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Ecological Degradation and Legal Gaps in Lake Patarcocha: Comprehensive Analysis and Normative Alternatives for its Recovery in Pasco

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ABSTRACT: Lake Patarcocha is undergoing severe ecological degradation caused by urban discharges, solid waste, and mining liabilities. This study examines the environmental and legal challenges that hinder its protection, using a mixed methodology: documentary analysis of Peru's regulatory framework and a quantitative survey applied to 20 local residents. Findings reveal a high perception of pollution and a significant correlation between ecological deterioration and legal gaps ($\rho = 0.723$; $p < 0.01$). The research also identifies structural weaknesses in state oversight, limited institutional coordination, and insufficient environmental liability mechanisms. An integral regulatory framework is proposed, including the recognition of rights for the lake, the appointment of an ecological legal representative, and an interinstitutional governance system. The study concludes that restoring Lake Patarcocha requires reforming current legislation and implementing sustainable public policies with active community participation.

1. INTRODUCTION

The high Andean lagoons are ecosystems of great ecological fragility, but of strategic importance for water regulation, the storage of water for human consumption, the sustainability of socioeconomic activities and the preservation of native biodiversity. Their location in high mountain areas, in extreme climatic conditions and sensitive hydrological dynamics, makes them highly vulnerable systems to variations in water quality, anthropic pressures and climatic disturbances. (García & López, 2022). In Peru, these ecosystems have acquired special relevance due to rapid urban growth, the expansion of open-pit metal mining and insufficient sanitation infrastructure, factors that intensify environmental deterioration. (Delgado & Jiménez, 2021).

In this context, the Patarcocha Lagoon, located in the urban center of Cerro de Pasco, at 4380 m a.s.l., represents one of the most critical cases of ecological degradation of lake ecosystems in the country. Its deterioration is due to decades of untreated domestic discharges, informal solid waste management and lack of adequate technologies for the treatment of urban and industrial effluents. (Gómez & Rivera, 2022). These processes have generated eutrophication, loss of aquatic species, alteration of physical-chemical parameters of the water and direct effects on public health, such as nauseating odors, proliferation of vectors and exposure of the population to heavy metals. (Folchi, 2001; Becerra & Contreras, 2023).

The Peruvian regulatory framework recognizes the State's obligation to protect the environment and guarantee sustainable management of water resources. This is reflected in the Political Constitution of Peru (arts. 2.22, 7-A, 66–68), in the General Environmental Law, Law No. 28611, in the Water Resources Law, Law No. 29338, and in Law No. 30653, which declared the recovery of the Patarcocha Lagoon to be of public necessity. Likewise, the Environmental Quality Standards, ECA, the

Maximum Permissible Limits, LMP, the National System of Environmental Evaluation and Inspection, SINEFA, and the Mine Closure Plans, should operate as tools of the ecological protection system. However, evidence shows that these regulations lack real effectiveness due to institutional limitations, poor inter-institutional coordination, absence of effective sanctions, and budgetary restrictions that prevent continuous monitoring. (Dourojeanni, 2001; Gudynas, 2020; Andrade & Gutiérrez, 2020).

To empirically know the citizen perception and the level of environmental deterioration in the Patarcocha Lagoon, we have applied a psychometric questionnaire to 20 inhabitants of the area of influence. The results show a significant correlation between perceived environmental deterioration and the existence of legal and institutional gaps, ($\rho = 0.723$; $p < 0.01$), which confirms that ecological collapse is not only a physical phenomenon, but also a legal and political one.

Faced with this situation, this research proposes a normative proposal, based on ecological justice and the recognition of the rights of nature, aimed at overcoming the limitations of classical environmental law, through the creation of a legal representative of the ecosystem and a participatory governance system. The adoption of an ecocentric approach will guarantee the protection of the lagoon not only for its social utility, but also for its intrinsic value and its leading role in the natural balance. (Gudynas, 2011; Arbeláez & Pérez, 2022).

This research contains the description of the general context, the research problem, the background, the hypotheses, the objectives and the importance of the study, emphasizing that the crisis of the Patarcocha Lagoon highlights structural failures of Peruvian environmental governance. Its recovery requires the implementation of a solid legal and institutional framework that ensures the sustainability of the ecosystem. (Boelens et al., 2021).

Despite the existence of environmental regulations and Law No. 30653, approved by the Congress of the Republic on July 19, 2017, which declares the recovery, conservation and protection of the Patarcocha Lagoon, located in the province, department and region of Pasco, Peru, of national interest and public necessity, urban dumping and the accumulation of solid waste reflect insufficient state oversight and the absence of integrated management of the resource water. This affects the quality of the water, the biodiversity and the health of the population of Cerro de Pasco. In this context, we ask the following question: What are the main legal and environmental factors that have prevented the effective management and sustainable recovery of the Patarcocha Lagoon, despite having a Law that protects it, and how do these factors affect water quality, biodiversity and the health of the population?

The objectives of the study are the following: to identify the legal and environmental challenges that hinder the sustainable management and recovery of the Patarcocha Lagoon, to propose legal and administrative mechanisms that guarantee the conservation of the ecosystem and the protection of the health of the population; to analyze the applicable environmental regulatory framework and evaluate the effectiveness of the institutions responsible for its implementation and oversight; to identify the responsibilities legal and administrative of the actors involved in the pollution and degradation of the ecosystem; to evaluate citizens' perception of environmental damage and the effectiveness of the current legal framework and to propose innovative regulatory mechanisms based on ecological justice and the rights of nature. (Ordinola, 2018; Mamani & Pinto, 2020).

The Patarcocha Lagoon is a high Andean ecosystem of great ecological importance and high ecological, health and social value. The progressive damage affects biodiversity, water quality and the health of the population. The presence of pollutants, solid waste and decomposing organic matter have generated loss of species, alteration of physical-chemical parameters of the water, proliferation of pathogenic bacteria and exposure to heavy metals. (Fernández & Solís, 2020). From a public health perspective, the damage contributes to the increase in respiratory, dermatological, gastrointestinal diseases and discomfort derived from toxic gases that violate, all of them, the fundamental rights recognized by Peruvian legislation. (Reyes-Bell & Ludeña, 2021).

The importance of the study lies in the fact that it identifies regulatory and institutional gaps that allow the persistence of environmental damage; it provides empirical evidence through a survey applied to local inhabitants; it proposes innovative legal mechanisms such as the recognition of rights to the lagoon and the creation of a legal representative of the ecosystem; and it offers a replicable model for other affected high Andean lagoons. (Acosta & Martínez, 2021). The scope of research is key to strengthening public policies, improving environmental governance, and promoting sustainable ecological recovery strategies.

The hypothesis of this research states that the persistence of the environmental deterioration of the Patarcocha Lagoon is mainly due to regulatory gaps, deficient oversight and limited inter-institutional governance, which prevents effective management of the ecosystem and affects water quality, biodiversity and the health of the population. It is argued that the

incorporation of ecocentric mechanisms, such as respect for the rights of nature and the designation of a legal representative of the ecosystem, are viable alternatives to improve management and guarantee its sustainable recovery.

The specific hypotheses state the following: The current regulatory framework presents gaps and contradictions that hinder the effective protection of the Patarcocha Lagoon. Weak environmental oversight and overlapping competencies between public entities generate inefficiency in ecosystem management. There is a significant correlation between citizens' perception of environmental deterioration and the identification of legal and institutional inadequacies. The adoption of ecological justice mechanisms, such as the recognition of ecosystem rights, would strengthen governance and contribute to the sustainable recovery of the lagoon. (Swyngedouw, 2015; Palomino & Saldaña, 2023).

2. MATERIALS AND METHODS

In the study, a mixed method has been used, with a quantitative predominance, complemented by qualitative documentary analysis. A cross-sectional non-experimental design was adopted, observing and analyzing environmental and legal variables without manipulation, which allowed evaluating, at a given time, the citizen perception of the environmental deterioration of the Patarcocha Lagoon and the regulatory gaps in its management. The approach was descriptive-correlational, which identified patterns of perception and the relationship between environmental damage and legal deficiencies. It was complemented by a review of the Peruvian regulatory framework of documents such as the General Environmental Law, the Water Resources Law, Law No. 30653, ECA, LMP, OEFA and ANA regulations, as well as the application of the Leopold Matrix to identify environmental impacts associated with urban discharges, solid waste and mining liabilities.

2.1. Population and sample for the qualitative study

Population. For the documentary analysis, we reviewed 30 current national, regional and local environmental regulations. A sample was not selected because a census of the norms was carried out that included all the norms of greatest legal relevance.

2.2. Population and sample for the quantitative study

Population: Inhabitants of the area of influence of the Patarcocha Lagoon. Sample: 20 people, selected by non-probabilistic convenience sampling, with a minimum residence of one year in the area of influence.

2.3. Data collection instruments

A Likert-type questionnaire was used, developed specifically for the research, composed of four dimensions: a. Environmental deterioration, b. Legal challenges, c. Proposal of legal and administrative mechanisms, and d. Impact on public health. Each item was rated on a scale of 1 to 5, with 1 being considered to strongly disagree and 5 to be in complete agreement.

The questionnaire was validated, in the opinion of experts, by three specialists in environmental law and water resources management, who evaluated the clarity, relevance and internal coherence of the items. The validity of the content was evaluated by specialists in environmental law and water ecosystem management. Reliability was calculated using Cronbach's alpha coefficient, obtaining satisfactory results. For Variable 1: Environmental damage: $\alpha = 0.81$. For Variable 2: Legal non-compliance: $\alpha = 0.77$.

2.4. Data analysis

For data analysis, we applied descriptive statistical techniques such as frequencies, means and standard deviations, which allowed us to characterize the responses of the participants. To determine the relationship between environmental deterioration and legal challenges, Spearman's correlation coefficient was used, appropriate for ordinal variables and small samples. The analysis showed that: $\rho = 0.723$, and $p < 0.01$; which indicates a strong and statistically significant positive correlation. The documentary analysis made it possible to compare the empirical findings with the current regulations, identifying legal gaps and opportunities for reform proposals. The data were processed using descriptive statistics and Spearman's correlation coefficient, suitable for ordinal variables.

For the documentary analysis, a matrix was developed that allowed the systematic analysis of current environmental standards. It also allowed us to examine institutional responsibilities, legal obligations, and regulatory gaps that affect ecosystem recovery.

2.5. Statistical analysis

The data collected were processed, first, through descriptive statistics of frequencies, percentages, measures of central tendency, and then the application of inferential statistics instruments. To evaluate the relationship between perceived environmental deterioration and regulatory gaps, Spearman's rho coefficient was used, obtaining a significant correlation ($\rho = 0.723$; $p < 0.01$).

2.6. Documentary analysis

The documentary analysis was carried out following criteria of regulatory coherence, legal relevance, institutional competencies and effectiveness in environmental control. The Leopold Matrix made it possible to link polluting activities and types of direct and indirect ecological impact on the lagoon.

3. RESULTS AND DISCUSSION

3.1. Perception of environmental deterioration

Table 1. Dummy Experimental Data

Item	Description	Mean
P1	Visible and progressive pollution.	4.8
Q2	Decreased water quality.	4.7
Q3	Presence of solid or chemical waste.	4.6
Q4	Reduction of aquatic species.	4.5
Q5	Decrease in plant biodiversity.	4.5
Q6	Loss of self-regeneration capacity.	4.6
P7	Human activity as the main cause.	4.7
P8	Social recognition of deterioration.	4.8
P9	Affected by rainfall/climate changes.	4.4
P10	Inaction of local authorities.	4.7
Overall average	Overall level of perceived impairment.	4.63 (Very high)

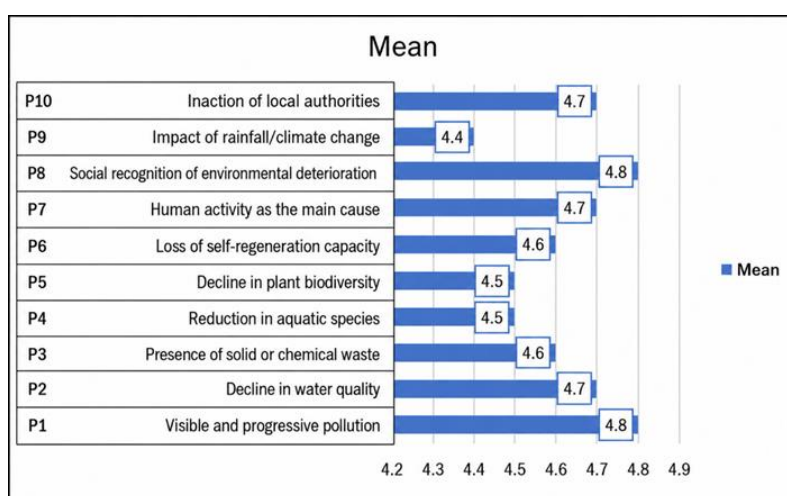


Figure 1. Perception of the environmental deterioration of the Patarcocha Lagoon

Interpretation. The results of Table 1 show a highly critical citizen perception regarding the environmental status of the Patarcocha Lagoon, with a general average of 4.63, classified as very high. The highest scores correspond to visible pollution, (4.8), and social recognition of deterioration, (4.8), indicating that ecosystem degradation is widely observable and recognized by the population. Likewise, the decrease in water quality (4.7), the presence of solid or chemical waste (4.6), and the loss of self-regeneration capacity (4.6) reflect that the impact is not superficial, but structural and sustained over time. The reduction of aquatic and plant species, (4.5), confirms the alteration of the ecological balance. Similarly, the population attributes the deterioration mainly to human activities, (4.7), and significant inaction by local authorities is perceived, (4.7), which suggests institutional responsibility for the persistence of the problem. Together, these indicators consistently demonstrate that the lagoon is going through a critical process of environmental deterioration whose magnitude is unanimously recognized by the respondents.

3.2. Impact on public health

There is concern about diseases associated with water pollution.

Table 2. Perception of the impact on public health associated with the contamination of the Patarcocha Lagoon

Item	Description	Mean
S1	Pollution directly affects people's health.	4.7
S2	Existence of diseases linked to contaminated water.	4.6
S3	Children and the elderly are the most affected.	4.8
S4	There are studies that link public health and pollution.	4.5
S5	Health authorities have not acted effectively.	4.6
S6	Little public information on health risks.	4.5
S7	Water should not be used for daily activities or for agriculture.	4.8
S8	Urgency of preventive health measures.	4.7
S9	Health centers without protocols for diseases due to contaminated water.	4.6
S10	Increase in respiratory or dermatological problems in the population.	4.7
Overall average	Level of perceived health impact.	4.65 (Very High)

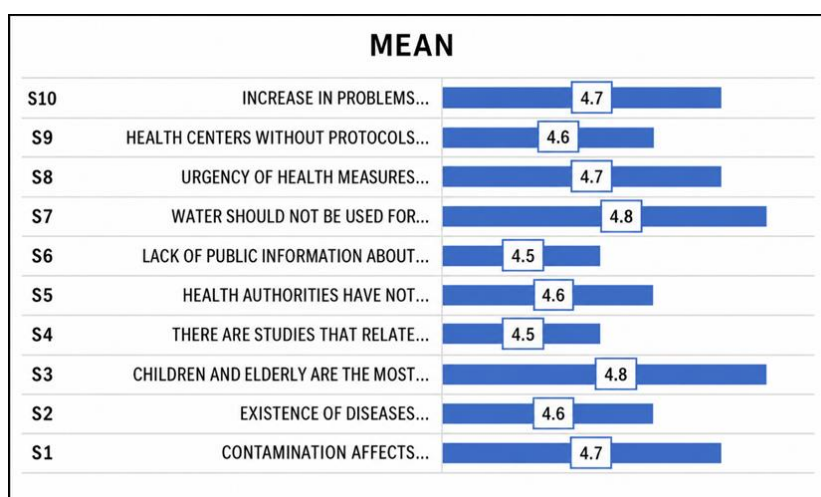


Figure 2. Perception of the impact on public health associated with the contamination of the Patarcocha Lagoon

Interpretation. The results on the health impact associated with the contamination of the Patarcocha Lagoon show an extremely high level of concern on the part of the population, (general average = 4.65), which confirms that the environmental crisis transcends the ecological and is consolidated as a public health problem. The perception that contamination directly affects health, (S1 = 4.7), and that there are diseases linked to contaminated water, (S2 = 4.6), show that the community identifies a clear relationship between poor water quality and health risks. The vulnerability of children and the elderly, young people and pregnant mothers (S3 = 4.8) is especially noteworthy, as they are the most exposed to infections, respiratory disorders and dermatological conditions, which correlates with epidemiological evidence in areas of water pollution. The population also perceives that the health authorities have not acted effectively, (S5 = 4.6), and that there is little public information on the risks, (S6 = 4.5), which reflects serious deficiencies in risk communication and epidemiological surveillance. The statement that the water of the lagoon should not be used for daily or agricultural activities, (S7 = 4.8), reveals a social recognition of the imminent danger posed by this polluted body of water. Likewise, the urgency of preventive health measures, (S8 = 4.7), and the lack of specific protocols in health centers, (S9 = 4.6), indicate that the local health system does not have adequate tools to deal with pathologies derived from exposure to aquatic pollutants. Finally, the perceived increase in respiratory and dermatological diseases, (S10 = 4.7), confirms that the contamination of the Patarcocha Lagoon is generating real and growing impacts on the health of the population. Taken together, these results reveal a critical scenario where environmental degradation translates into severe health risks, which demand the immediate intervention of the health sector, the implementation of prevention measures, and the articulation of integrated environmental and health policies. (Castro & Zamora, 2023; Poma & Aguilar, 2021; Sánchez & Hurtado, 2020).

3.3. Legal challenges identified

The results show an equally high perception that pollution is aggravated by a lack of specific regulations, deficient oversight and gaps in environmental responsibility.

Table 3. Perception of legal challenges in the management of the Patarcocha Lagoon

Item	Description	Mean
L1	Lack of specific regulations for Patarcocha.	4.6
L2	Failure to comply with environmental regulations.	4.5
L3	Insufficient oversight.	4.7
L4	Legal loopholes that prevent effective sanctions.	4.6
L5	Lack of mechanisms for autonomous defense of the ecosystem.	4.7
L6	Insufficient rules to prevent further damage.	4.5
L7	Scarce citizen participation in current regulations.	4.4
L8	Lack of legal recognition as a subject of rights.	4.8
L9	Absence of specific legal protection for loopholes.	4.6
L10	Non-deterrent sanctions against pollution.	4.6
Overall average	Global level of perceived legal challenges.	4.60

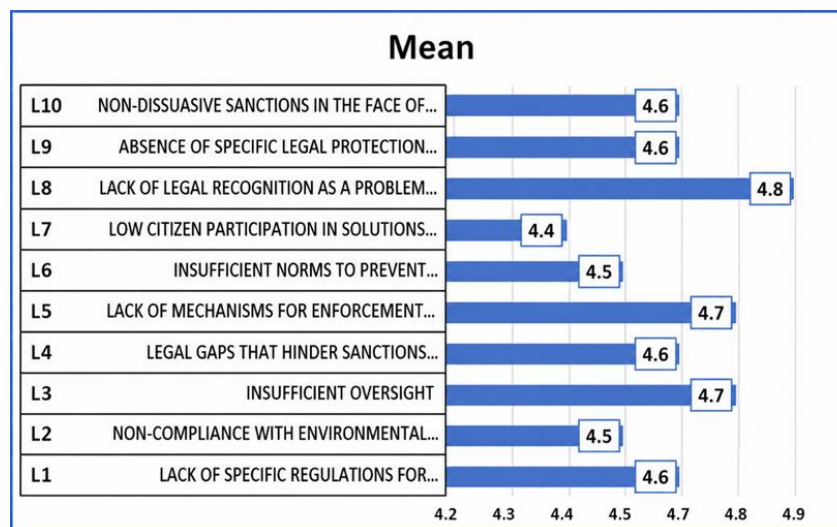


Figure 3. Perception of legal challenges in the management of the Patarcocha Lagoon

Interpretation. Citizen perception of the legal challenges that affect the management of the Patarcocha Lagoon is significantly high, with an overall average of 4.60, which shows a solid consensus regarding the ineffectiveness of the current legal framework. The participants identify that there are no specific and operational regulations for the lagoon, (L1 = 4.6), to which is added a systematic non-compliance with existing environmental standards, (L2 = 4.5), and insufficient oversight by the competent entities, (L3 = 4.7), which allows the continuity of polluting activities. Likewise, legal gaps that prevent the application of effective sanctions (L4 = 4.6), and the absence of legal mechanisms that allow an autonomous defense of the ecosystem, (L5 = 4.7), elements that severely limit the institutional capacity of the State to act in a timely and prompt manner, are recognized. It is perceived that current regulations are insufficient to prevent further damage, (L6 = 4.5), and that citizen participation in the formulation and monitoring of regulations is scarce, (L7 = 4.4), which weakens environmental governance. The highest score corresponds to the lack of recognition of the lagoon as a subject of rights, (L8 = 4.8), reflecting citizen support for innovative legal approaches that allow direct legal actions in favor of the ecosystem. In addition, the absence of a specific legal protection regime for lagoons (L9 = 4.6), and the ineffectiveness of current environmental sanctions, perceived as non-deterrent, (L10 = 4.6) are identified. Taken together, these results show that the ecological crisis of the Patarcocha Lagoon responds not only to environmental dynamics, but also to structural failures of the legal and institutional system, whose strengthening is essential to guarantee a sustainable recovery of the lake ecosystem. (Herrera & Mamani, 2023).

3.4. Legal and administrative proposals

Participants show a high level of support for structural legal reforms.

Table 4. Legal and administrative proposals for the protection of the Patarcocha Lagoon

Item	Description	Mean
R1	Recognition of legal personality for the lagoon.	4.7
R2	Creation of regional and municipal ordinances.	4.7
R3	Implementation of community policing with legal backing.	4.6
R4	Designation of a legal representative of the ecosystem.	4.8
R5	Strengthening environmental justice.	4.7
R6	Creation of an environmental fund for the recovery of Patarcocha.	4.7
R7	Collaboration between the State, companies and communities.	4.6

R8	Incorporation of ancestral and communal knowledge.	4.5
R9	Inclusion of the ecological justice approach in legislation.	4.8
R10	National Law for the Recognition of Water Ecosystems.	4.8

Overall average = 4.69 (Very high)

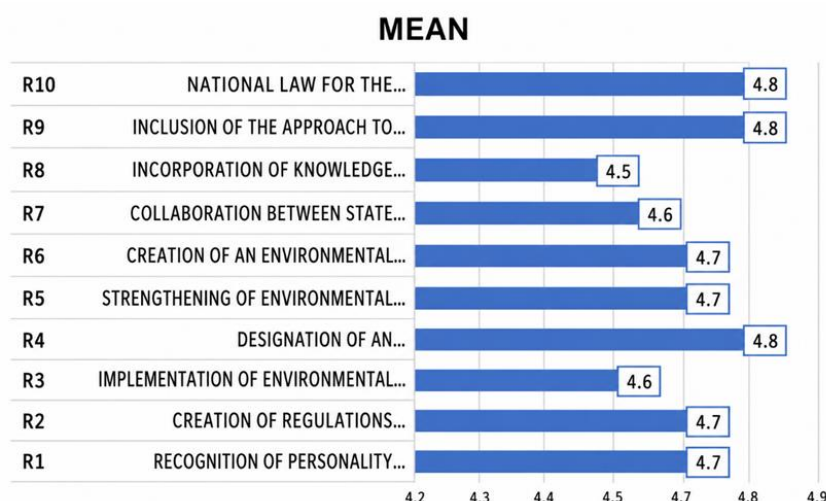


Figure 4. Legal and administrative proposals for the protection of the Patarcocha Lagoon

Interpretation. The results on the legal and administrative proposals reveal strong citizen support for profound reforms aimed at the protection of the Patarcocha Lagoon, reaching an overall average of 4.69, one of the highest in the study. There is a strong acceptance of the recognition of the legal personality of the lagoons (R1 = 4.7), which shows the perception that traditional approaches to environmental law have been insufficient and that it is necessary to provide the ecosystem with autonomous legal tools for its defense, as is already the case in countries such as Ecuador, Colombia and New Zealand. (O'Donnell & Talbot-Jones, 2018). Similarly, citizens support the creation of specific regional and municipal ordinances, (R2 = 4.7), reflecting the need for more operational and binding local regulations. Likewise, the value of community surveillance with legal support is recognized, (R3 = 4.6), which underscores the importance of social control in contexts where state oversight is limited. The highest score corresponds to the appointment of a legal representative of the ecosystem, (R4 = 4.8), reinforcing the idea that the ecosystem should have an institutional voice that acts in defense of its interests. There is also strong support for the strengthening of environmental justice, (R5 = 4.7), and for the creation of an environmental fund exclusively for the recovery of Patarcocha, (R6 = 4.7), which shows the urgency of sustainable financial resources. Collaboration between the State, companies and communities, (R7 = 4.6), is perceived as a key element to guarantee efficient environmental governance, while the incorporation of ancestral knowledge, (R8 = 4.5), highlights the recognition of the role of local communities in ecological management. Finally, the inclusion of the ecological justice approach in Peruvian legislation (R9 = 4.8) and the approval of a national law on rights for water ecosystems (R10 = 4.8) confirm a clear trend towards advanced environmental protection models, where nature is recognized as a subject of rights and protected through robust, participatory and preventive legal instruments. Taken together, these results demonstrate the urgent and widely supported need to transform the current legal framework to ensure the effective and sustainable protection of the Patarcocha Lagoon. (Huerta & Chávez, 2021).

3.5. Correlational analysis

To analyze the relationship between the main variables, Spearman's correlation coefficient, suitable for ordinal data, was applied.

Table 5. Legal and administrative proposals for the protection of the Patarcocha Lagoon

Correlated variables	Spearman coefficient (ρ)	Significance (p)
Environmental deterioration ↔ Legal challenges	0.723	< 0.01

Interpretation. The correlation obtained between the environmental damage of the Patarcocha Lagoon and the perceived legal challenges, ($\rho = 0.723$; $p < 0.01$), indicates a statistically significant, strong and positive relationship: the greater the ecological deterioration, the greater the perception of regulatory gaps and legal deficiencies in environmental management. This relationship suggests that the problem is not explained only by natural factors or direct pollutants, but by an insufficient legal and institutional framework to prevent, monitor and sanction pollution.

The statistical significance ($p < 0.01$) reinforces that this finding is not the product of chance, confirming that regulatory gaps and institutional weakness have concrete effects on the degradation of the lagoon. Empirical evidence shows that the absence of oversight and the dispersion of competencies allow dumping and waste to continue affecting the ecosystem without consequences for polluters.

Finally, these results validate the need to simultaneously address environmental issues and legal gaps to achieve a sustainable recovery of the lagoon. Comprehensive regulatory reform, the creation of innovative legal mechanisms, and the implementation of participatory environmental governance systems that reduce the gap between the norm and its compliance are required, recognizing that environmental deterioration and legal challenges are interdependent variables that explain the current ecosystem crisis. (Ibáñez & Quinteros, 2023; Valdez & Cutipa, 2022).

Table 6. Classification of levels by variable

Variable	Theoretical range	Average obtained	Classification
Environmental deterioration	1 – 5	4.63	Very high deterioration
Legal challenges	1 – 5	4.60	Very high legal deficiency
Policy proposals	1 – 5	4.69	Very high social support
Health Impact	1 – 5	4.65	Critical health risk

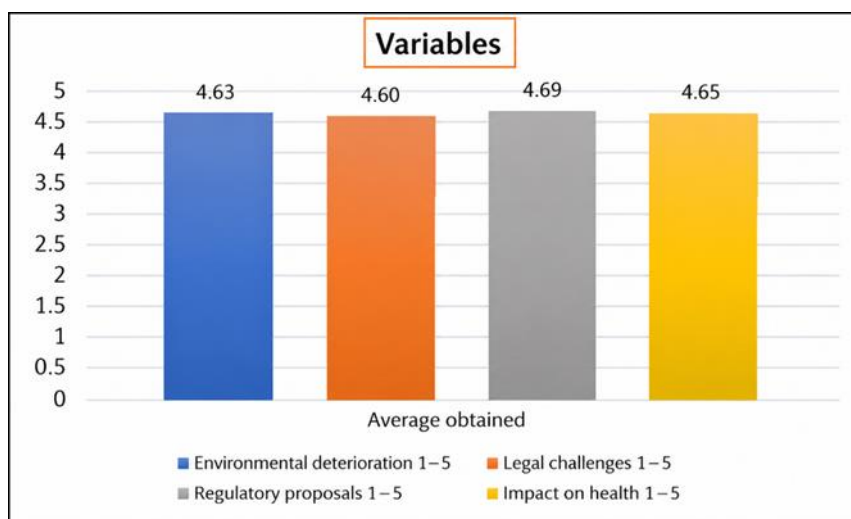


Figure 5. Classification of levels by variable

Interpretation. The general evaluation shows that the crisis of the Patarcocha Lagoon is severe, multidimensional and persistent, simultaneously affecting the environment, institutionality and public health. Environmental deterioration obtained a very high average, (4.63), which confirms an ecosystem subjected to sustained pollution, accelerated loss of biodiversity and absence of effective recovery measures. In addition, legal challenges reached 4.60, reflecting that the population recognizes serious regulatory and institutional failures, consistent with the legal analysis carried out: laws exist, but they are not applied, lack operational instruments and do not generate real results, which shows a vacuum of environmental governance. (Castro & Zamora, 2023).

Likewise, the health impact obtained 4.65, demonstrating that pollution directly affects the health and well-being of the population due to the lack of protocols and institutional responses. The high support for regulatory proposals, (4.69), confirms that citizens demand structural reforms that include effective oversight, citizen participation, and innovative legal mechanisms. Overall, the data show that Patarcocha's problem is environmental, legal and institutional at the same time, which requires a comprehensive approach based on regulatory reforms, institutional strengthening and public policies that guarantee an effective and immediate recovery. (Limachi & Salinas, 2022).

3.6. Comparative legal analysis between Law No. 30653 and the ideas behind the bill for the effective recovery of the Patarcocha Lagoon

Law No. 30653 was approved in 2017 with the aim of declaring the recovery, conservation and enhancement of the Patarcocha Lagoon of national interest and public necessity. However, despite its symbolic importance, the regulation did not produce real effects on the environmental situation of the ecosystem. The comparative analysis between this law and the strong ideas that we propose to formulate the Bill for the effective recovery of the lagoon, reveals, in a clear and structural way, the reasons why the original norm was insufficient and the way in which the proposal fills its gaps, guaranteeing effective state intervention.

Nature of the norm: from the declarative to the operational. Law No. 30653 is strictly declaratory in nature. It limits itself to recognizing the environmental importance of the Patarcocha Lagoon, without establishing obligations, procedures, management instruments, responsibilities or deadlines. This type of norms has a political and programmatic character, but they do not legally bind public entities, which is why their compliance depends exclusively on the administrative will. (Pérez & Rojas, 2022). The strong ideas that we present to formulate the Bill for the protection of the lagoon, transform the declarative into an operational and binding regulatory framework. They define mandatory procedures, create concrete instruments, such as the Comprehensive Plan for the Recovery of the Patarcocha Lagoon, PIRLP, set peremptory deadlines, establish direct institutional responsibilities and articulate a permanent financing system. This amendment converts a merely declaratory mandate into an enforceable legal regime, which obliges the institutions to act and allows compliance to be assessed. (Ramos & Cuya, 2022).

Budget: from the absence of financing to a mandatory Special Fund. One of the main reasons why Law 30653 was never executed is that it did not allocate a budget. By not establishing a budget item or creating a specific fund, it depended on occasional and voluntary resources, which in practice meant that no entity allocated resources for its implementation. The ideas force to formulate the Bill overcomes this gap through the creation of the Special Fund for the Recovery of Patarcocha, FERPA. This fund is not only financed with resources from the MEF, canon, canon and international cooperation, but also incorporates as a permanent source of financing the environmental fines applied by the OEFA. In this way, the standard generates financial sustainability and ensures that environmental recovery has continued economic support. In legal-administrative terms, budget allocation is the essential condition for the enforceability of any environmental policy. For this reason, the proposal corrects the structural deficit of the current law.

Institutional leaders: from lack of definition to clear and binding governance. Law 30653 did not define which institution should lead the recovery of the lagoon, which entities should supervise, which should remedy, or how the State's action should be coordinated. This indeterminacy generated a vacuum of authority that prevented real achievements. None of the entities assumed direct responsibility and, at the same time, all claimed not to have express competence. The ideas force to formulate the Bill correct this shortcoming by creating an articulated governance system. It assigns specific competencies to MINAM, ANA, OEFA, Regional Government of Pasco and Provincial Municipality of Pasco. Each institution will have verifiable obligations: MINAM prepares and approves the PIRLP; the ANA regulates and controls discharges; the OEFA supervises and sanctions; the Municipality manages waste and controls the environment; DIRESA implements health surveillance. This order is consistent with the constitutional principle of the prohibition of arbitrariness and with the duty of State coordination contemplated in the Law on General Administrative Procedure. (Morales, 2016).

Intervention plan: from non-existence to a mandatory technical instrument. Law 30653 did not contemplate the creation of an intervention plan nor did it define environmental actions, phases, strategies or goals. This absence of planning made it impossible to implement any articulated action and left recovery in the hands of isolated initiatives, without continuity or follow-up. The ideas behind the formulation of the Bill introduces the PIRLP, a mandatory document that includes a detailed environmental diagnosis, elimination of discharges, remediation of sediments, restoration of flora and fauna, treatment infrastructure, sanitary surveillance, physical-financial schedule and measurable goals. This technical plan converts the

declaration of public interest into a rigorous process of environmental recovery, as required by the General Environmental Law (arts. 6, 8, 19 and 21). In addition, it establishes a specific deadline for its approval, avoiding administrative delays.

Sanctioning regime: from total emptiness to a comprehensive system of responsibility. Law 30653 did not establish sanctions. In legal terms, a rule without consequences in the event of non-compliance lacks binding effectiveness. This vacuum encouraged the continuity of polluting practices and institutional omission, since there were no consequences for breaking the law. (Acosta, 2017). The ideas behind the formulation of the Bill incorporate a robust sanctioning regime that includes very serious infractions such as dumping, manipulation of reports, obstruction of inspection, recidivism, and economic, administrative, civil and criminal sanctions. It also applies the principle of strict liability, consistent with Article 71 of the General Environmental Law. This incorporation raises the standard of environmental protection and creates real incentives for compliance.

Environmental monitoring: from omission to a permanent and public system. Law 30653 did not require monitoring or establish environmental indicators. As a result, no public information was generated to evaluate progress or setbacks. The ideas behind the formulation of the Bill establish mandatory quarterly monitoring of water, sediments, flora, fauna and health risks, with mandatory publication. Environmental transparency is an indispensable element for citizen oversight and decision-making. Likewise, an Early Warning System is implemented, aligned with international risk management standards. (Maldonado et al., 2020; Ríos & Carbajal, 2022).

Sanitary measures: from omission to the protection of public health. Law 30653 did not consider the health dimension, despite the evidence of diseases linked to pollution. The ideas behind the formulation of the Bill incorporate DIRESA obligations, health protocols, health prohibitions and prevention mechanisms, consistent with the constitutional right to health.

Table 7. Comparative legal architecture for the recovery of Lake Patarcocha

Dimension	Law No. 30653	Proposed reform	Expected legal effect
Legal status	Declares national interest and public necessity	Recognizes enforceable ecological duties and ecosystem representation	Moves from declarative recognition to enforceable protection
Governance	No detailed permanent governance architecture	Assigns roles to MINAM, ANA, OEFA, regional and municipal authorities	Reduces institutional fragmentation and clarifies accountability
Recovery planning	No mandatory integrated recovery plan	Creates a binding recovery plan with goals, deadlines and indicators	Makes recovery measurable and subject to monitoring
Financing	No dedicated funding mechanism	Creates a dedicated recovery fund with identified sources	Improves financial continuity of restoration actions
Monitoring	No permanent monitoring system specified	Requires periodic environmental and health monitoring with public reporting	Strengthens transparency, prevention and citizen oversight
Participation	No detailed participation mechanism	Integrates community participation and local knowledge	Improves legitimacy and social control of environmental governance

3.4 Discussion

The results obtained show that the Patarcocha Lagoon is going through a severe environmental crisis, of a legal, educational, political and cultural nature, characterized by high levels of pollution, loss of biodiversity and health effects on the population. This finding coincides with previous studies on high Andean ecosystems, which highlight their high vulnerability to anthropic pressures and the lack of effective management of water resources. (López & Molina, 2021). The average score of 4.63 in environmental deterioration reflects that the population perceives a critical and sustained state of degradation, which is

consistent with technical reports from MINAM and OEFA that for years have documented discharges, accumulation of waste and the presence of heavy metals in bodies of water in Pasco. (López, A., & Molina, R., 2021; Vela, R., & Escalante, J. 2021).

The result of 4.60 in the variable of legal challenges confirms that the ecological crisis is closely linked to the inefficiency of the legal and institutional framework. The public perception of weak oversight, legal loopholes, lack of effective sanctions, and absence of specific rules for urban lagoons reflects a recurring problem in Peruvian environmental law: the existence of rules, but without an articulated implementation or compliance mechanisms that guarantee real effectiveness. This coincides with the approaches of Bustamante (2013), Morales (2016) and Ordinola (2018), who warn about the gap between regulation and enforcement in environmental protection.

3.4.1. Qualitative interpretation of the Leopold Matrix

The matrix shows, firstly, that untreated urban dumping and inadequate disposal of solid waste generate high and direct impacts on water quality and aquatic and riparian biodiversity, configuring a picture of structural deterioration of the ecosystem. These impacts are aggravated by the presence of mining liabilities in the basin, whose effects on sediments and the bioaccumulation of heavy metals are classified as high and direct, with an indirect projection on the health of the exposed population. (Becerra & Contreras, 2023).

In addition, the absence and insufficiency of wastewater treatment infrastructure (WWTP) and the deficient management of solid waste, despite being regulated by the General Environmental Law, the Water Resources Law, PIGARS and municipal ordinances, translate into high and indirect impacts on water quality, biodiversity and public health. The Leopold Matrix shows that the problem is not limited to specific events, but to a structurally deficient model of urban management and sanitation, which allows polluting contributions to continue to be produced. (Ortiz & Delgado, 2021).

The matrix shows that weak environmental oversight and the lack of effective application of Law No. 30653 and environmental emergency ordinances produce high and indirect impacts on all the components evaluated, especially in the dimension of governance and regulatory compliance. In legal terms, this confirms that the gap between the regulatory design and its execution constitutes a factor of environmental impact in itself: the ineffectiveness of the inspection, the dispersion of competencies and the absence of effective sanctions intensify and prolong the deterioration of the Patarcocha Lagoon, even though the legal framework, established by the Peruvian Political Constitution, Law 28611, Law 29338, Law 30653, the ECA for water and local ordinances, offer sufficient tools to prevent and reverse it if they were correctly applied.

3.4.2. Contributions of the study to legal sciences and society

This study makes significant contributions both to the field of legal sciences and to society. In the legal field, the article contributes to rigorously identifying the regulatory gaps, the limitations of Peruvian environmental law and the institutional deficiencies that have allowed the degradation of the Patarcocha Lagoon to continue for decades without an effective response. By proposing alternatives such as granting legal personality to the ecosystem, the creation of a legal representative and the integration of the ecological justice approach, the study broadens the conceptual horizon of environmental law and introduces more advanced protection mechanisms. (O'Donnell & Talbot-Jones, 2018). In this way, the article provides theoretical and empirical bases that can serve as a basis for future regulatory reforms and academic research.

From the social dimension, the research makes visible how the environmental crisis of Patarcocha directly affects the health, well-being and quality of life of the population, especially vulnerable groups. The statistical evidence presented allows us to understand that environmental degradation is also a health and social problem, which reinforces the need for a more solid and articulated state response. (Quispe & Salazar, 2023). The study contributes to society by generating reliable information, by strengthening citizen participation through the incorporation of local perceptions and by offering viable proposals that can guide sustainable public policies in Pasco and in other territories of Peru with similar problems. Overall, the article constitutes a comprehensive contribution that combines theory, empirical evidence, and regulatory proposals aimed at the public interest and the effective protection of ecosystems. (Martínez-Alier, 2019; Yupanqui & Torres, 2023).

3.4.3. Limitations of the study

The findings should be interpreted in light of the small, non-probabilistic sample of 20 residents and the cross-sectional design. The survey captures perceived environmental and legal conditions rather than direct measurements of water quality, pollutant

concentrations or health outcomes. Future studies should integrate longitudinal environmental monitoring, laboratory water-quality data, geospatial analysis and larger probabilistic samples to strengthen causal inference and external validity.

4. CONCLUSION

FIRST. The Patarcocha Lagoon is in a situation of environmental and structural collapse, characterized by persistent pollution, the presence of solid and liquid waste, affecting water quality, loss of biodiversity and direct risks to the health of the population. This reality has been confirmed both by the normative analysis and by the citizen perception collected through the quantitative study.

SECOND. The Peruvian legal system has a robust regulatory framework at the formal level, which is headed by the Political Constitution, art. 2.22, arts. 66–68, art. 7-a; the General Law of the Environment, Law No. 28611; the Water Resources Law, Law No. 29338; Law No. 30653; the ECAs for water, D.S. No. 004-2017-MINAM; the actions of the ANA and various municipal ordinances. However, there is a critical gap between the standard and its effective implementation.

THIRD. Law No. 30653, although it is a specific legal milestone for the Patarcocha Lagoon, has not been able to reverse the environmental deterioration due to insufficient oversight, weak inter-institutional coordination, the limited technical and budgetary capacity of public entities, the lack of rigorous follow-up to the PROPATARCOCHA Multi-Stakeholder Committee and the absence of effective citizen participation.

FOURTH. The management of solid and liquid waste in the province of Pasco continues to be the central factor of the problem, despite the existence of PIGARS, Ordinance No. 009-2015-CM/HMPP, and regulations such as Ordinance No. 004-2021-CM/HMPP. The insufficient implementation, inspection and environmental education causes waste to continue to reach the lagoon and aggravate its deterioration.

FIFTH. The declaration of an environmental emergency through Ordinance No. 058-2023-CM/HMPP is an important step forward, but its temporary nature, insufficient resources and lack of a long-term strategy reveal that it is a necessary but insufficient measure if it is not integrated into a structural policy of recovery and ecological governance.

SIXTH. Sectoral environmental quality standards, such as the ECA for water, LMP, MINAM and ANA directives, provide technical and legal tools to control the pollution of Patarcocha, but their compliance is weak, which produces failures in the supervision, in the sanctioning regime and in the demand for environmental responsibility from polluting actors.

SEVENTH. The quantitative study carried out confirms the citizens' perception of the ecological crisis and the legal vacuum, showing high levels of agreement regarding the deterioration of the lagoon, the insufficiency of the regulations and the lack of a statistically reliable instrument by the authorities and a strong and significant positive correlation between environmental deterioration and legal challenges.

EIGHTH. The crisis of the Patarcocha Lagoon is not only environmental, but also legal and institutional, as it reveals the limits of an anthropocentric and fragmented regulatory model that does not fully recognize nature as a subject worthy of protection, nor does it ensure real mechanisms for the enforceability of environmental rights.

NINTH. The article demonstrates the need to move towards a model of ecological justice and recognition of the rights of lake ecosystems, articulating the Peruvian constitutional framework with comparative experiences of other countries and proposing a new regulatory design that combines the following: legal recognition, ecological governance, strict environmental responsibility, citizen participation and financing mechanisms for the integral restoration of the Patarcocha Lagoon.

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AUTHOR CONTRIBUTIONS

Isabel Angélica Quillatupa-Machuca, Degollación Andrés Páucar-Coz, Elias Mejia-Mejia: Conceptualization, Investigation.

Isabel Angélica Quillatupa-Machuca, Degollación Andrés Páucar-Coz, Elias Mejia-Mejia: Methodology, Laboratory Analysis.

Isabel Angélica Quillatupa-Machuca, Degollación Andrés Páucar-Coz, Elias Mejia-Mejia: Data Curation, Formal Analysis.

Isabel Angélica Quillatupa-Machuca, Degollación Andrés Páucar-Coz, Elias Mejia-Mejia: Supervision, Writing, Review & Editing.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

Ethical approval was not required for this study.

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