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Application of Ostrom's Institutional Analysis and Development Framework in River Water Conservation in Southern Ecuador. Case Study—The Zamora River

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Abstract: Water is essential for life and human activities. In addition to the constant increase in water demand, there are problems caused by inefficient governance, such as the discharge of untreated wastewater into rivers and seas, which is aggravated by the limited participation of civil society in decision-making. To face current and future challenges, solid public policies must be implemented, focused on measurable objectives, following planned and predetermined schedules on an appropriate scale, based on a clear assignment of functions to the competent authorities, and subject to periodic monitoring and evaluation. The Institutional Analysis and Development framework proposed by Ostrom made it possible to identify gaps in the existing governance, and to establish actions that could strengthen the institutional framework with the active participation of social actors, in order to achieve an effective conservation of water resources in southern Ecuador. The present study determined that regulations are not coherent with the conflict, the design of policies, and the effects of decision-making. The formal rules for wastewater management are not applied, and there is an incipient citizen participation, as well as disarticulation in institutions responsible for wastewater management. Recommendations were made to strengthen the institutional framework and governance of wastewater.

Keywords: governance; Ostrom's IAD; governance of wastewater

1. Introduction

Water is essential to sustain life; thus, proper water management is necessary for the well-being of the population. It is estimated that global water demand will increase by 55% by 2050 [1], therefore, managing and guaranteeing access to water for all requires efficient governance [2]. The lack of wastewater treatment is one of the main problems in water management [3]. Currently, approximately 80% of wastewater is discharged without treatment into rivers and seas [1] and only 4% of all the water used is reused [4]. Innovative practices are needed to improve water security, to provide better services to the population, and to achieve the UN's Sustainable Development Goal No. 6 [5].

An estimated 90% of all wastewater in developing countries is discharged untreated directly into rivers, lakes or oceans [6]. Ecuador is considered to have an innovative legal framework when compared to other countries in the region [7]. The State is established as the only regulatory agent and controller of the nation's natural heritage, including water, which is considered as strategic public patrimony. Furthermore, the human right to water is guaranteed by prohibiting the privatization and private commercialization of water. Additionally, an integrated management model by hydrographic basins is incorporated, different rates are collected according to the use and exploitation of water, equitable access to water and its sources is promoted, ecological flows are proposed, a single water authority is defined, and a deconcentrated management model is incorporated. Although it has positive characteristics, it needs to develop stronger environmental policies to avoid water pollution [8], as well as include civil society in the decision-making process [9].

Water governance is a decision-making process of multiple levels and actors [10]. It is defined as the set of rules, principles, and incentives aiming to achieve sustainable development through mechanisms that guide and coordinate the behavior of people according to agreed objectives [11]. Most water problems originate from poor governance, therefore, to face current and future challenges, it is necessary to apply solid public policies oriented to measurable objectives, following planned and predetermined timetables on the appropriate scale, based on a clear assignment of functions to the competent authorities, and subject to periodic monitoring and evaluation [2].

Considering the most general governance principles, such as legitimacy, transparency, accountability, human rights, the rule of law, and inclusiveness, the Organization for Economic Cooperation and Development (OECD) has established governance principles of water. These principles focus on (1) its effectiveness to define clear and sustainable goals and objectives in all levels of government; (2) its efficiency to maximize the benefits of sustainable water management at the lowest cost to society; (3) the trust generated in the population; and (4) the inclusive participation of social actors [2]. According to these principles, water governance systems must be designed considering the challenges they must face.

The Institutional Analysis and Development framework (IAD) proposed by Ostrom et al. [12] identifies the main variables that should be considered when evaluating the role of institutions in the formation of social interactions and decision-making processes.

The IAD framework identifies three groups of variables: (1) the rules for the field of action (institutions); (2) the collective unit of interest (community); and (3) the attributes of the physical environment in which the community acts. Institutional arrangements can be produced only through interaction and cooperation [13,14]. Ostrom's IAD has been used successfully to evaluate the effectiveness and sustainability of soil and water conservation activities [15], to understand the factors and political-economic dynamics that trigger air pollution and propose alternative solutions [16], and for the analysis of the governance of water use from alluvial aquifers and community participation [17], among others.

This study analyzes the governance of wastewater in an urban watershed located in the southern Andes of Ecuador, for which Ostrom's IAD framework was used along with the water governance indicators proposed by the OECD [18] which support the implementation of the OECD Water Governance Principles [2]. The water quality index designed by Brown et al. [19] was calculated and the collection of indicators was carried out through surveys. The aim of this study is to identify the gaps in the existing governance and establish actions that could strengthen the institutional framework with the active participation of social actors, to achieve an effective conservation of water resources in southern Ecuador.

2. Materials and Methods

2.1. Study Area

The upper basin of the Zamora River (230 km^2) is located in the south of Ecuador (Figure 1) and starts in the Podocarpus National Park at an elevation of 3200 m. It is a mountain river that presents an average slope of 8.3%. The basin has a vegetation cover in good condition, mainly composed of grasslands, scrublands, and forests [20]. The Zamora River is a tributary of the River Santiago and part of the hydrological system of the Amazon River. The Zamora River crosses the city of Loja, located in the inter-Andean region between meridians 3.85° S and 4.11° S and parallels 79.14° W and 79.27° W, at an average altitude of 2100 m. Its climate is equatorial subhumid temperate [21].

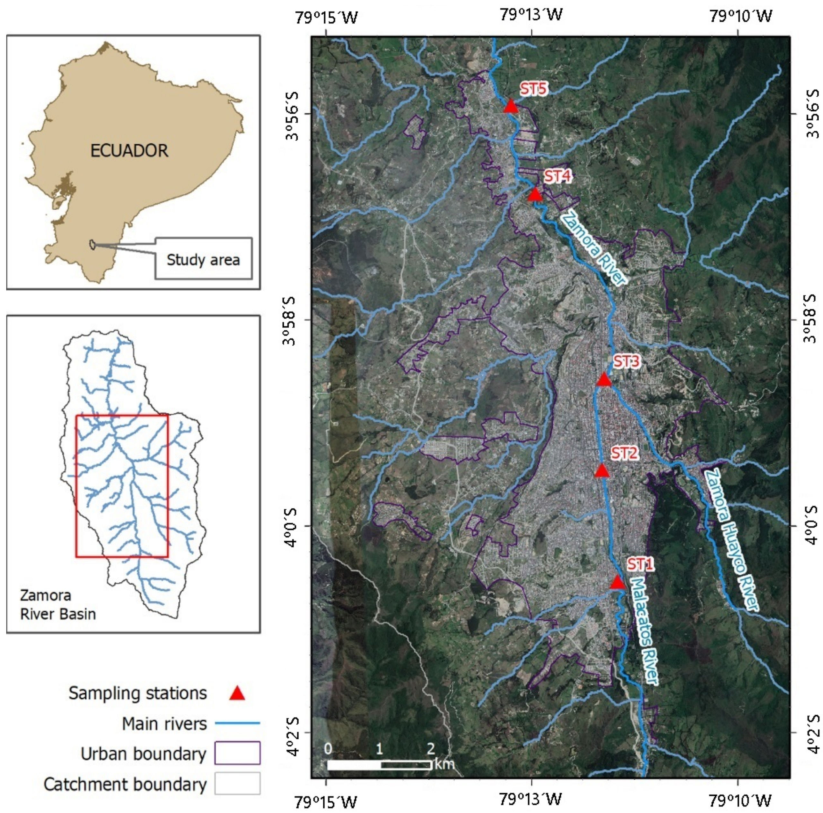

Figure 1. Location of the city of Loja in the upper basin of the Zamora River, its main tributaries, and wastewater discharge sites (ST 1–5).

Problematic

The city of Loja covers an area of 57.42 km^2 with a population of 210,000 people [22]. Only 77% of the homes in the city of Loja are connected to the sanitary sewer system [23]. The city does not have a wastewater treatment plant, so wastewater is discharged directly into the Zamora River in different locations. (Figure 1). The ratio of river flow to wastewater flow can be 2:1, although during the dry season it can be 1:1 [24].

Various studies have shown that the water quality of the Zamora River is deficient [25–27]. Despite this, downstream the city this water is used in agricultural activities, exposing the population to numerous potential diseases of bacterial, viral, and parasitological origin related to the consumption of contaminated water.

The environmental conditions of the Zamora River are not adequate despite that the population is aware of the poor quality of the water in the river, and even though there is an institutional and legal structure that establishes the needs for wastewater treatment, discharge controls, and permissible limits. For that reason, the Zamora River has been selected as a case study. The possible weaknesses of the institutional framework may cause a serious environmental problem, which is not exclusive to the study area as evidenced by the percentages of untreated wastewater that is discharged into rivers worldwide and particularly in Ecuador.

2.2. Institutional Analysis by the Ostrom Methodology

The IAD is considered an analysis framework for common resources (as in the case of water bodies) and specifically for territories where the rules, norms, and strategies that come from the institutions significantly influence the behavior of the individuals [13]. All interaction among individuals or organizations in the IAD framework happens in a territory, arena, or space of action, and this interaction is affected by exogenous variables that affect both the participants and the action situations [13]. Figure 2 presents the components of the Ostrom IAD framework.

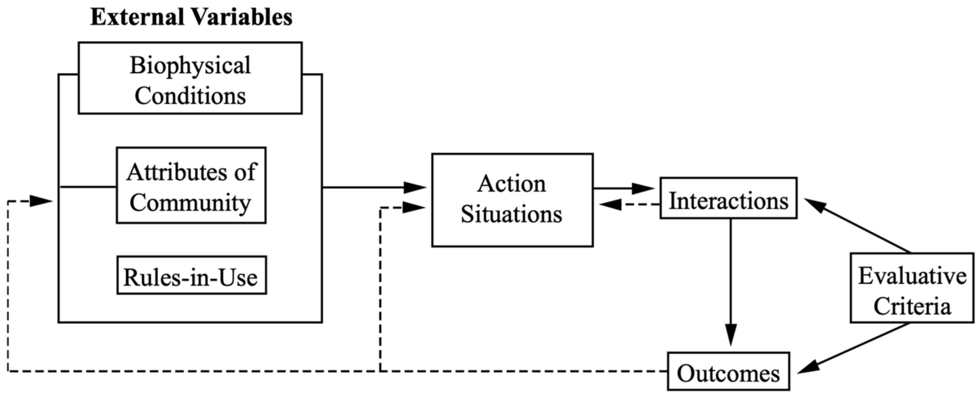

Figure 2. The Institutional Analysis and Development (IAD) framework, adapted from [13,28].

It is important to mention that the IAD considers that the action scenarios are flexible, especially when it comes to analyzing the institutional dynamics of a territory given the formal and informal rules and decision-making.

The IAD framework is based on the investigation of the main stakeholders involved in the decision-making process, the study of current laws at the national and local levels, the analysis of the interactions between the stakeholders, and the design of wastewater governance recommendations. Therefore, the IAD framework is divided into two stages:

2.2.1. External Variables

Inputs into an action situation are organized into 3 categories of contextual factors (attributes of the community, rules-in-use, nature of the good) that encompass all aspects of the social, cultural, institutional, and physical environment that set the context within which an action situation is situated [29]. The variables are selected and adapted according to the characteristics of the project; in this case, the current legal framework in Ecuador was considered in order to study the institutional arrangements and the water quality index was determined as a means to characterize the biophysical and environmental conditions of the case study.

Biophysical and Environmental Conditions: The Water Quality Index

The water quality index (WQI) was determined according to the model proposed by the National Sanitation Foundation (NSF) [30]. The WQI_{NSF} estimates water quality based on 9 representative parameters [19] applying Equation (1).

$$WQI_{NSF} = \sum_{i=1}^{n} W_i Q_i \quad (1)$$

where n is the number of water quality parameters, Wi is the weight of each parameter, and Qi is the water quality equivalent of the measured value of each parameter, which is obtained from the use of transformation functions published by Brown et al. [19]. The WQI_{NSF} values are classified as very bad (0–25); bad (26–50); medium (51–70); good (71–90); and excellent (91–100). In the present work, the following water quality parameters were adopted with their corresponding weight indicated in parentheses: pH (0.11), Dissolved Oxygen (0.17), Temperature change (0.10), Total phosphate (0.10), Nitrate (0.10), BOD (0.11), Turbidity (0.08), Total Solids (0.07), Fecal Coliform (0.16).

Five wastewater discharge sites were identified along the Zamora River, the coordinates of which are included in Table 1. Three samples were taken at each site in December 2018, which is part of the wet season (December to May) and close to the dry season (June to November). The samples were analyzed in the laboratory to determine pH, dissolved oxygen, conductivity, temperature, phosphate, nitrite, nitrate, chemical oxygen demand (COD), BOD5, total solids, turbidity, and fecal coliforms.

Table 1. Location of water sampling sites.

Station	Longitude (UTM)	Latitude (UTM)	Altitude (m)	River Flow (m^3/s)	Discharge Flow (m^3/s)
ST1	699,685	9,554,932	2109	5.09	2.91
ST2	699,377	9,557,094	2075	1.84	0.18
ST3	699,417	9,558,867	2052	2.57	—
ST4	698,076	9,562,461	2005	1.17	0.25
ST5	697,606	9,564,166	1996	2.41	0.88

Rules-in-Use: Current Legal Framework of Ecuador

The following laws related to river water quality in Ecuador were analyzed: Constitution of the Republic of Ecuador, Organic Law of Water Resources and its Uses, the Law on Prevention and Control of Environmental Pollution, Organic Code of Territorial Organization, National Development Plan 2017–2021, and United Nations Sustainable Development Goals.

2.2.2. Action Situations

An action situation is where operational, collective, or constitutional choices are made. The central focus on action situations of this framework helps to explain or predict how and why actors behave in a certain situation. An analysis of key action situations can therefore help to find incentives and disincentives that explain operational performance of drinking water supply organizations. In addition, an analysis of action situations can also be used to predict outcomes of a designed incentive structure to assess whether changes will lead to an improvement in the situation and contribute to better outcomes [31]. In this case, the actors with competence in the quality of the water of the Zamora River were identified and their performance was evaluated through participatory surveys based on the principles of water governance of the OECD.

Organizational Aspects: Participatory Surveys

To identify the organizational aspects and existing gaps in water governance, a questionnaire of 34 multiple-choice questions was posed to a random sample of professionals (40%), public officials (30%), and citizens (30%). These proportions were chosen considering that independent professionals have more adequate technical criteria, public officials would probably not be objective if they work for an institution involved, and citizens, although they experience the consequences, do not have sufficient technical criteria. The survey was designed considering 12 of the indicators proposed by the OECD [32] and enabled the identification of opinions of those involved in the governance of wastewater in the city of Loja [2,33]. The principles on which the survey was based are included in Table 2.

The sample size was selected by applying Equation (2).

$$n = \frac{N\sigma^2 Z^2}{(N-1)e^2 + \sigma^2 Z^2} \tag{2}$$

where n is the sample size, N is the population size, σ is the standard deviation of the population, Z is a constant that depends on the confidence level, and e is the acceptable limit of sampling error.

The analysis of the survey results in terms of the principles included in Table 2 allowed the evaluation of effectiveness and efficiency of governance, as well as the trust that governance generates in those involved and their participation in its implementation.

Table 2. OECD Principles on Water Governance, adapted from [2].

Principle	Indicator	Description
Effectiveness of water governance	1	Clearly assign and distinguish roles and responsibilities for water policy formulation and implementation, operational management, regulation, and coordination among responsible authorities.
	2	Manage water at the appropriate scale(s) within integrated river basin governance systems to reflect local conditions and encourage coordination among different scales.
	3	Promote policy coherence through effective intersectoral coordination, especially between water and environment, health, energy, agriculture, industry, spatial planning, and land use policies.
	4	Adapt the capacity level of responsible authorities to the complexity of the water challenges that must be met, and to the set of competencies necessary to carry out their functions.
Efficiency of water governance	5	Produce, update, and share data and information related to water: timely, consistent, comparable, and relevant to policy, and use these data to guide, evaluate, and improve water policy.
	6	Ensure that governance arrangements help mobilize water finance and allocate financial resources in an efficient, transparent, and timely manner.
	7	Ensure that robust water management regulatory frameworks are effectively implemented for public interest.
	8	Promote the adoption and implementation of innovative water governance practices among responsible authorities, levels of government, and relevant stakeholders.
Trust and participation in water governance	9	Implement integrity and transparency practices into water policies, water institutions, and water governance frameworks for greater accountability and confidence in decision-making.
	10	Promote stakeholder participation for informed and results-oriented contributions to water policy design and implementation.
	11	Foster water governance frameworks that help manage trade-offs among water users, rural and urban areas, and generations.
	12	Promote regular monitoring and evaluation of water policy and governance when appropriate, share results with the public, and make adjustments if necessary.

2.2.3. Analysis of Interactions and Outcomes and Formulation of Recommendations

The results obtained through the applied surveys allow identifying possible deficiencies in the efficiency and effectiveness of governance, as well as the degree of trust and commitment of those involved. Under the assumption that institutions and social behaviors generate the current conditions of water resources, we proceeded to analyze the interactions between institutions, legal bodies, territorial organizations, and financing, which made it possible to identify possible gaps in governance. With this approach, identifying vulnerabilities, several recommendations are established to achieve greater institutional robustness.

Considering that participatory, inclusive, and complementary processes are essential for effective governance, the recommendations seek the inclusion of all the stakeholders and its competencies with the good governance of wastewater in the territory. Additionally, they aim to integrate the financial availability and human resources necessary to generate the required changes, establishing a framework for cooperation, developing synergies, and minimizing conflicts between stakeholders.

3. Results and Discussion

3.1. External Variables

3.1.1. Biophysical and Environmental Conditions: Water Quality Index (WQ_{INSF})

Figure 3 shows the results of the WQI_{NSF}. After wastewater discharge, all the analyzed samples present values that oscillate between 46 and 48, which show an inadequate quality of water in the Zamora River. Only the ST1 before the wastewater discharge presents an average quality according to the classification proposed by Brown et al. [19]. The general

WQI_{NSF} of the Zamora River is of bad quality (ST 01—ST 05). These results are consistent with the results of previous research carried out by [25,26].

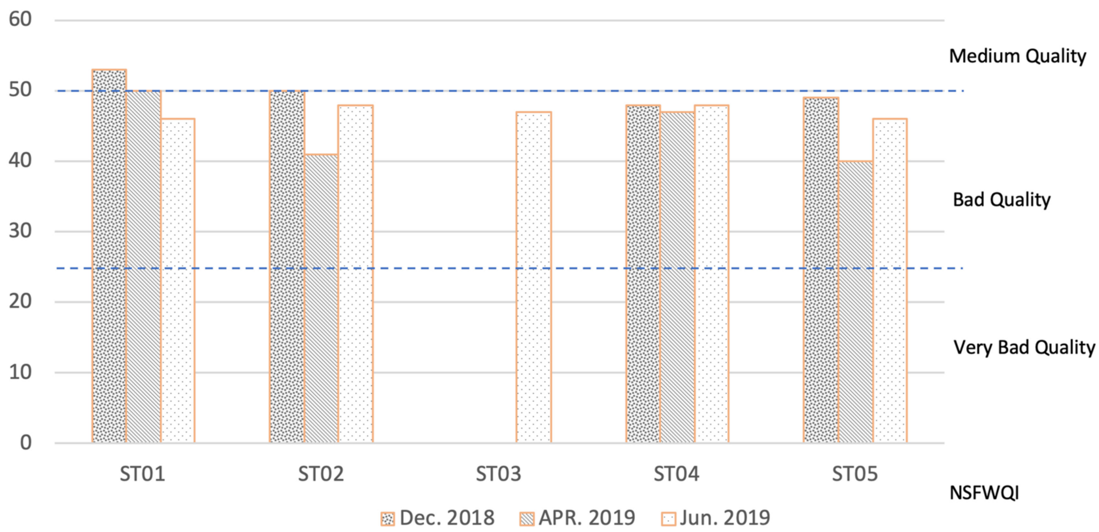

Figure 3. WQI_{NSF} for each station.

The main source of contamination of the Zamora River is the discharge of untreated wastewater. Those discharges contain suspended solids, fecal coliforms, and total coliforms that exceed the maximum permissible limits for a river. According to [34], Ecuador is the country with the highest number of pollutants (11) present in wastewater, followed by Mexico (7), Brazil and Colombia (3), and Argentina and Venezuela (1). As agriculture and livestock increase the pressure and alteration of natural ecosystems, they introduce hydro morphological changes and physicochemical contamination [35].

According to the scale proposed for the WQI [19], the level of contamination observed in the Zamora River is high.

3.1.2. Rules-in-Use: Current Legal Framework of Ecuador

Ecuadorian legislation expresses the following regarding the issues related to the discharge of wastewater into water bodies:

(1) Article 14 of the Constitution of the Republic of Ecuador establishes that society has the right to live in an ecosystem free of contamination, declaring its preservation and conservation of public interest [36].
(2) Articles 261, 262, 263 and 264 establish that the Central State, the Regional Governments, the Provincial Governments, and the Municipal Governments have the following responsibilities: The protection of natural resources, the ordering of the hydrographic basins, the provincial environmental management, and the provision of sewerage and water purification services residuals [36].
(3) In September 2015, the 193 member states of the United Nations outlined a sustainable development agenda for 2030 with 17 Sustainable Development Goals (SDGs) which will be monitored through global indicators [37].
(4) Among these, SDG 6 states the following: By 2030, water sources must be decontaminated, the amount of untreated wastewater cut in half [37].
(5) Regarding the organic and ordinary laws, we have the following statements:
(6) The Organic Law of Water Resources and its Uses established in Article 19 that the creation of an Intercultural and Pluricultural Water Council contributes to the formulation, evaluation, and control of policies on water, focusing on the social control of equitable access to water [38].
(7) For the control and regulation of the actors involved in the use of water, Article 21 promotes the creation of the Water Regulation and Control Agency (ARCA) which,

according to Article 23, is in charge of drafting technical regulations on water control, as well as regulating its management so that the contamination of watercourses by wastewater does not permanently affect ecosystems [38].

(8) Article 25 creates the Hydrographic Basin Council which is involved in the planning, control, and elaboration of all policies that affect the water resources in its jurisdiction. It is composed of a representative of the Single Water Authority and representatives of the users [38].

(9) In the event that wastewater discharges pollute a waterway, the state entity, natural, or legal persons must compensate the injured parties as established in Article 66, repairing the ecological impact caused, These may be sanctioned [38] and according to Article 82, all of this must be accompanied by an involvement of citizens and users who feel affected by the wastewater discharges in their locality [38].

(10) The National Environmental Authority (Ministry of the Environment, Water and Ecological Transition) and the Decentralized Autonomous Governments (GADs) must protect the integrity of water resources, and if these are degraded, they must restore them (Article 69 and Article 80) [38].

(11) In Article 151 and Article 161, the untreated wastewater discharges into water bodies are established as a serious offense and its remediation is compulsory. If not complied with, the Ministry of the Environment, Water and Ecological Transition must make the remediation and charge the offender the value of remediation and an additional 20% fine [38].

(12) Article 162 states that very serious infractions will be sanctioned with a fine ranging from 51 to 150 minimum wages [38].

(13) Article 8 of the Environmental Management Law provides as environmental authority the Ministry of the Environment which issues and regulates the environmental policy [39].

(14) Article 6 of the Law on Prevention and Control of Environmental Pollution prohibits polluting watercourses due to its negative impacts to ecosystems [40].

(15) In Article 210 of agreement No. 061 of the Reform of Book VI of the Unified Text of Secondary Legislation, it is prohibited to use water to lower the pollutant load of the discharge of wastewater into watercourses, making it impossible for offenders to dump wastewater exceeding the parameters established in the annexes of this agreement [41].

(16) The Organic Code of Territorial Organization (COOTAD) establishes in its Article 41 and 42 the functions of the provincial GADs on environmental management; Articles 54 and 55 establish the competencies of the cantonal GADs, which are in charge of avoiding environmental contamination within the cantonal territory. Both GADs must adopt their policies in accordance with national policies [42].

(17) The cantonal GADs must be coordinated with parochial GADS to eliminate wastewater discharges to watercourses [42].

(18) In the National Development Plan 2017–2021 "Toda una vida", the objective 3 establishes that the rights of nature must be guaranteed for current and future generations [43].

(19) The hierarchy of the regulatory framework in Ecuador, according to Article 425 of the Constitution of the Republic of Ecuador, establishes the priority of the regulations in the country. Their order is as follows: The Constitution of the Republic, international treaties and conventions, organic laws, ordinary, regional regulations, ordinances, decrees, and regulations [36]. For this reason, we cite governance according to its hierarchical level.

3.2. Action Situation

3.2.1. Actors with Competence in the Quality of the Water of the Zamora River

Those involved with competence in water governance in the study area are described below:

(1) Ministerio del Ambiente, Agua y Transición Ecológica (Ministry of the Environment, Water and Ecological Transition): This institution is in charge of guaranteeing the quality, conservation, and sustainability of natural resources, through the effective planning, regulation, control, coordination, and environmental management of water resources, all through the participation of public and private organizations, as well as citizens, within a framework of respect, integrity, responsibility, and transparency. Although the law prohibits the discharge of wastewater into bodies of water, there has been no tangible effort from this ministry in terms of controlling wastewater discharges. The degree of contamination of the Zamora River is alarming, as shown by the analyses carried out.

(2) Agencia de Regulación y Control del Agua (Agency for the Regulation and Control of Water—ARCA): This organization regulates and controls the integrated management of water resources, the quantity and quality of water in its sources and recharge areas, and the quality of public services-related water. To date, it has not been involved in solving the serious environmental problem of the Zamora River.

(3) Gobierno Autónomo Descentralizado (GAD) Municipal de Loja (Decentralized Autonomous Government of Loja Province): Among other competencies, it is in charge of preparing and executing the provincial development plan, including land use planning and public policies (within the scope of its powers and in its territorial district). This is done in a coordinated manner with national, regional, and cantonal planning, maintaining a constant follow-up on the fulfilment of its established goals. Additionally, it is in charge of planning, building, operating, and maintaining irrigation systems in accordance with the Constitution and the Law. It is also responsible for providing public services, such as drinking water, sewerage, wastewater treatment, solid waste management, and environmental sanitation activities. It is also responsible for avoiding the contamination of the Zamora River. Nevertheless, this institution has not worked in reducing the contamination in the river, nor has it carried out control activities to avoid agricultural irrigation with contaminated water in agricultural areas located in the lower part of the basin. However, it has recently made the decision to build a wastewater treatment plant in Loja, to partially solve the contamination in the river. However, this solution is not definitive as important areas located in the western portion of the city are outside the project's area of influence. Additionally, clandestine discharges are not controlled.

(4) Inhabitants of the City of Loja. They are the main affected by the contamination of the Zamora River, not only by the bad odors produced in the river, but also by the consumption of agricultural products that are irrigated with contaminated water. Unfortunately, the inhabitants of the city do not have sufficient information on the environmental status of the Zamora River nor spaces for deliberation, which could allow them to be involved in the decision-making process on issues that affect them directly and indirectly.

3.2.2. Organizational Aspects: Participatory Surveys

A sample of 381 surveys was defined and was applied randomly. The results of the applied survey are summarized in Table 3 and presented in Figure 4.

Table 3. Results of indicators and research to support them [2].

Principle	Indicator	Description	Value	SD
Effectiveness	1	Clear roles and responsibilities	45%	2.56
	2	Appropriate scales within basin systems	44%	2.48
	3	Policy coherence	43%	2.47
	4	Capacity	40%	2.57
Efficiency	5	Data and information	36%	2.34
	6	Financing	39%	2.48
	7	Regulatory frameworks	42%	2.85
	8	Innovate governance	41%	2.44
Trust and participation	9	Integrity and transparency	35%	2.38
	10	Stakeholder engagement	37%	2.37
	11	Trade-offs across users	36%	2.48
	12	Monitoring and evaluation	31%	2.09

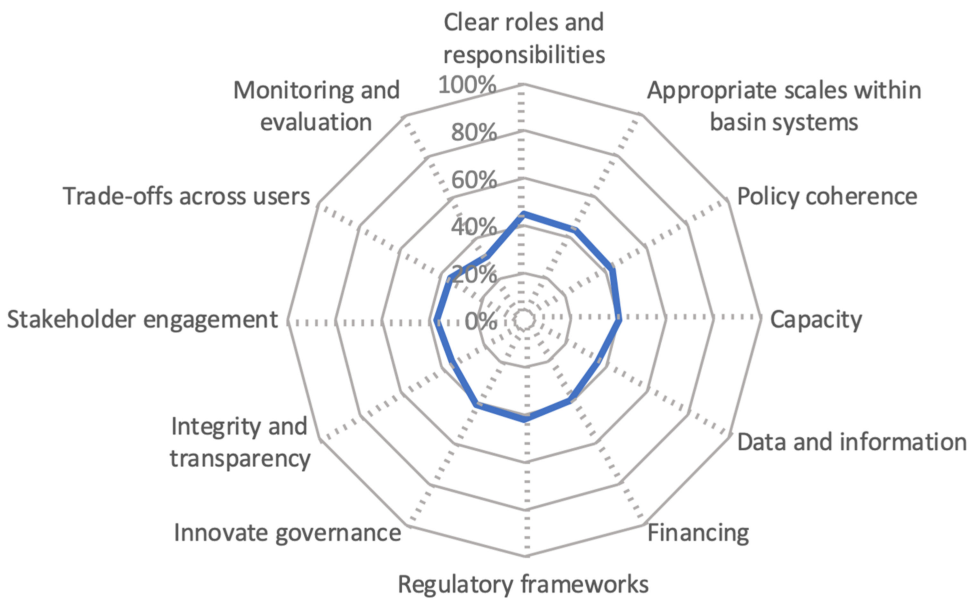

Figure 4. Indicator values.

The wastewater governance effectiveness indicators reach values that range between 40% and 45%. Indicator 1 presents a value of 45%, showing that there is an unclear assignment of roles and responsibilities for the formulation and implementation of water policies, as well as for their operational management and regulation. Unfortunately, there is no adequate coordination among the responsible authorities.

Water management in terms of integrated systems does not reflect local conditions, so the Indicator 2 principle reaches 44%. The level obtained in the principle Indicator 3 (43%) is evidence of the lack of coherence that exists between the policies of water and environment, health, energy, agriculture, industry, territorial planning, and land use. Apparently, there is no common objective to these areas.

Indicator 4 presents the lowest level, reaching only 40%, which questions the competencies of the authorities responsible for water governance. They are not in a position to respond to the great challenges that water governance poses. The values achieved by the indicators show that the effectiveness of water governance in the study area is insufficient [44,45].

Governance efficiency is related to its contribution to maximize the benefits of sustainable water management and well-being at the lowest cost to society [46,47]. The efficiency indicators vary between 36% and 42%. Indicator 5 presents the lowest value of the indices in this group (36%), which suggests a lack of relevant information to evaluate and improve water policies, since information is limited and difficult to access.

Indicator 6 is related to the financing and allocation of resources for water management; this indicator reaches 39%, a rather low value that shows the deficiencies the institutions have in the financial order. Indicator 7 presents a value of 42%, which shows that the application of regulatory frameworks is inefficient, and although there are regulations, the authorities have limitations to achieve compliance. Finally, Indicator 8 (41%) shows that there is little adoption of innovative practices in water governance from interested parties, authorities, and different government newcomers. In general terms, the efficiency of governance is low.

Trust and commitment relate to the contribution of governance to build public confidence and ensure stakeholder inclusion through democratic legitimacy and equity for society at large [45]. The indicators fluctuate between 31% and 37%, being the lowest values of all the indicators analyzed. According to the respondents, transparency in water policies is deficient (Indicator 9, 35%), the participation of all sectors interested in the design and implementation of water policies is not promoted (Indicator 10, 37%), governance frameworks that help manage commitments among users are not encouraged (Indicator 11, 36%), and monitoring and evaluation of water policies and governance is not promoted.

All the indicators reach values below 45%, which shows a low efficiency of governance, limited efficiency, lack of trust, and insignificant levels of commitment of stakeholders.

Figure 4 shows a radial graph that summarizes the values of the indicators obtained. In an ideal case, the values of each indicator should be close to 100%, which is not the case in the present study. The values are grouped around 40%, which shows important deficiencies in efficiency and effectiveness of governance, as well as in trust and commitment of those involved. The image shows that there are not indicators in acceptable conditions. Therefore, it is necessary to carry out an institutional analysis to identify governance gaps and to be able to make recommendations based on an analysis of interactions among the elements involved.

3.3. Analysis of Interactions and Outcomes and Formulation of Recommendations

3.3.1. Wastewater Governance Gaps

The results obtained for each indicator analyzed in Section 3.2.2, showed significant deficiencies in the efficiency and effectiveness of governance, which produce little trust and reduced commitment of those involved. Therefore, an analysis of the interactions was carried out between institutions, legal bodies, territorial organizations, and financing to identify the gaps in governance, which are presented below:

In the political sphere, it was possible to identify a gap due to the fragmentation of roles and responsibilities in water-related policies. Article 318 of the Constitution of the Republic of Ecuador establishes that it will be directly responsible for the planning and management of water resources used for human consumption, irrigation, ecological flow, and productive activities, in this order of priority. The Organic Law of water resources and use of water defines the functions and competencies of the Single Water Authority, which was the Secretariat of Water until March 2017 and now is in the hands of the Ministry of the Environment and Water after the merging of government entities [48]. However, the Decentralized Autonomous Municipal Governments (GADs) are responsible for water treatment. Therefore, there is no coordinated work between these institutions, nor regulations for their interactions. The coherence of the water policy depends on the institutional settings and the assignment of tasks at the different levels of government [49].

At the administrative level, a gap was identified between administrative areas and territorial organizations. This gap discourages integrated and territorially personalized planning for effective water management. The type and number of public agencies involved in water policy processes also produce inefficient administration. According to [33], there is no one-size-fits-all solution to all water challenges around the world. Governance responses need to be tailored to territorial specificities, recognizing that governance is highly context dependent.

As far as information is concerned, a gap is identified in its production and distribution. Additionally, a dispersion of water data in the different institutions of the country was evidenced. The lack of information makes governance difficult because it is needed for the establishment of monitoring and evaluation programs at the basin scale to evaluate physical, chemical, and biological aspects [50].

In the area of responsibility, a significant gap was identified in the governance of river water quality in Ecuador, requiring greater control by local authorities to ensure compliance with the law [27]. Institutions in charge of water quality could not provide transparent and credible evidence on the performance of water policy. Ensuring accountability is not possible without monitoring procedures and actions by governments, as well as without citizen participation.

Regarding financing, there is evidence of a significant lack of resources that prevents carrying out the activities required for water management, such as the construction and maintenance of infrastructure [51,52].

Looking at capacity, there is a gap produced by insufficient knowledge, lack of human resources, and outdated infrastructure and technology in the institutions in charge of wastewater governance. Currently, the absence of monitoring programs for evaluating the environmental quality of rivers (that is, physical, chemical, and biological conditions) imposes barriers to understanding the dynamics of aquatic systems, limiting the ability to identify, predict, and mitigate impacts [50].

Finally, there was a gap characterized by unclear objectives of water governance and conflicts among them in the context of economic, social, and environmental issues. In Ecuador, limited attention has been paid to water quality and even less to the assessment of aquatic ecosystems and environmental services.

3.3.2. Recommendations for Wastewater Governance

To reduce the existing gap between administrative areas and territorial organizations, and the resulting fragmentation of institutional roles, it is necessary to review the current competencies in the Organic Code of Territorial Organization (COOTAD). The COOTAD establishes the political-administrative organization of the Ecuadorian territory and defines the competencies of the state institutions. This, in order to avoid overlapping functions and clarify the responsibility of each public body related to water and wastewater disposal.

The Ministry of the Environment, Water and Ecological Transition must have up-to-date data and information on water quality and based on this, design, execute, and evaluate annual monitoring and evaluation plans. This will provide reliable evidence for the evaluation of the performance of water policies. It is necessary to establish clear provisions to centralize the information collected by different institutions and make it available to decision makers efficiently, through the WEB.

It is imperative that GADs fulfil the control function to avoid discharges of polluted water to rivers. Specific units should be created dedicated to ensuring compliance with the standards established to ensure water quality. Quality control must be carried out through continuous monitoring, in which physical, chemical, and microbiological analysis are executed, and sanitary inspections to supply systems are carried out from the source to the user. Operational control should also be implemented.

As it is a primary function to conserve the environment, the annual budgets must include sufficient resources to guarantee the performance of monitoring and control activities, as well as the construction and maintenance of infrastructure for wastewater treatment.

Continuous training will ensure the execution of projects based on state-of-the-art technologies, with sustainability awareness and effective citizen participation. Strategic alliances with universities will allow staff training in the short term.

It is necessary to analyze public policy related to water, environment, health, energy, agriculture, industry, territorial planning, and land use, evaluating its coherence and objectives, in such a way that there is a correct articulation among them and a convergence towards a common goal.

It is recommended to consider the criteria and participation of civil society in actions and decision-making related to wastewater, to give legitimacy to the governance processes.

4. Conclusions

Ostrom's IAD Framework was implemented to identify and analyze governance weaknesses over wastewater discharged into the Zamora River. To enrich the analysis, the calculation of the water quality index was introduced, quantitatively determining the biophysical conditions of the river under study. In order to evaluate the performance of the actors involved in the governance of wastewater, information was collected through a survey designed considering the OECD Principles on Water Governance.

The water quality index determined for different points of the Zamora River, as it passes through the city of Loja, shows an inadequate quality of the water caused by the discharge of untreated wastewater, which contradicts all the specifications.

The IAD model proposed by Ostrom allowed to observe that the regulations and the set of rules referring to the quality of water in the Zamora River are not coherent with the conflict, the design of policies, and the effects of decision-making. The formal rules for wastewater management in the city of Loja are not applied, and practice is very far from what the regulations indicate. Additionally, citizen participation is incipient and is not considered within the wastewater management model.

It was determined that government agencies carry out actions in an uncoordinated manner without considering the dynamics of the territory when making decisions. The monitoring of water quality, the treatment of wastewater, and the design of public policies for the management and handling of wastewater are carried out by different public institutions, totally disconnected from each other. Furthermore, the information generated is collected and managed in isolation, so there is no centralized service, which prevents access to information for both decision makers and common citizens.

The deficient generation and management of information, the shortage of technical personnel, technological resources, and financing are obstacles that have not allowed to identify objectives framed in good governance that could address the territorial conflicts generated by the inadequate management of wastewater in the city of Loja.

If it is considered that approximately 90% of the wastewater produced in developing countries is discharged without treatment into watercourses, the problem identified in this case study acquires a greater dimension since the weaknesses identified in governance could have correspondence in other similar cases, affecting the environment, and being necessary to take actions in favor of its conservation.

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