eugercios et al. (2017), who attribute these concentrations to the leaching of nitrogen fertilizers in nearby agricultural areas. This phenomenon is particularly concerning due to its ability to promote water eutrophication, a process that alters the ecological balance of water bodies and can lead to excessive algal blooms and oxygen depletion, affecting aquatic biodiversity. In addition, water connections between surface and underground water bodies facilitate the export of nitrates, aggravating the problem of pollution in rivers, lakes and seas.

In contrast, point 6 has some of the lowest values in several important parameters, such as ammonia (0.01 mg/L), chlorides (0.112 mg/L), and nitrates (0.009 mg/L). Although these values are favorable, the abrupt decrease in oils and fats (0.204 mg/L) compared to the constant value at other points (0.4 mg/L) could indicate a change in water quality that also deserves further evaluation to better understand the causes of this decrease.

Point 4 stands out for its high pH value (7.89), which, although it is within acceptable ranges, could affect aquatic flora and fauna if it deviates even more towards alkaline values. Although this value is not alarming, its constant monitoring is recommended.

On the other hand, sulfates show significant variations between points, with a maximum at point 2 (37.19 mg/L) and a minimum at point 7 (0.0019 mg/L). These fluctuations suggest the influence of different geological sources or possible industrial activities, underscoring the importance of continuing monitoring in these stretches of the river.

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

The water temperature also presents notable differences between the points, being warmer at point 1 (13.2 °C) and colder at point 7 (9.8 °C), which may be due to the altitude and proximity to glaciers. Although these changes are natural, it is crucial to monitor them due to the impact they can have on aquatic fauna and nutrient dynamics.

Points 1, 2, and 7 require special attention in future studies and control programs due to the presence of parameters that are not expected to indicate contamination or alterations in water quality, while point 6, despite its favorable values, must be evaluated to understand the variations observed in its physical-chemical parameters.

Table 2 presents the detailed results of the inorganic parameters obtained at the eight sampling points.

Table 2. Inorganic Parameters of the Upper Santa River Basin

Parameter	Unit of Measure	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Item 7	Point 8
Aluminium	mg/L	2.758	0.415	0.3	0.398	0.295	0.472	0.055	0.279
Arsenic	mg/L	0.0088	0.0239	0.0053	0.0032	0.025	0.0002	0.0017	0.0123
Cadmium	mg/L	0.00034	0.00041	0.00005	0.00007	0.00028	0.0121	0.00003	0.0002
Copper	mg/L	0.00529	0.00211	0.00032	0.00038	0.00143	0.00008	0.00009	0.00147
Iron	mg/L	8.1568	0.7198	0.3286	0.4078	0.7465	0.7465	0.1841	0.4845
Mercury	mg/L	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009	0.00009
Lead	mg/L	0.0019	0.0025	0.0006	0.0006	0.0056	0.0056	0.0006	0.0006
Sodium	mg/L	7.21	19.728	7.583	8.357	2.422	2.422	2.322	8.22
Uranium	mg/L	0.0017	0.00016	0.00015	0.00007	0.00016	0.00016	0.00053	0.00015

Fountain. Based on ANA reports (2020)

Table 2 presents the results of the concentrations of inorganics (metals and metalloids). Each parameter is then analyzed by point, evaluating whether the results are adequate or present abnormal levels that could indicate environmental or human health risks.

At Point 1, the most alarming value at this point is that of iron, which reaches 8.1568 mg/L, an extremely high value compared to the acceptable limits for aquatic life (1.0 mg/L) and human consumption (0.3 mg/L), which could indicate a source of mining or natural contamination in this section. In addition, aluminum (2,758 mg/L) is also elevated, which affects aquatic life. Other metals, such as mercury and lead, are in lower concentrations, although lead (0.0019 mg/L) could start to be a concern if it accumulates.

At point 2, arsenic (0.0239 mg/L) stands out for being at a relatively high level, which represents a health risk if this water were used for human consumption. Sodium also shows a significant increase (19,728 mg/L), which could be associated with industrial discharges or nearby mining activity. Although iron has decreased considerably from the previous point (0.7198 mg/L), it is still a remarkable value that requires monitoring.

At point 3, it shows a slight decrease in the levels of most metals, but arsenic (0.0053 mg/L) is still present at a concentration that is concerning in the long term. Copper, although low (0.00032 mg/L), is a metal that must be controlled due to its potential toxicity in aquatic organisms. Iron (0.3286 mg/L) has continued to fall, which is a positive sign, but it is still a value that should be kept under surveillance.

At point 4, at this point, a slight recovery is observed in terms of water quality, as the levels of most metals decrease. Aluminium (0.398 mg/L) is still somewhat high, but it is within more manageable limits. Iron (0.4078 mg/L) also continues to decline, which is a good indication that the potential source of pollution is being diluted as the river advances. Cadmium and mercury levels remain low, which is favorable.

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

Point 5 shows a worrying increase in the levels of lead (0.0056 mg/L), a highly toxic metal, which suggests a possible source of contamination in this section, such as industrial or mining discharges. Arsenic (0.025 mg/L) also rises again, which is alarming given that this element is carcinogenic in the long term. Iron (0.7465 mg/L) has risen again, indicating a possible source of additional contamination in this section.

At point 6, aluminium shows a significant increase (0.472 mg/L), which is worrying for aquatic fauna. An increase in cadmium (0.0121 mg/L) is also observed, a metal that in such small concentrations can have long-term toxic effects, especially in aquatic environments. However, mercury and lead values remain low, which is positive, although lead (0.0056 mg/L) should continue to be monitored due to its toxic effects.

Point 7 shows a significant reduction in almost all parameters, with aluminium (0.055 mg/L) and iron (0.1841 mg/L) being much lower than in the previous sections. However, trace amounts of arsenic (0.0017 mg/L) remain, which could be concerning if it accumulates over time. This point seems to be one of the least contaminated, although there are still metals present that must be monitored long-term to avoid accumulation and toxicity.

Point 8, a slight recovery in water quality is observed, although arsenic (0.0123 mg/L) and aluminum (0.279 mg/L) are still present in concentrations that deserve attention. Iron levels (0.4845 mg/L) are lower than in the first spots, but still require monitoring, especially if the water is used for irrigation or human consumption. Although mercury and lead levels remain low, they should continue to be controlled for their high toxicity.

From the results presented, several critical points are identified where inorganic parameters exceed the acceptable limits for water quality. At point 1, one of the most worrying points, with extremely high values of iron (8.1568 mg/L) and aluminum (2.758 mg/L), both above the safe limits for aquatic life and human consumption, which poses serious risks. According to Aconsa (2023), although the presence of iron in water is common and generally does not pose an immediate health hazard, high concentrations can negatively affect the taste of water and cause reddish stains on clothing and utensils. On the other hand, high levels of aluminum are also of concern, as this metal can be toxic to aquatic species and, in high concentrations, poses potential risks to human health. In comparison, Padrón et al. (2020) found that in their studies the levels of heavy metals in water, including lead, remained below normative parameters, which contrasts with the results obtained in our analysis.

Point 2 where arsenic (0.0239 mg/L) is elevated and poses a potential health risk if the water is used for human consumption. For Rodríguez (2021), arsenic is a highly toxic compound that, as it has no taste or smell, can be consumed inadvertently, causing acute or chronic hydroarsenicism. This element has negative effects on several body systems, such as dermatological, cardiovascular, neurological and renal, in addition to possessing carcinogenic properties. The situation is particularly alarming because arsenic can come from both natural sources, such as volcanic activity or erosion, and anthropogenic sources related to industrial or agricultural activities, highlighting the importance of identifying its origin and taking preventive measures.

In point 5, an increase in lead (0.0056 mg/L) is highlighted, which is toxic and requires immediate attention. Arsenic (0.025 mg/L) is high again, which is concerning for its long-term carcinogenic effects. Iron (0.7465 mg/L) also rises, indicating a possible source of additional contamination. Poma (2008) stresses that lead, historically used, affects multiple systems of the body, and its impact is more serious on children, who absorb it in greater proportion due to their developmental process. Prolonged exposure to lead can cause neurological damage and other systemic effects, justifying the need for constant monitoring and intervention measures in affected areas. On the other hand, arsenic, as mentioned by Saborío and Hidalgo (2015), is a ubiquitous element whose inorganic forms are highly toxic. Chronic exposure to arsenic in drinking water is linked to cardiovascular disease, type II diabetes, and elevated cancer risks, among other serious health problems.

Point 6 where aluminum (0.472 mg/L) and cadmium (0.0121 mg/L) show significant increases. Cadmium, although in low concentrations, is highly toxic, especially to aquatic ecosystems. For Pérez et al. (2012),

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

cadmium is a common by-product of zinc and copper metallurgy, used in various industries due to its resistance to corrosion. However, its toxicity mainly affects the bones and kidneys, and its chronic exposure, as in this case, represents a considerable risk to environmental and human health. In addition, studies by Mero et al. (2019) reveal that this metal tends to accumulate in sediments and aquatic organisms, endangering the local biota. Although cadmium may not be immediately detectable in water, its accumulation in sediments and biota underscores the need for continuous monitoring, especially in ecosystems that serve as water sources for human or wildlife communities.

In point 8, although a slight improvement is observed, arsenic (0.0123 mg/L) and aluminum (0.279 mg/L) are still at worrying levels that warrant monitoring. Morales et al. (2022) highlight that arsenic is one of the first elements identified as carcinogenic and its presence in water is a common problem in Latin America. Although the concentration in this case is lower, it still poses a potential health risk, since, according to the study, even low levels can contribute to a significant disease burden, especially in areas with high seasonal variability in water quality, such as in dry seasons.

Table 3 presents the detailed results of the microbiological and parasitological parameters obtained at the eight sampling points along the Santa River.

Table 3. Microbiological and Parasitological Parameters of the Upper Basin of the Santa River

Parameter	Unit of Measure	Point 1	Point 2	Point 3	Point 4	Point 5	Point 6	Item 7	Point 8
Dissolved cesium	mg/L	0.0107	0.0223	0.0051	0.0063	0.0003	0	0.0003	0.0056
Thermotolerant coliforms	NMP/100ml	1.8	110	13	490	23	79	23	14
Escherichia coli	NMP/100ml	1.8	4.5	1.8	4.5	1.8	49	1.8	1.8
Dissolved lutetium	mg/L	0.00006	0.00006	0.00006	0.00006	0.00006	0	0.00006	0.00006
Dissolved rubidium	mg/L	0.0105	0.02	0.0072	0.0089	0.0013	0	0.0011	0.008

Fountain. Based on ANA reports (2020)

The results presented in Table 3 correspond to different sampling points in the Santa River.

At point 1 the value of dissolved cesium is 0.0107 mg/L, while thermotolerant coliforms and E. coli have values of 1.8 NMP/100ml. This indicates a low presence of bacteria and moderate levels of cesium. The values of Lutetium and Dissolved Rubidium are low (0.00006 mg/L and 0.0105 mg/L, respectively), suggesting that the water quality at this point is acceptable in terms of chemical and microbiological contamination.

At point 2, a considerable increase in the concentration of thermotolerant coliforms (110 MPN/100ml) and E. coli (4.5 MPN/100ml) is observed, indicating a higher level of microbiological contamination at this point. Dissolved cesium is also higher (0.0223 mg/L), which could be an indication of some nearby source of contamination. However, the concentrations of Lutetium and Dissolved Rubidium are similar to those of Point 1, with a slight increase in Rubidium. For Huayanay et al. (2016), who also found elevated concentrations of microbiological contaminants in their samples. Despite the fact that no pathogenic serotypes were identified in their study, the presence of these microorganisms represents a risk to public health, as confirmed by Peruvian regulations that qualify these conditions as unacceptable.

At point 3, the levels of dissolved cesium (0.0051 mg/L) and dissolved rubidium (0.0072 mg/L) are low compared to the previous points. However, thermotolerant coliforms and E. coli are higher than at Point 1 (13 and 1.8 MPN/100ml respectively), although not as high as at Point 2. This suggests that there is some microbiological contamination, but not as critical.

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606
At point 4, the highest levels of thermotolerant coliforms (490 MPN/100ml) are observed, suggesting a significant source of bacterial contamination. E. coli levels are also elevated (4.5 MPN/100ml), indicating a risk to public health if the water is used untreated. The levels of Cesium, Lutetium, and Rubidium are similar to the previous points, so the main concern at this point is microbiological contamination.

At point 5, thermotolerant coliforms decrease to 23 NMP/100ml, indicating an improvement in water quality in terms of bacterial contamination compared to point 4. E. coli levels remain stable (1.8 MPN/100ml). Dissolved cesium is low (0.0003 mg/L), and lutetium and rubidium levels are also reduced. This point seems to have a better water quality compared to the previous points, although there is still bacterial presence.

In point 6 it shows a reduction to zero in the levels of dissolved cesium and thermotolerant coliforms, which could indicate a cleaner area in terms of contamination. However, there is a concentration of 49 MPN/100ml of E. coli, which is concerning. The values of Lutetium and Dissolved Rubidium are extremely low, suggesting that chemical contamination is minimal.

At point 7, thermotolerant coliforms are at low levels (23 MPN/100ml) and E. coli is also low (1.8 MPN/100ml), indicating a significant improvement in the microbiological quality of the water. The levels of Cesium, Lutetium and Rubidium are comparable to the previous points, without great variations.

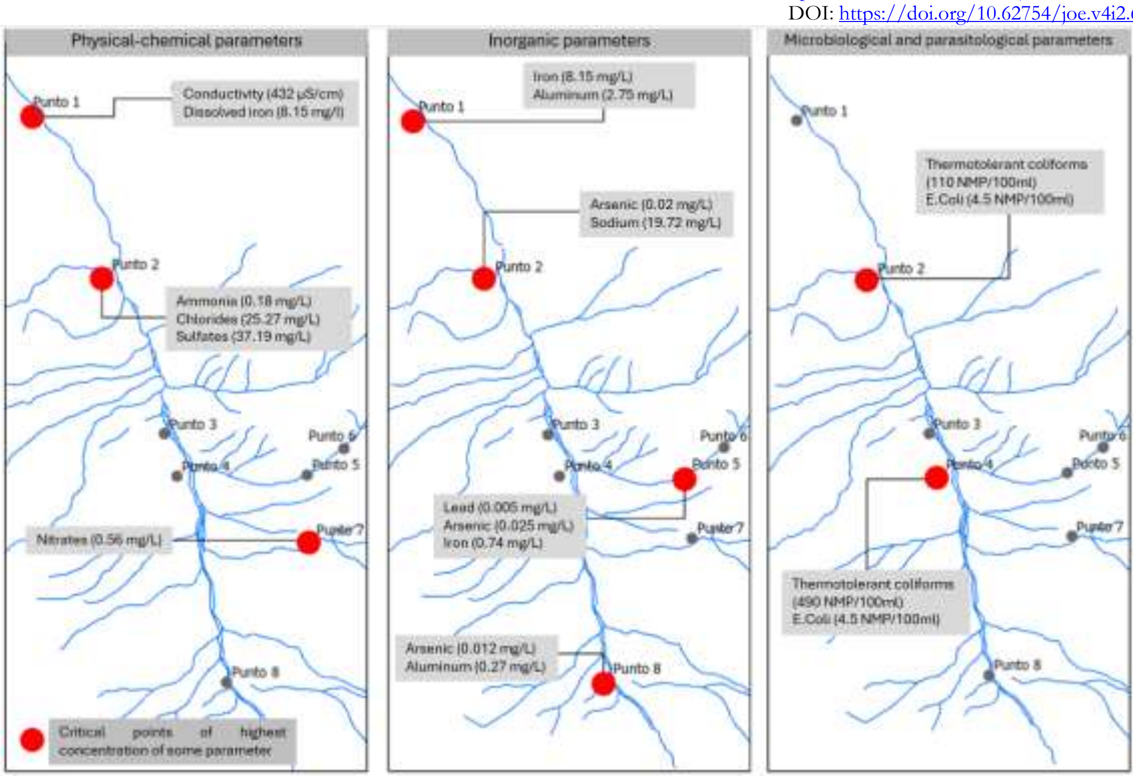
At point 8 it shows a low concentration of thermotolerant coliforms (14 NMP/100ml) and E. coli (1.8 NMP/100ml), which indicates good water quality. Cesium and Rubidium levels are slightly higher than at some previous points, but they are still relatively low. Points 7 and 8 show low levels of thermotolerant coliforms and E. coli, suggesting a significant improvement in the microbiological quality of the water compared to other points analyzed. This is consistent with what Larrea et al. (2013) have argued, who highlight that coliforms and E. coli are key indicators for the evaluation of fecal contamination and the sanitary classification of water.

Hotspots in the upper Santa River basin include Point 2 and Point 4, which present concerning levels of microbiological and chemical contamination. In point 2, a significant increase in the concentration of thermotolerant coliforms (110 NMP/100ml) and E. coli (4.5 NMP/100ml) is observed, along with an increase in dissolved cesium (0.0223 mg/L), suggesting a possible source of nearby contamination. Point 4 is even more alarming, with the highest levels of thermotolerant coliforms (490 MPN/100ml) and a high value of E. coli (4.5 MPN/100ml), which poses a high risk to public health if the water is used without treatment. For Rodríguez et al. (2017), who also observed elevated levels of thermotolerant coliforms in their monitored stations. The significant increase in thermotolerant coliforms and E. coli together with the concentration of dissolved cesium suggests a nearby source of contamination, possibly of anthropic origin.

Figure 2 shows the critical points of the physical-chemical, inorganic and microbiological-parasitological parameters of the Santa River.

Figure 2. Critical Parameters at the Analysis Points of the Santa River

2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606



The analysis of the physical-chemical contamination in the upper basin of the Santa River shows abnormally high concentrations of conductivity and dissolved iron, which could be related to mining contamination or erosion processes. It also highlights high levels of ammonia, chlorides and sulfates, which suggest contamination from agricultural and industrial activities.

In the inorganic parameter there are critical levels of iron and aluminum, exceeding the acceptable limits for aquatic life and human consumption. It also has high levels of lead and arsenic, which represents a potential health risk.

Microbiological contamination is also a critical aspect. There are high levels of thermotolerant coliforms and E. coli, along with a concerning concentration of dissolved cesium, which points to a possible source of both chemical and microbiological contamination. Point 4 is the most affected in terms of bacterial contamination.

Conclusion

The analysis of the physical-chemical parameters of the upper basin of the Santa River reveals the presence of critical points, such as points 1, 2 and 7, which require exhaustive monitoring due to the high concentration of pollutants such as iron, ammonia, chlorides and nitrates, associated with agricultural or industrial activities or natural erosion processes. On the other hand, point 6 presents more favorable values, although the decrease in oils and fats suggests the need for more in-depth research. These results underscore the importance of implementing control measures to preserve water quality and ecological balance.

In inorganic parameters, inorganic metals and metalloids at various sampling points exceed acceptable limits for aquatic life and human consumption. In particular, the high levels of iron and aluminum at point 1, as well as arsenic at points 2 and 5, pose significant risks to health and the environment. Although improvements are seen in some stretches of the river, several metals, such as lead and cadmium, require constant monitoring to avoid long-term toxic effects. These results underscore the need to implement control and remediation measures in critical areas to protect water quality and aquatic ecosystems.

ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

In the microbiological and parasitological parameters, especially in points 2 and 4, where high levels of thermotolerant coliforms and E. coli are recorded, which represents a significant risk to public health. These points require priority attention to mitigate sources of pollution and improve water quality.

References

Aconsa, R. (2023). Calidad del agua de consumo, indicadores hierro y manganeso. https://higieneambiental.com/calidad-del-agua-de-consumo-hierro

Adiansyah, J. S., Rosano, M., Vink, S., & Keir, G. (2015). A framework for a sustainable approach to mine tailings management: disposal strategies. Journal of Cleaner Production, 108, 1050–1062. https://doi.org/10.1016/j.jclepro.2015.07.139

Araya, N., Ramírez, Y., Cisternas, L., & Kraslawski, A. (2021). Use of real options to enhance water-energy nexus in mine tailings management. Applied Energy, 303, 117626. https://doi.org/10.1016/j.apenergy.2021.117626

Benavente, S., Huarcaya, R., Chui, H., Pérez, K., Roque, E., & Guillen, N. (2022). Metales pesados en las aguas provenientes de la Rampa San Marcelo, CIA de Minas Sillustani S.A. Revista Alfa, 6(18), 516–523. https://doi.org/10.33996/revistaalfa.v6i18.187

Cacciuttolo, C., & Valenzuela, F. (2022). Efficient Use of Water in Tailings Management: New Technologies and Environmental Strategies for the Future of Mining. Water, 14(11), 1741. https://doi.org/10.3390/w14111741

Carneiro, A., & Fourie, A. (2019). An integrated approach to cost comparisons of different tailings management options. Proceedings of the 22nd International Conference on Paste, Thickened and Filtered Tailings. https://doi.org/10.36487/acg_rep/1910_05_carneiro

Cornejo, D., & Pacheco, M. (2009). Contaminación de aguas y sedimentos por As, Pb y Hg de la cuenca del rio Ramis, Puno - Perú. Revista de investigaciones, 5(4). https://doi.org/10.26788/riepg.v5i4.13

Escalante, J. (2023). Diseño de un depósito de relave reubicado frente a un relave contaminado en Ticapampa – Recuay - Ancash. Revista Del Instituto de Investigación de La Facultad de Minas Metalurgia Y Ciencias Geográficas, 26(52), e26106–e26106. https://doi.org/10.15381/iigeo.v26i52.26106

Eugercios, A.; Álvarez, M.; Montero, E. (2017). Impactos del nitrógeno agrícola en los ecosistemas acuáticos Ecosistemas, 2681), 37-44. Asociación Española de Ecología Terrestre Alicante, España. https://www.redalyc.org/pdf/540/54050575006.pdf

Gagnon, A. (2019). Key considerations when developing a risk management framework for tailings facilities. https://doi.org/10.36487/acg_rep/1905_16_gagnon

Gamboa, N. (2021). La presencia de los metales pesados en los cuerpos de aguas. Revista de La Sociedad Química Del Perú, 87(3), 193–194. https://doi.org/10.37761/rsqp.v87i3.355

Huayanay, C, Aldoradin, V y Guerra, A. (2022). Presencia de Escherichia coli en la playa Pucusana, Lima y su potencial efecto en la Salud Pública. Acta Med Peru. 2022; 39(1): 031-9. https:// doi.org/10.35663/amp.2022.391.2305

Larrea, C., Rojas, A., María, M., Romeu, Rojas, B., Mercedes, N., & Heydrich, M. (2013). Bacterias indicadoras de contaminación fecal en la evaluación de la calidad de las aguas: revisión de la literatura. Revista CENIC. Ciencias Biológicas, 44(3), 24-34 Centro Nacional de Investigaciones Científicas Ciudad de La Habana, Cuba https://www.redalyc.org/pdf/1812/181229302004.pdf

Menéndez, J., & Muñoz, S. (2021). Contaminación del agua y suelo por los relaves mineros. Paideia XXI, 11(1), 141–154. https://doi.org/10.31381/paideia.v11i1.3622

Mero, M., Pernía, B., Ramírez, N., Bravo, K., Ramírez, L., Larreta, E. & Egas, F. (2019). Concentración de cadmio en agua, sedimentos, Eichhornia crassipes y Pomacea canaliculata en el río Guayas (Ecuador) y sus afluentes. Revista internacional de contaminación ambiental, 35(3), 623-640. Epub 21 de agosto de 2019.https://doi.org/10.20937/rica.2019.35.03.09

Morales, E., Barrantes, K., Beita, W., & Chacón, L. (2022). Estudio de caso: Evaluación de riesgo por arsénico, en bajas concentraciones, para trabajadores agrícolas de Cartago, Costa Rica. UNED Research Journal, 14(2), e4070. https://doi.org/10.22458/urj.v14i2.4070

Novoa, H., Arizaca, A., Huisa, F., Novoa, H., Arizaca, A., & Huisa, F. (2022). Efectos en los ecosistemas por presencia de metales pesados en la actividad minera de pequeña escala en Puno. Revista de Investigaciones Altoandinas, 24(3), 182–189. https://doi.org/10.18271/ria.2022.361

Padrón, L., Paz, S., Gutiérrez, A., Rubio, C., González, D. y Hardisson de la Torre, A. (2020). Contenido de metales y elementos traza en aguas subterráneas de abastecimiento de la isla de el hierro. (94)-1,10. https://dialnet.unirioja.es/descarga/articulo/7721433.pdf

Peña, S., & Araya, P. (2021). Aguas de contacto, efectos en la minería y el medioambiente. Revista de La Facultad de Derecho, 50. https://doi.org/10.22187/rfd2020n50a6

Pérez, P., Azcona, M., (2012). Los efectos del cadmio en la salud Revista de Especialidades Médico-Quirúrgicas. 17(3), 199-205. Instituto de Seguridad y Servicios Sociales. https://www.redalyc.org/pdf/473/47324564010.pdf

Poma, P. (2008). Intoxicación por plomo en humanos. Anales de La Facultad de Medicina, 69(2), 120–126. http://www.scielo.org.pe/scielo.php?script=sci_arttext&pid=S1025-55832008000200011

Rodríguez, C. (2021). Intoxicación por arsénico. Medicina Legal de Costa Rica, 38(2), 4-16. http://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S1409-00152021000300004&lng=en&tlng=es.

Rodríguez, R., Rocío Retamozo-Chavez, Aponte, H., & Valdivia, E. (2017). Evaluación microbiológica de un cuerpo de agua del ACR humedales de Ventanilla (Callao, Perú) y su importancia para la salud pública local. Ecología Aplicada, 16(1), 15–21. https://www.redalyc.org/journal/341/34152002003/html/

Journal of Ecohumanism
2025
Volume: 4, No: 2, pp. 2118 – 2129
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v4i2.6606

Saborío, L, & Hidalgo, L. (2015). Consumo de arsénico y riesgo cardiovascular. Medicina Legal de Costa Rica, 32(1), 114-118. Retrieved October 15, 2024, from http://www.scielo.sa.cr/scielo.php?script=sci_arttext&pid=S1409-00152015000100013&lng=en&tlng=es.

Watts, B., Palmeira, C., Lakshmi Gopakumar, Ghazaryan, K., & Movsesyan, H. (2023). Uncharted risk measures for the management of sustainable mining. Integrated Environmental Assessment and Management, 19(4), 949–960. https://doi.org/10.1002/ieam.4769