The degree of contamination of the waters of the ramis river due to indiscriminate spillage of substances derived from tailings and its impact on the living standards of the population near the mouth of the river

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Abstract
The aim of the study was to analyse the level of pollution at the mouth of the Ramis River and understand how this affects the quality of life of nearby communities. Explanatory-correlational research was conducted, combining the analysis of water samples for laboratory chemical testing and the collection of social data through surveys and interviews. The findings show that the contamination of the Ramis River is mainly caused by the uncontrolled dumping of mine tailings, both from informal and formal activities, which represents 58.7% of the pollutants detected. This situation has a considerable impact on local economic activities, especially in fishing, and to a lesser extent on livestock and agriculture. The statistical analysis of the hypotheses corroborated a direct relationship between pollution levels and the detrimental effects on the health, flora, fauna and socioeconomic conditions of the population. It is concluded that the existence of heavy metals and other pollutants in the waters of the river causes negative effects on ecosystems and human communities, significantly deteriorating their living conditions and highlighting the need to implement immediate measures for environmental control, surveillance and mitigation.

Keywords: Water Pollution, Mine Tailings, Public Health, Andean Ecosystems, Quality of Life.

1. Introduction

The Ramis River is one of the most important water systems in the Peruvian highland region, both for its length and for its impact on the ecological, social, and economic dynamics of the Lake Titicaca basin. From its origin in the mining area of Ananea, where it is known as the Rio Grande, until it flows into the Titicaca after traveling more than 200 km, the Ramis passes through different ecosystems and communities that depend on its waters for agriculture, livestock, fishing, human consumption and other subsistence activities.

However, the natural course of the river has been severely modified due to increasing pollution resulting from the indiscriminate discharge of mine tailings. Gold mining activities, both legal and mainly informal and artisanal, located in the upper part of the basin, dump large quantities of harmful substances such as mercury, lead, cadmium, zinc, arsenic, as well as sediments and fine slats derived from mineral extraction processes without any environmental control. This type of dumping occurs in a historical context where there are no adequate tailings dams, lack the necessary technology, no waste management and an extractive culture prevails that for decades has prioritized gold production over ecological sustainability.

As a result, the Ramis carries huge volumes of contaminated sediments, causing extreme turbidity in its course, blocking sunlight penetration to the bottom, directly affecting primary productivity and severely altering food chains in the water. The effects of this pollution have spread downstream over more than 180 to 200 km, impacting various communities such as Crucero, San Antón, Asillo, Azángaro, Calapuja, Achaya, Caminaca, Samán, Taraco and Yanaoco. In all these areas, significant damage to aquatic vegetation has been documented, including reeds and other macrophytes that are food and material of local utility, as well as a notable decrease in native fish species and an evident change in the ecological balance of Lake Titicaca.

The seriousness of this problem goes beyond the ecological and also affects the social and economic sphere. The pollution of the Ramis River directly impacts the living standards of the communities that depend on its waters as an essential resource for their existence. The inhabitants of the riverside suffer from gastrointestinal, dermal, infectious and respiratory diseases related to the consumption or contact with these waters. Farm animals show intestinal problems, signs of infections and a noticeable loss of energy, while crops are experiencing progressive infertility due to salinity caused by irrigation with contaminated water. This series of problems has led to a continuous deterioration of the local economy, forcing part of the population to migrate due to the impossibility of maintaining their traditional productive activities such as agriculture and fishing.
The situation is degraded by the lack of policies at both the national and regional levels that can effectively regulate and monitor mining activities. Although there are regulations related to the environment and water resources, their implementation has been scarce, allowing highly polluting extractive practices to continue without adequate controls. This has led to social conflicts among farmers, fishermen, and miners, as well as frequent protests demanding state action to curb environmental damage and safeguard public health. In addition,

there is a lack of sanitation infrastructure in the municipalities of the basin, which discharge wastewater directly into the river, which increases the organic and bacteriological load, increasing health risks.

The Ramis problem is not a unique case, but is part of a global trend of degradation of water resources in areas where the pressure for extraction exceeds the capacity of ecosystems to recover. Water pollution is one of the most pressing environmental problems of the 21st century. According to global estimates, more than one billion people lack access to safe drinking water, and diseases linked to water pollution remain one of the leading causes of child death in developing countries. In this context, the situation of the Ramis River becomes especially important, not only because of its local effect, but also because it affects the environmental quality of Lake Titicaca, which is shared by Peru and Bolivia and is an ecosystem of great biological and cultural relevance for the Andean region.

The different monitoring carried out by DIGESA, INRENA, the Lake Titicaca Special Project (PELT), national universities and the University of Montana Tech have revealed worrying levels of heavy metals in several parts of the basin. Mercury concentrations well above the limits considered safe have been detected, especially in tributaries such as the Cecilia River, where levels above 350 ng/L pose a serious risk to both human health and organisms in the food chain. In addition, high levels of lead, arsenic, cadmium, iron and zinc have been found in sediments and water samples, as well as evidence of mercury bioaccumulation in fish from Lake Titicaca, increasing the toxicological risk to the communities that consume them.

In view of this situation, the proposal of this study is based on the pressing need to generate solid scientific evidence that helps to understand the complexity and magnitude of the pollution of the Ramis River and its effect on the quality of life of the population. Assessing the level of contamination through physicochemical analyses, identifying the presence of heavy metals, and studying their socioeconomic implications is a crucial step in formulating effective environmental policies, establishing constant monitoring systems, and fostering mitigation and rehabilitation initiatives in the basin.

In this context, the goal of the research is to review the level of contamination at the mouth of the Ramis River and determine how toxic elements from mining waste affect the living standards of nearby inhabitants. Using an explanatory-correlational approach that combines water sampling, laboratory chemical tests and the collection of social data through surveys and interviews, it is intended to establish a link between the sources of pollution, the intensity of exposure and the impacts on health, the local economy, aquatic and terrestrial ecosystems, as well as the viability of traditional productive activities.

This analysis, therefore, is framed in a scientific, social and environmental need that requires immediate and complete responses. The study of the Ramis River not only generates crucial information to understand a significant environmental problem, but also provides essential elements to design sustainable development strategies, integrated management of water resources and safeguarding public health in the Peruvian highland region.

2. Theoretical framework

Water pollution is considered globally as one of the most serious environmental challenges, as it has the potential to modify the essential functions that this resource plays in ecosystems and in human existence. Several experts agree that water pollution affects fundamental ecological processes, food security and public health, as water is vital for all forms of life. The research presented provides a clear definition by indicating that "water pollution refers to the introduction of foreign substances that impair the quality of water and compromise its purity", highlighting that once water is contaminated, it ceases to adequately fulfill crucial functions such as consumption, sustenance of aquatic life, crop irrigation or hygiene uses. This explanation aligns with modern definitions from international bodies and scientific studies that emphasize that any chemical, physical, or biological alteration that exceeds the water's ability to self-clean causes significant environmental and health risks.

From a physicochemical perspective, water has characteristics that favor the presence of contaminants. Its ability to dissolve, disperse or keep in suspension various substances makes it extremely susceptible to discharges of industrial, agricultural or mining origin. As the research mentions, "one of the repercussions of the particular physicochemical properties of water is that it attracts or absorbs pollutants easily," which helps to understand why water sources used for agriculture or human consumption deteriorate quickly when they receive toxic waste. This concept is aligned with hydrological theory, which states that rivers function as natural transporters of pollutants, accumulating them in sediments, distributing them along their channels and, on numerous occasions, transferring them to aquatic living beings. The research correctly points out that "the natural sources that are most rapidly polluted are rivers and lakes, since all pollutants are poured through these bodies of water to their mouth", a statement that corresponds to limnological studies that show how these bodies, especially in closed basins, tend to concentrate pollutants due to their limited water renewal.

In the high Andean mountain area, the case of the Ramis River is extremely alarming due to its origin in an area with very intense gold mining activity, where informal and artisanal mining is carried out without any type of environmental protection measures. The research indicates that these practices cause "the runoff of heavy metals (such as mercury, lead and copper) and suspended particles, mud and clayey sediments of cementitious appearance," which, in the absence of appropriate tailings or waste management, are dragged by rainfall, seepage and surface drainage towards the riverbed. This incessant transport, which can reach more than 200 kilometers, profoundly affects ecosystems: it decreases the entry of light, destroys habitats in the riverbed and alters the food chain affecting phytoplankton and zooplankton, as expressed in the research when it mentions that pollutants prevent "the sun's rays from reaching the bottom of the river, which hinders the growth of phytoplankton and the existence of zooplankton." This phenomenon, known as clogging and darkening of the water column, causes a decrease in primary productivity, crucial for sustaining fish and macroinvertebrate populations.

An important element of the theoretical framework relates to the presence of heavy metals in water and their impact on public health and the environment. The technical studies referred to in the thesis show that entities such as the General Directorate of Health have detected "levels of heavy metals in the adjacent areas and in the area of influence of gold mining", confirming that elements such as mercury, lead, zinc, arsenic and cadmium are present at dangerous levels. Specific investigations reveal that the Cecilia River showed "the highest concentration of Hg (375 ng/L)", a figure that considerably exceeds the limits set by international regulatory bodies and turns the water into a toxic agent. Mercury, in particular, is known for its ability to bioaccumulate and biomagnify in aquatic species, which is evidenced in studies of Lake Titicaca where fish were found with levels of up to "0. 63 μg/g" Hg. Not only does this reflect ecological damage, but it also poses an immediate danger to human communities that depend on these species as a source of protein.

The consequences for public health are equally alarming. The investigation contains testimonies and evidence that indicate that the communities near the river suffer from "gastrointestinal, neurological and respiratory diseases", which are related to ingestion, domestic use or simple contact with contaminated water. These pathologies are caused not only by the presence of heavy metals, but also by the high load of organic matter and bacteria that the river receives due to the lack of wastewater treatment systems. The research shows that "in all the municipalities of the basin [...] wastewater is thrown or diverted directly into the waters of the Ramis River," which promotes eutrophication processes, increases the amount of fecal coliforms and increases risks to public health. The combination of chemical and biological agents creates a toxic cocktail that causes chronic exposure, particularly affecting children, the elderly, and people with weak immune systems.

From an ecological point of view, the effects of pollution are catastrophic. The research records a notable decline in aquatic life, stating that native species "have declined significantly and are at risk of extinction." It is also mentioned that the riparian vegetation suffers, since "they do not manage to develop completely and do not sprout again", and that many plants end up "withering" due to the debris that adheres to their stems or due to the chemical alteration of the water. These observations support the ecological theory that pollution caused by heavy metals and fine sediments alters habitat composition, affects gas exchange, destroys natural spawning sites, and contributes to the gradual reduction of both aquatic and terrestrial biodiversity in flooded areas.

From a socio-economic perspective, environmental degradation has a direct connection to the quality of life of rural communities. The research points out that the population has suffered "the disappearance of farm animals", "the loss of crops due to the salinity of the soils" and "the extinction of aquatic species that are a source of food for the inhabitants". These consequences, which directly affect the family economy, translate into a decrease in agricultural production, reduced income, food insecurity and forced migration. The pollution of the Ramis River has created a vicious cycle of environmental poverty, where ecological deterioration fosters socio-economic precariousness, complicating the implementation of solutions.

Regarding the legal and management framework, the thesis argues that "regulations to prevent environmental pollution are inadequate" and that a large number of companies ignore environmental impact studies, which reveals a structural problem in governance. Additionally, it argues that "in the Ramis basin there is no integrated management of water resources", a point that is aligned with the international literature that emphasizes the urgency of applying Integrated Water Resources Management (IWRM) approaches to address complex problems that involve various actors, such as mining, agriculture and domestic water use.

This theoretical framework, therefore, incorporates the hydrological, toxicological, ecological, sanitary, socio-economic and governance dimensions that are essential to understand the complexity of the Ramis River case. In this way, the need to rigorously evaluate water pollution and its effects on the living standards of local communities is highlighted, since the impacts observed are the result of prolonged environmental processes that demand urgent, multisectoral intervention based on scientific evidence.

3. Objectives

3.1 General objective

Evaluate the degree of contamination in the waters of the mouth of the Ramis River, applying laboratory sample tests to determine the control and measurement of the levels of danger that affect the standard of living of the surrounding population.

3.2 Specific objectives

a) To determine the degree of contamination of the river waters by toxic chemical substances derived from mine tailings and their impact on the flora and fauna of the place.

b) Determine the level of knowledge of the population about the pollution and environmental conservation of their environment.
c) To establish to what extent the waters of the Ramis River are polluted by pollutants, causing unhealthiness in the surrounding population.

4. Methodology

4.1 Description of the method and design

4.1.1 Type of research

Basic: Because it is aimed at increasing and enriching theoretical knowledge, as well as discovering principles, laws, theories and doctrines, in a given scientific field.

4.1.2 Research level

Correlational: Because it determines the degree of association that exists between two or more variables, to make it a perfect inverse association, perfect direct or that there is no association between them.
Explanatory: Because it identifies the relationship that exists between two variables, it focuses on explaining why a certain event occurs and through the cause the effect is known.

4.1.3 Research method

In the present study it has been determined to use the method of reasoning, which proceeds through explanation, aimed at convincing, among them we have the following:

- Research history
- Statistician
- Correlation
- Abstraction
- Abduction

4.1.4 Research Design

Research by objectives: Demonstrates the objectives and tests the hypotheses using a logical sequence.
Research by association: Identifies the degree of association between two variables and indicators.

4.2 Population and sample

4.2.1 Population

The inhabitants of the Ramis River basin, near the mouth of the rivers, constitute the population for the purposes of the survey: 730 families.

4.2.2 Sample

The most appropriate methodological criterion was considered, which is the "sample; this was obtained using a formula that takes into account the size of the population, the level of acceptance expressed in an acceptance coefficient and the margin of error, expressed in Table No. 01.

VARIABLES	DESCRIPTION	VALUES
N	Total Population (inhabitants)	730
Z	Acceptance Level (95%)	1,96
E	Level of Accuracy or Degree of Error (5%)	0,05
p	Chance of Hit (50%)	0,5
q	Probability of Error (50%)	0,5
n	Sample Size	252

Table 1. The formula and calculation for the sample size is:

$$n = \frac{Z^2 * p * q * N}{E^2 * N + Z^2 * p * q}$$

$$n = \frac{(1{,}96)^2 * (0{,}5)(0{,}5) * 730}{(0{,}05)^2 * 730 + (1{,}96)^2 * (0{,}5)(0{,}5)}$$

$$n = \frac{0{,}9604 * 730}{1{,}825 + 0{,}9604}$$

$$n = \frac{701{,}092}{2{,}7854}$$

$$n = 251{,}7 \approx 252$$

4.3 Data collection techniques and instruments
4.3.1 Techniques

Survey: It is a technique that allows information to be obtained from a representative sample of a given population. It is a process through which first-hand data is obtained and all those that allow the problem to be better explained. It is formulated only with the indicators of the variables and the questions are formulated for each of the specific objectives of the research. It has been determined to use this technique because the research has a scientific-social characteristic, in which it works with a certain population.

Interview: It is a technique that allows obtaining information about the properties of a problem. This technique is applied to key informants who are previously selected representative people (important for their social, economic, political and religious position).
It has been taken into account to consider the interview as a support technique for our research given their characteristics.

Water sampling for chemical analysis: It is a technique typical of scientific research, which is important because it helps and allows the hypothesis of an investigation to be confirmed. Despite the high costs, the analysis of samples has been taken into account to determine with greater certainty the problem of contamination in the study area.

4.3.2 Instruments

Questionnaire: It is a research instrument of greater use, and it is structured based on a set of questions to obtain information about the problem being investigated.
In this research, the questionnaire has been used as an instrument of the survey technique through a form of 20 structured or closed questions, because it facilitates the interview with the interviewee.

Interview Guide: It is an instrument of the interview; it uses is aimed at key informants or selected from a social group, it uses a greater proportion of unstructured or open-ended questions. In this article, they have been used, being prepared in a format of 7 unstructured questions, and addressed to authorities, important people in the sector.

Analysis Test Report: These are the results of the chemical analysis of laboratories specialized in environmental analysis. Laboratories are used as external sources located outside our region and far from the unit of analysis.

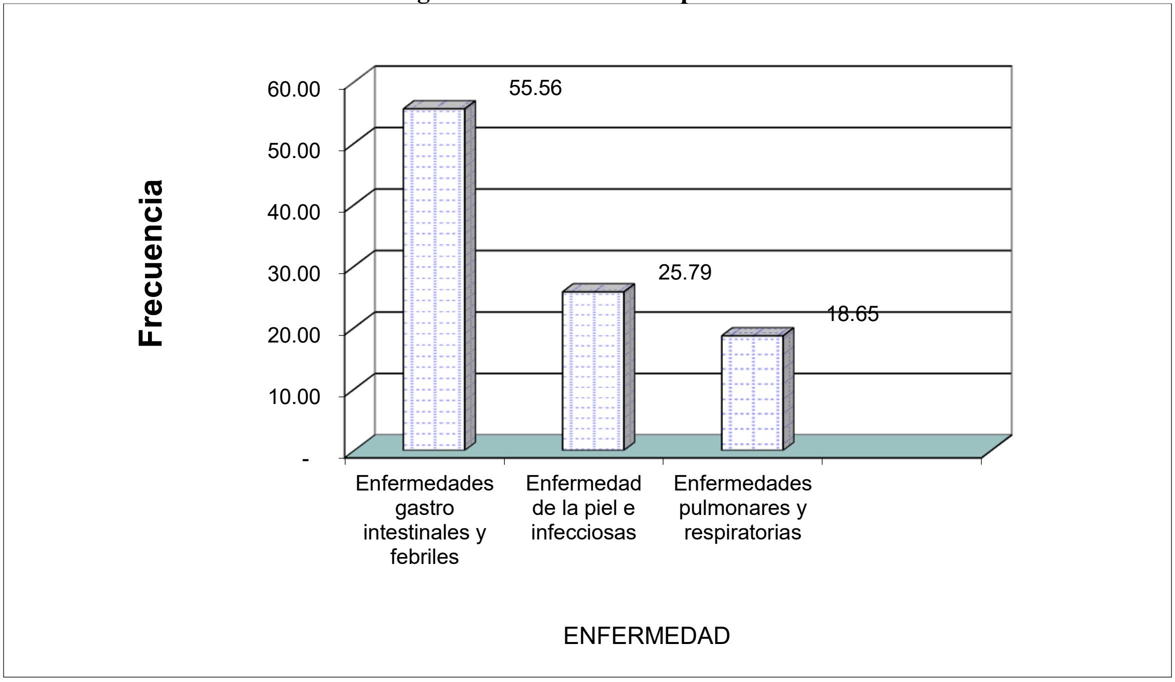
5. Results

5.1 Effects caused by the pollution of the Ramis River.

Table 2.: In people's health

ILLNESS	Frequency	Percentage
Gastro-intestinal and febrile diseases	140	55,56
Skin and infectious diseases	65	25,79
Lung and respiratory diseases	47	18,65
Total	252	100.00

Figure 1. Diseases due to pollution



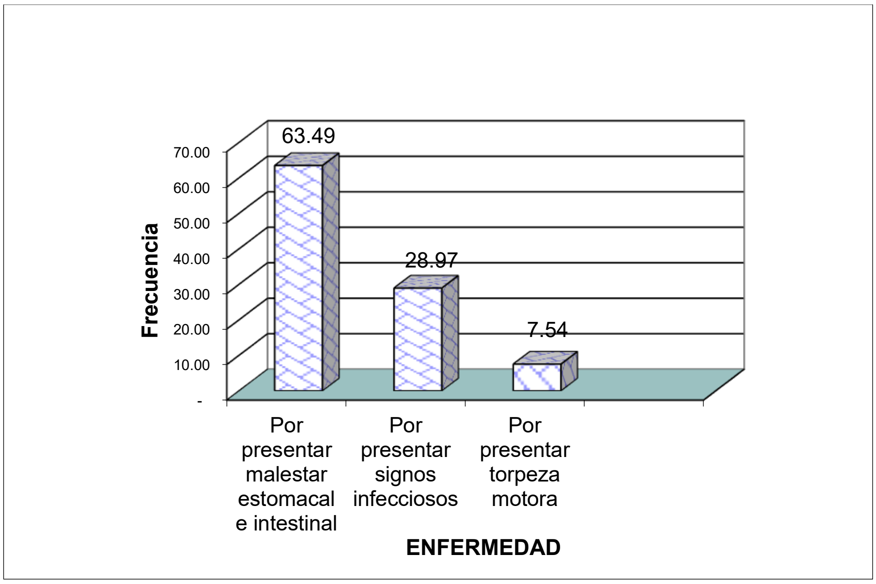
Regarding the effects that pollution causes on diseases in people, it is observed that 55.56% suffer from gastrointestinal and febrile diseases, this indicates that most of the people who live in the vicinity of the Ramis River suffer from this discomfort.

Table 3: In animals

ILLNESS	Frequency	Percentage
Because he has stomach and intestinal discomfort	160	63,49
Because of infectious signs	73	28,97
Due to motor clumsiness	19	7,54
TOTAL	252	100.00

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco – Huancane.

Figure 2. Effects of Ramis River Water Pollution on Animals in %



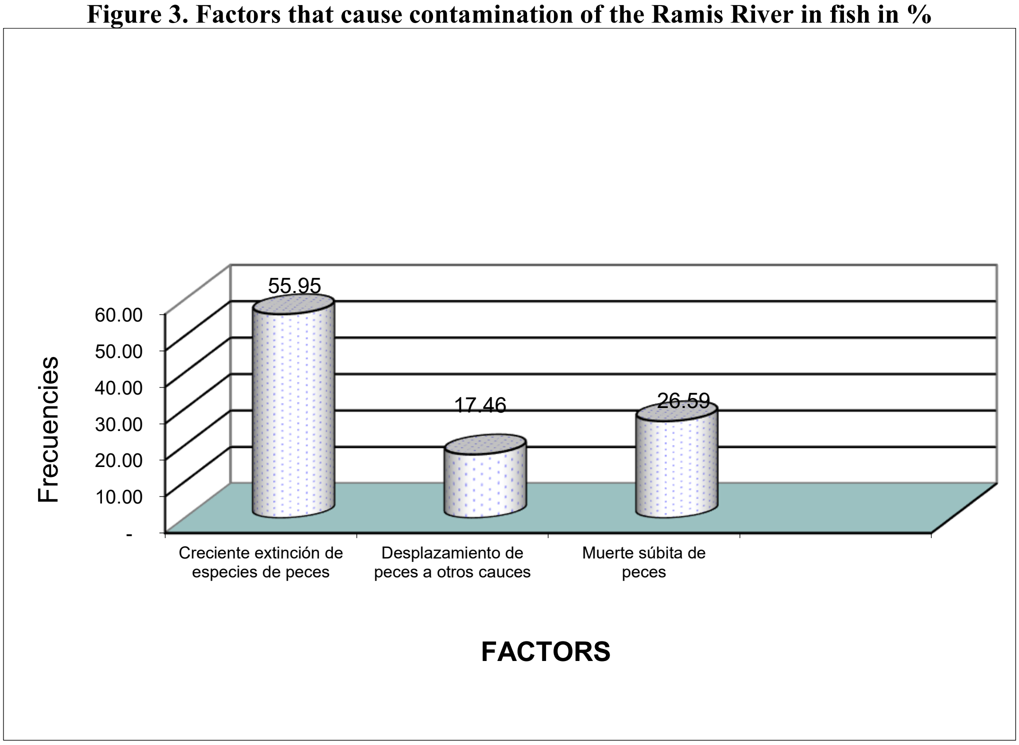
Regarding the effects of pollution on diseases in animals, it is observed that 63.49% present stomach and intestinal discomfort, this indicates that most animals suffer from this discomfort as well as humans living in the Ramis River basin.

Table 4. In the fish

FACTORS	Frequency	Percentage
Increasing extinction of fish species	141	55,95
Movement of fish to other channels	44	17,46
Sudden fish death	67	26,59
TOTAL	252	100.00

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco – Huancané**.**

Figure 3. Factors that cause contamination of the Ramis River in fish in %



Most fish are increasingly endangered by the effects of pollution with 55.95% followed by sudden death which is 26.59%. Therefore, pollution has an impact on the living standards of the beings that live in the vicinity of the Ramis River.

Table 5: In aquatic plants

FACTORS	Frequency	Percentage
They do not fully develop and do not sprout	107	42,46
They have very weak roots	65	25,79
They are dry due to substance adhering to the stem and wither	80	31,75
Total	252	100.00

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco 2008

42.46% of aquatic plants do not develop properly and do not sprout. 31.75% have dryness due to substances adhered to the stem and then wither as a result of pollution, this effect has an alarming negative impact on the flora of the area.

Table 6: On farmland.

FERTILITY	Frequency	Percentage
Have progressive infertility	154	61,11
Have complete infertility	63	25,00
Have normal fertility	35	13,89
Total	252	100.00

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco – Huancané. 2008.

Figure 4. Opinion on the retility of cropland in %
Only 13.89% of the lands have normal fertility and 61.11% have progressive infertility, which harms the production of the farmland.

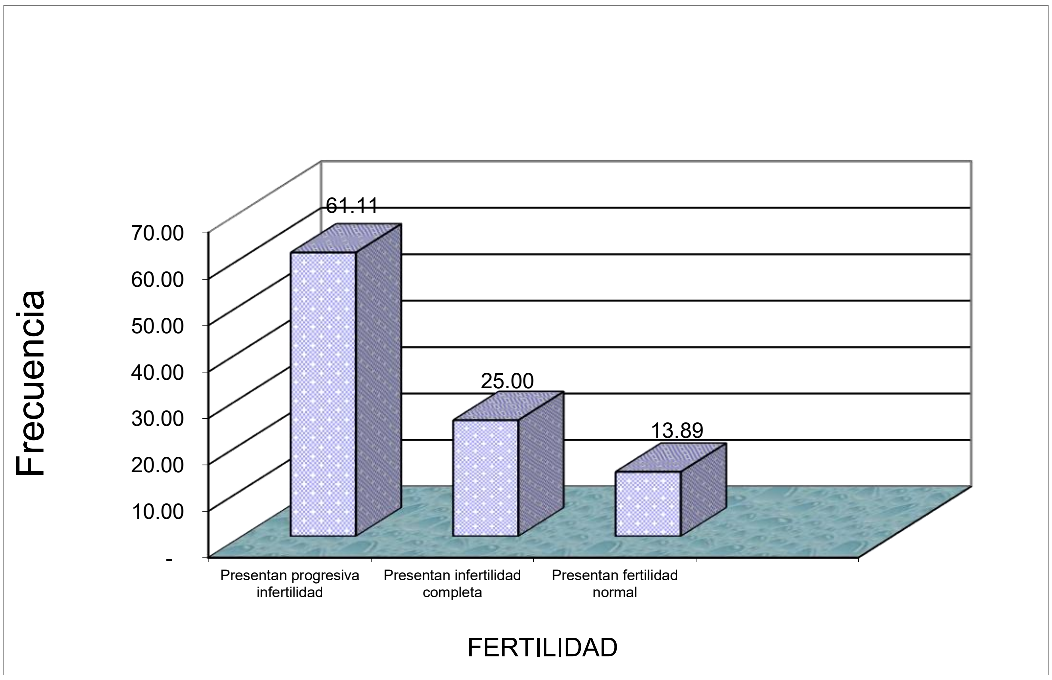


Table 7: In demographic behavior

MIGRATION	**Frequency**	**Percentage**
Yes	**125**	**49,60**
No	**86**	**34,13**
Don't know/don't give your opinion	**41**	**16,27**
Total	**252**	**100.00**

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco – Huancané - 2008.

Figure 5. Opinion on population migration
According to the graph above, 49.60% of the population surrounding the Ramis River prefers to migrate to other places due to the effect of pollution.

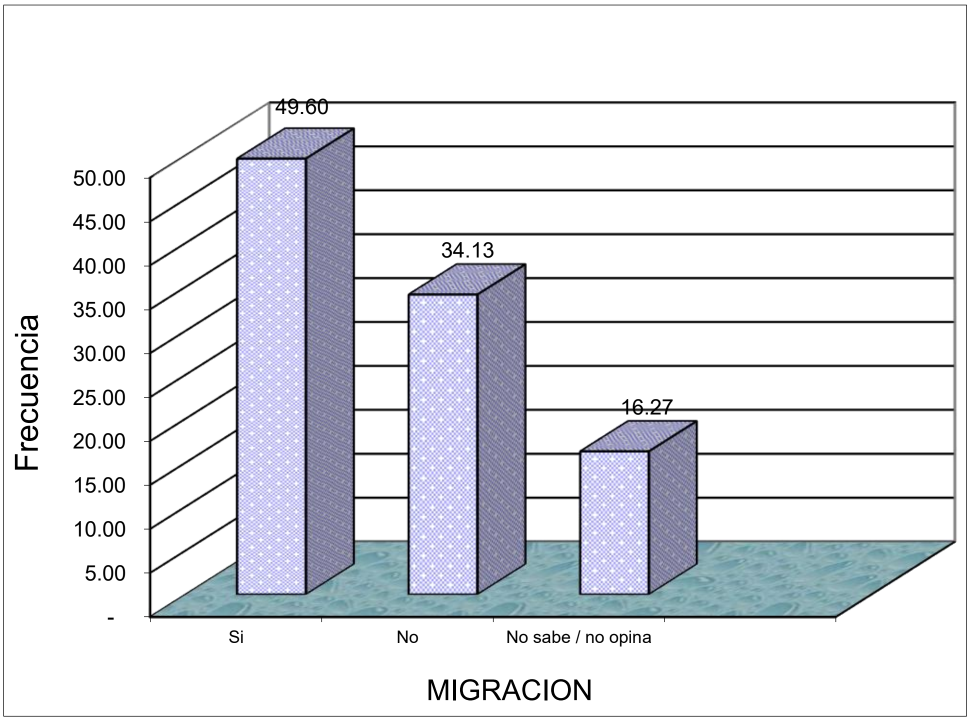


Table 8: In employment

EMPLOYMENT	Frequency	Percentage
Ambulatory trade	130	51,59
Minor transport (Tricycle, Motorcycle taxi)	72	28,57
Informal trade (smuggling)	50	19,84
Total	**252**	**100.00**

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco – Huancané – 2008

Figure 6. Opinion on alternative employment in %
51.59% have a preference for an alternative job such as ambulatory commerce, this due to the effect of pollution that affects agricultural production and fishing in the area.

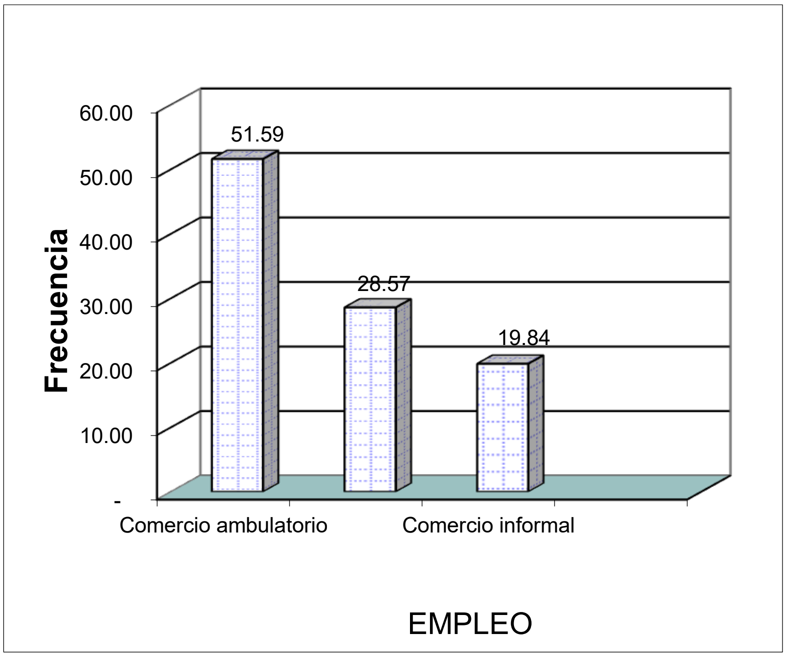


Table 9: Official evidence of the contamination of the ramis river by public and private institutions

INSTITUTIONS	Frequency	Percentage
Water analysis by INRENA	50	19,84
Water analysis by the PELT	66	26,19
Water analysis by Montana Tech University – USA	15	5,95
TOTAL	**252**	**100.00**

Source: Questionnaire addressed to the inhabitants of the Ramis River in the District of Taraco – Huancané. 2008.

Figure 7- Analysis of the water of the Ramis River by parts of the intiuttions in %
According to Table No. 9 and Graph No. 7, it is shown that the PELT Institution has a greater participation in the contaminated area with 29.19%, followed by INRENA with 19.84% and the University of Montana – USA with 5.95%. which indicate that few institutions are concerned about the consequences that the contamination of the Ramis River basin may cause on the living standards of the population surrounding the area.

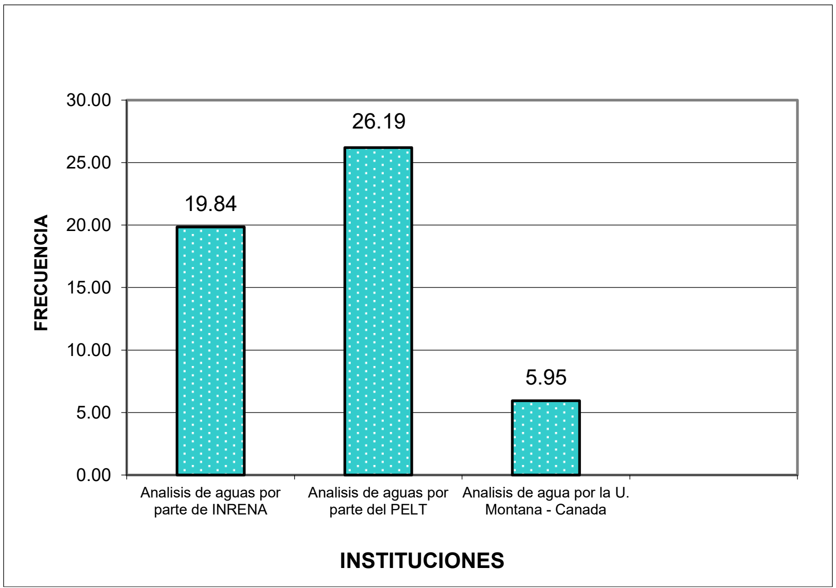


Table 10: analysis of results and interpretation from chemical laboratory tests of water results of chemical - physicochemical tests

DETERMINATION	RIVER WATER SAMPLE 02 FORK	AGUA DE RIO MUESTRA 01 HATUN PAMPA DESEMBOCADURA	RIVER WATER SAMPLE 03 RAMIS BRIDGE	UNITS
Cyanide (CN-)*			< 0.004	mg/L
Arsenic (As)*	0,014	0,012		mg/L
Cadmium (Cd)*	< 0.006	< 0.006		mg/L
Lead (Pb)*	0,016	< 0.01		mg/L
Mercury (Hg)*	< 0.0002	< 0.0002	< 0.0002	mg/L
Nickel (Ni)*	0,007	< 0.001		mg/L
Fierro (Fe)	3,64	1,72		mg/L
Zinc (Zn)	0,52	2,68		mg/L

Source: Ramis River Water Analysis (M-1 Hatun Pampa Lago). Bhios Laboratories TEST REPORT Nº 0108- Huancané - Puno – 2008

Figure 8. Cyanide and mercuary determination.

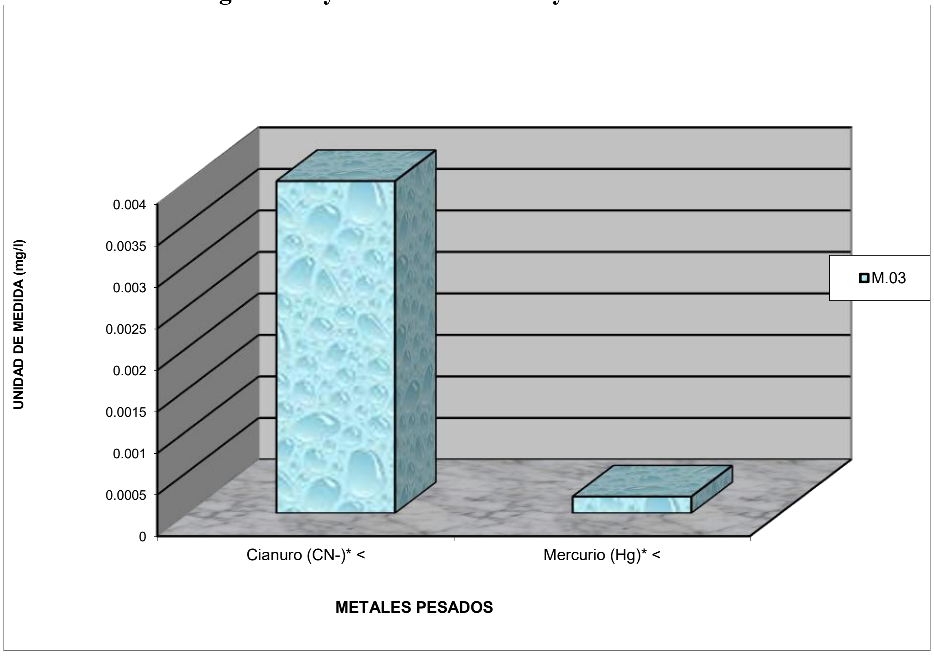
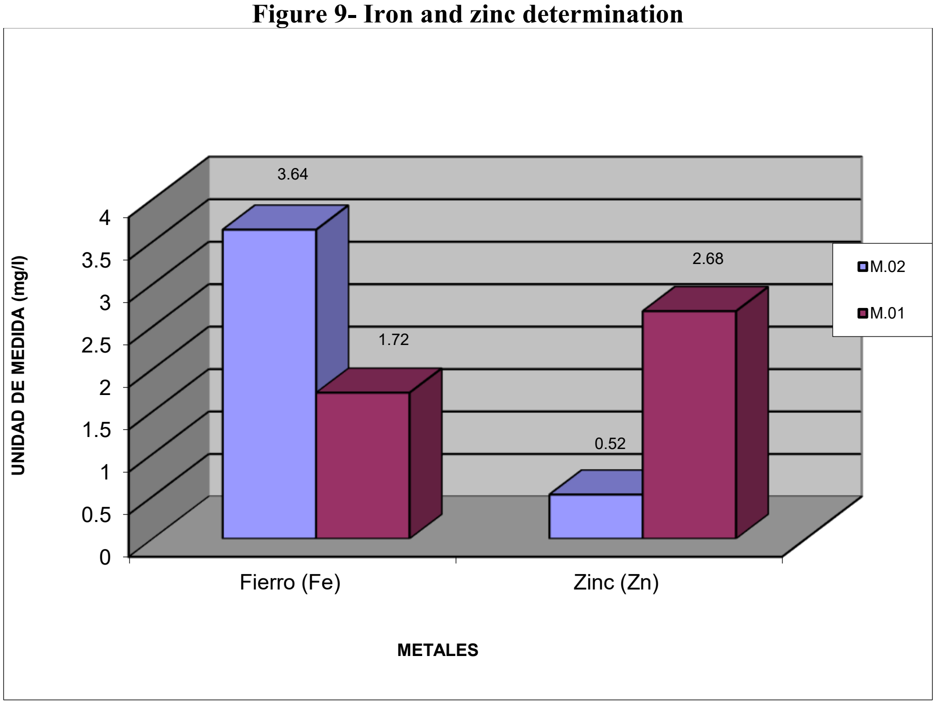
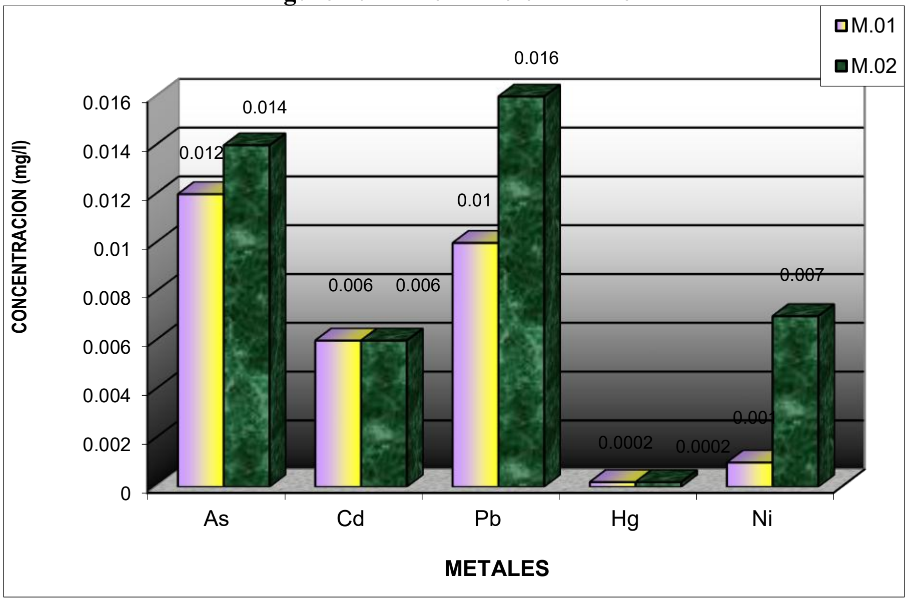


Figure 9- Iron and zinc determination



Graph 9 In the chemical tests of the water of the Ramis River, two samples were taken for Fierro and Zinc; in which it is determined in Sample 01 of the mouth of the river the Zinc content was 2.68 mg/l. higher than Sample 02 of the river fork with a much lower content of only 0.52 mg/l. With regard to the substance Fierro, the content for sample 01 was 1.72 mg/l., lower than the content of Sample 02 of 3.64 mg/l. From this it is concluded that at the mouth the pollutant content of Zinc is much higher than at the bifurcation of the river; the opposite happens with the Fierro.

Figure 10- Mineral Determination



Graph No. 10 shows the comparison of two types of samples in which chemical tests show that in Sample 02 taken at the fork of the Ramis River the concentration level of the contaminant of the metals: Arsenic, Cadmium, Lead, Mercury and Nickel are higher than in Sample 01 at the mouth of the river.

Table 11: comparison of the result of river sampled water with the permissible limits for water uses

DETERMINATION	RIVER WATER SAMPLE 02 FORK	AGUA DE RIO MUESTRA 01 HATUN PAMPA DESEMBOCADURA	RIVER WATER SAMPLE 03 RAMIS BRIDGE	PERMISSIBLE LIMIT M.E.M	PERMISSIBLE LIMIT FOR HUMAN CONSUMPTION		PERMISSIBLE LIMIT FOR IRRIGATION		UNITS
					Class I & II (LGA)	WHO	Class III (LGA)	FAO	
Cyanide (CN-)*			< 0.004	1,0 - 0,07	0,2	0,07	0,005	0,1	mg/L
Arsenic (As)*	0,014	0,012		1,0 - 0,01	0,1	0,01	0,2	0,1	mg/L
Cadmium (Cd)*	< 0.006	< 0.006			0,01	0,003	0,05	0,01	mg/L
Lead (Pb)*	0,016	< 0.01		0,40 - 0,01		0,01	0,1	5,0	mg/L
Mercury (Hg)*	< 0.0002	< 0.0002	< 0.0002		0,002	0,001	0,01	0,003	mg/L
Nickel (Ni)*	0,007	< 0.001			0,002	0.02	0,002	0,2	mg/L
Fierro (Fe)	3,64	1,72		2,0	0,3	0,1	1,0	5,0	mg/L
Zinc (Zn)	0,52	2,68		3,0		5,0			mg/L

Source: Ramis River Water Analysis (M-1 Hatun Pampa Lago). Bhios Laboratories TEST REPORT Nº 0108-Huancané - Puno - 2008.

Source: Permissible limits for water. Ministry of Energy and Mines – 1996 and World Health Organization – 1985.

Chart 11 - Comparison of water tested with permissible limit for water use

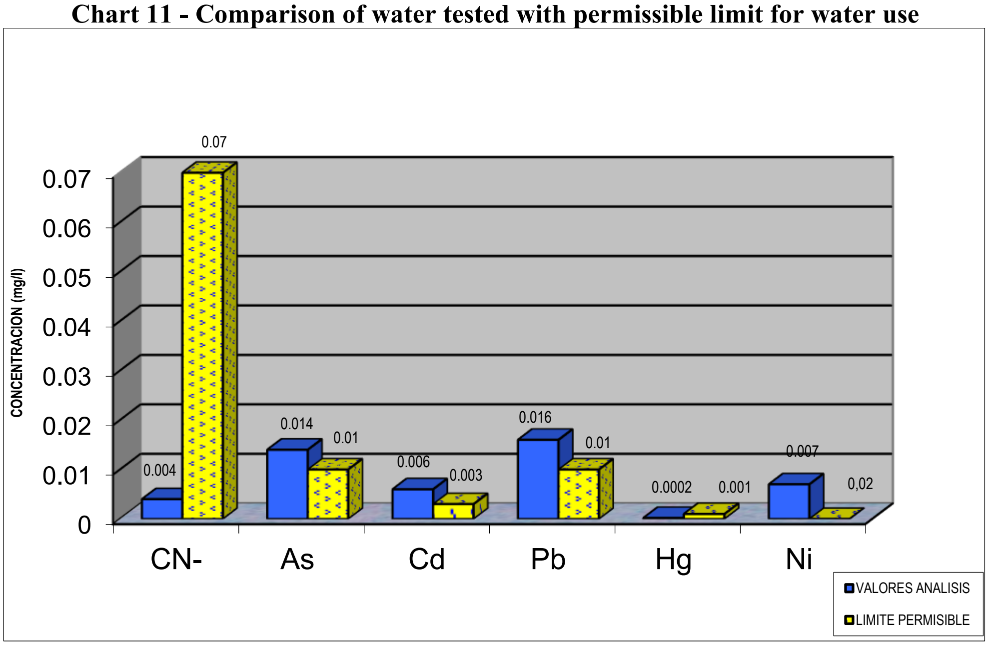
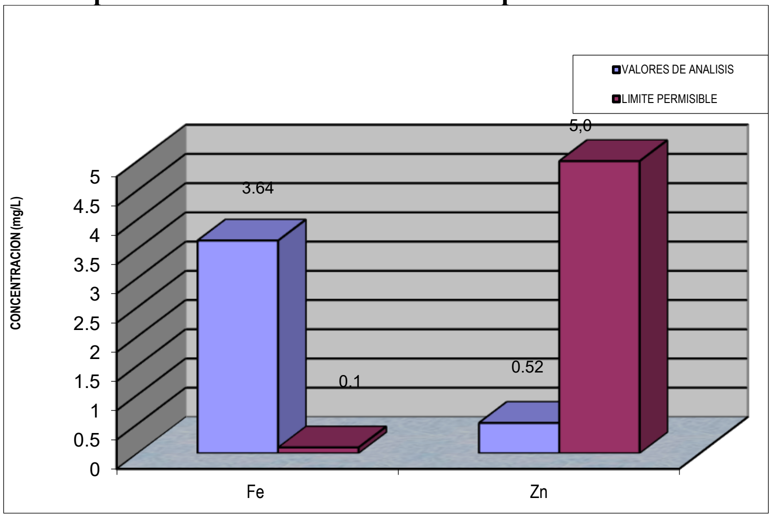


Chart 12. Comparison of the water tested with the permissible limit for water use



6. Conclusions

The findings of the research allow us to affirm that the contamination of the Ramis River is a complicated and serious environmental phenomenon, whose main origin is the informal and unregulated mining activity that takes place in Ananea and its surroundings. The constant discharge of waste, sludge and heavy metals has caused a degradation process that is observed throughout the basin with a notable increase, impacting both water quality and the ecological functions of the river. Technical data indicate that sedimentable solids exceed 230 g/L at different points, which shows an unusual level of silting that modifies the shape of the river, decreases its hydraulic capacity and destroys aquatic habitats along more than 180 kilometers of its course.

The physicochemical studies carried out show that the sediments and water of the river present worrying concentrations of heavy metals (mercury, cadmium, lead, arsenic, zinc), exceeding in several sections the Maximum Permissible Limits established by environmental regulations. These results coincide with the perceptions of the inhabitants, who report direct effects on human health, such as gastrointestinal disorders, skin and respiratory problems, as well as the progressive loss of domestic and aquatic animals. The complete disappearance of fish, amphibians and other aquatic species in large areas of the basin is a clear indicator of considerable ecological stress, which endangers food security and contributes to the disintegration of local food chains, the effects of which have not yet been fully analyzed.

From a socioeconomic perspective, the pollution of the Ramis River has a significant impact on agricultural and livestock activities, which are the economic base of communities in the middle and lower basin. The accumulation of sediment in canals and irrigation intakes complicates or makes it impossible to irrigate crops, decreases the availability of pastures and affects the quality of water intended for animal consumption. As a result, there is a constant reduction in agricultural and livestock production, which directly affects the economy of more than 70 thousand people who depend on these production systems. Declining incomes, coupled with environmental degradation, increase social vulnerability and perpetuate cycles of extreme poverty. This explains why the community has resorted to protests, road blockades and public demands to demand state intervention in the regulation of mining activity and the environmental rehabilitation of the basin.

The analysis also points to a crucial institutional aspect: the lack of unified management of water resources in the Ramis basin. The lack of spaces for dialogue, the fragility of control and monitoring mechanisms, and the scarce response of the sectoral and regional authorities have facilitated the continuation of damage to the environment and the intensification of social conflicts. The data indicate that, despite having decrees and regulations to regulate mining, these have not been enough to stop polluting practices or ensure water protection. Local and regional governments have shown interest in acting, but without a comprehensive and coordinated policy, isolated efforts are not able to address a problem of such magnitude.

On the other hand, the findings of the sediment analysis using the geochemical index (Igeo) allow us to point out critical areas in the basin, such as the Jampaturi ravine and areas surrounding the San Rafael mine, where levels of metal contamination ranging from moderate to very high are recorded. Although significant contamination was not found in some localities, these are not indicative of a reduction in the problem, but of normal variability in diffuse and cumulative contamination processes. The contamination observed in tributary rivers, such as the Crucero, where a moderate presence of zinc and arsenic is detected, reinforces the idea that the degradation process is systemic and that several minor tributaries act as conduits for the transport and dispersion of toxins to the main channel.

In summary, the research argues that the contamination of the Ramis River constitutes one of the most serious and long-lasting environmental challenges of the Lake Titicaca basin. The combined effects – in the ecological, economic, social and public health spheres – show that the degradation of the river does not only come from unregulated extractive activities, but also from an institutional failure that has hindered the implementation of effective measures for prevention, control and restoration. Although the situation is alarming, the findings also suggest that there are structural alternatives that could help alleviate the damage, such as the creation of infrastructure for sediment retention, the design of public investment projects focused on integrated water resources management, and the strengthening of the regional environmental monitoring system.

Finally, the conclusions indicate that the recovery of the Ramis River is possible, provided that sustained interventions are carried out, technically justified and supported by a genuine political commitment, both from the State and from the productive actors involved. Ecological restoration, safeguarding public health, and boosting the livelihoods of riverside communities depend on a comprehensive strategy that combines regulation, infrastructure, environmental monitoring, and active participation of the local community. Only through a coordinated, data-driven effort will it be feasible to reverse the cumulative effects of decades of pollution and ensure a sustainable future for the Ramis Basin.

references

1. Gerbrandt, b., et al (2004). "**contamination of lake titicaca and tributaries by mercury and other heavy elements. Metallurgy, materials and welding",** n° 1, pp. 34-39.
2. Gammons, christopher et al. (2003). "**preliminary assessment of mercury contamination due to gold mining in the rio ramis-lake titicaca watershed",** perú. Montana tech, school of mines and engineering -usa; univ. Of california-davis; ept. Of environmental science and policy – usa.
3. Zavala, b. & guerrero, c. (2005). "**geoenvironmental study of the ramis river basin**", report in edition. Riverside standards
4. Vaux, p., et al, "**ecology of the pelagic fishes of lake titicaca, perú-bolivia, biotrópica**", 20, 220-229 (1988).
5. Gammons, c. H., gerbrandt, b., weight, w., mc nearny, r., young, c., slotton, d., huamani, a., camac, a., calderon, r. Y tapia, h. **"preliminary assessment of mercury contamination due to gold mining in the ramis river-titicaca lake watershed**", perú, proceedings tms-epd congress, san diego, ca, ed. M. Schlesinger, warrendale, pa (march 2-6, 2003).
6. Gammons, c. H., b. Gerbrandt, w. Weight, r. Mcnearny, c. Young, d. Slotton, a. Huamani, a. Cámac, r. Calderón, and h. Tapia. **Preliminary assessment of mercury contamination due to gold mining in the ramis river-titicaca lake watershed**, perú.
7. Carlos guerrero b. & bilberto zavala c. **"influence of mining activity in the ramis river basin – puno**" ingemmet, av. Canada 1470, san borja, lima-peru, guerrero@ingemmet.gob.pe
8. Salinas et al, **"systematization of pollution studies of the ramis basin".** Gsaac-grrnma. Gore, puno, 2004.
9. Müller, g. (1979), **heavy metals in the sediments of the rhine – changes since. Umschau**, 79, pp. 778-783
10. Young, c., c.h. gammons, r. Mcnearny, d. Slotton, a. Cámac, f. Quispe and e. Aquino, **environmental assessment of gold processing by mercury amalgamation in a developing country, in: recycling and waste treatment in mineral and metal processing: technical and economical aspects**, lulea, sweden, 2002, edited by b. Bjorkman, c. Samuelsson and j.o. wikstrom, pp. 599-608 (2002).
11. Urteaga, patricia and boelens, rurgerd. **"collective rights and water policies in the andean region".** Walir. Iep. Lima, peru, 2006.
12. Siboil del perú. S.a. 2007. **Environmental impact study. 2d seismic prospecting and drilling of 13 exploratory wells in block 105**. Executive summary. Puno, peru.
13. Canter, larry w. (1998). **"manual of environmental impact assessment",** mc graw hill edition, spain, 1998. Pages 71-175.
14. Northcote, t.g. et al. (1991). **"contamination in lake titicaca", peru: training, research and management.** Wetswater research centre university od bristh columbia, vancouver, canada. University of the altiplano – puno.
15. Tolmos, a., raúl. (2004). "**challenges and proposals for the most effective implementation of economic instruments of environmental management in latin america and the caribbean case":** the case of peru. Division of sustainable development and human advice, santiago de chile. Eclac-united nations.
16. Solano, pedro (compiler) .2002. **Compendium of legislation on protected natural areas, national institute of natural resources** - peruvian society of environmental law. Lima, peru.
17. Escobar, fortunato, aymara researcher, specialized in socio-environmental issues and indigenous rights; member of the board of directors of the civil corporation for socio-economic infrastructure and agricultural transformation - cciseta - and of the south american indian council - cisa - entity with consultative status with ecosoc of the united nations - un: www.puebloindio.org, www.cciseta.org.
18. Cbc cuzco, iproga, wur. 2006-2007. Professional specialization course. "**integrated management of water resources macro region south".** Modules i, ii, iii, iv and v. Cuzco, cajamarca, arequipa - peru.
19. Cepis. Module iii building consultation processes. **Course: "prevention, constructive management of conflicts and principles of consultation and political advocacy".** Lima, peru.
20. Conam. Report: "**environmental emergency in the ramis punno basin**". 2006.
21. www.conam.gob.pe
22. Regional directorate of energy and mines (drem) of puno. 2006. "**evaluation of the state of natural resources and environmental contamination of the ramis river basin".**
23. A - national agrarian university la molina and ministry of energy and mines general directorate of environmental affairs (1999). "**investigation and monitoring of the carabaya - ramis and cabanillas del titicaca rivers".** Lima, peru.
24. Pelt, "**investigation and monitoring of the carabaya - ramis and cabanillas rivers of lake titicaca", (**1999). Pp. 62.
25. Ministry of agriculture of peru. Multisectoral committee. **"national strategy for the integrated management of continental water resources of peru".** December 2004.

26. Uni (2001). Inventory of inactive mines of the department of puno. Ministry of energy and mines: **project for the elimination of environmental liabilities.** National university of engineering – faculty of geological, mining and metallurgical engineering.
27. Us epa, **“water quality criterion for the protection of human health: methyl mercury”**, federal document: epa-823-r-01-001. Office of science and technology, office of water, u.s. environmental protection agency washington, dc 20460 (2001).
28. García o., celestino. **"descriptive statistics and probabilities".** First
29. Edition. Edit. Princelines. Lima. 1996.
30. Marques de c., maria josé. **"probability and statistics"**., pre-edition. Mc graw hill.
31. Acuña, edgar. **"analysis of categorical data".** Dept. Of mathematics. University of puerto rico-moyaguez. Http://math.uprm.edu./~edgar.
32. Mitacc meza, máximo. "**topics of statistical inferences".** Editorial san marcos. Lima. 1990.
33. Statistical software, **spss 15.0** for windows version 15.01. Copyright (c) spss inc., 1989 – 2006 spanish version.
34. Hernandez sampieri, roberto; fernandez collado, carlos and baptista lucio, pilar "**methodology of research",** second edition, 1999, editorial mc.graw-hill, mexico. Pp. 501
35. Torres bardales, coloníbol "**orientación básicas de método de la investigación científica",** first edition, 1992, editorial san marcos, peru. Pp.376.
36. Fernades valderrama, oscar "**scientific research i**", lima – peru.
37. Rodriguez sosa, miguel a. **"scientific research theory and methods",** editores pacífico. Pp.233.
38. Hilario valenzuela, pelayo "**operational criteria to make the thesis",** first edition, 2000, ayacucho – peru. Pp. 152.