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Operational control and monitoring measures for water safety risks in the surface catchment of the Corumbataí River in the municipality of Rio Claro (SP)

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Medidas de controle e monitoramento operacional de riscos à segurança da água na captação superficial do Rio Corumbataí no município de Rio Claro (SP)

RESUMO

Objetivo - Propor medidas de controle e monitoramento à contaminação do manancial e da área de captação superficial do Rio Corumbataí, no município de Rio Claro (SP).

Metodologia - A pesquisa baseou-se em revisão bibliográfica e análise exploratória da área de estudo com indicadores de sustentabilidade e priorização da matriz de riscos para proposição do plano de melhorias com base nas recomendações da Organização Mundial da Saúde e NBR 17080.

Originalidade/relevância – A priorização de riscos à contaminação da água é elemento complementar à análise da qualidade hídrica. No entanto, gestores públicos não adotam o Plano de Segurança da Água (PSA) como instrumento de decisão da gestão dos recursos hídricos e do abastecimento local por falta de conhecimento das exigências pela Portaria Ministerial 888/2021 ou pela falta de empenho na gestão pública para condução do tema. A originalidade da pesquisa consiste na estruturação de um plano de medidas baseado em eventos perigosos, identificação do grau de risco, objetivo do controle, medidas de controle e estratégias de monitoramento.

Resultados - Entre os eventos perigosos mais agressivos, destacam-se o carreamento de contaminantes pelo escoamento superficial; descarga de efluentes devido a limpeza de tanques; existência de erosão e rejeitos pela ação de mineradoras; existência de fossas próximas à captação. Os indicadores de sustentabilidade em níveis insatisfatórios estão mais relacionados às mudanças climáticas do que água e saneamento e a resiliência climática demonstra ser o elo frágil desta adaptação.

Contribuições teóricas/metodológicas – A metodologia adotava teve sua subjetividade minimizada por estudos prévios e visita a campo para coleta de dados primários no entorno da captação que se localiza em área rural.

Contribuições sociais e ambientais – As principais indicações sociais e ambientais referem-se à necessidade de reflorestamento e obras de terra para controle de erosão, ações de mobilização socioambiental, monitoramento da qualidade da água com discussão na sociedade, mudança da forma de gestão pública para gestão adaptativa e inclusiva, além do fortalecimento da governança da água como critério ímpar à sustentabilidade e resiliência de cidades.

PALAVRAS-CHAVE: Sustentabilidade. Governança. Plano de Ação.

Operational control and monitoring measures for water safety risks in the surface catchment of the Corumbataí River in the municipality of Rio Claro (SP)

ABSTRACT

Objective – Proposing measures to control and monitor contamination of the Corumbataí River source and surface catchment area, in the municipality of Rio Claro (SP).

Methodology - The research was based on a bibliographic review and exploratory analysis of the study area with sustainability indicators and prioritization of the risk matrix to propose an improvement plan based on the recommendations of the World Health Organization and NBR 17080.

Originality/relevance - The prioritization of risks to water contamination is a complementary element to the analysis of water quality. However, public managers do not adopt the Water Safety Plan (PSA) as a decision-making instrument for the management of water resources and local supply due to lack of knowledge of the requirements of Ministerial Ordinance 888/2021 or lack of commitment in public management to address the issue. The originality of the research consists in structuring a plan of measures based on dangerous events, identification of the degree of risk, objective of control, control measures and monitoring strategies.

Results - Among the most aggressive hazardous events, the following stand out: the transport of contaminants by surface runoff; discharge of effluents due to tank cleaning; the existence of erosion and waste from mining operations; and the existence of septic tanks near the water intake. Sustainability indicators at unsatisfactory levels are more related to climate change than to water and sanitation, and climate resilience proves to be the weak link in this adaptation.

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Theoretical/methodological contributions - The adopted methodology had its subjectivity minimized by previous studies and field visits to collect primary data in the vicinity of the water intake, which is in a rural area.
Social and environmental contributions – The main social and environmental indications refer to the need for reforestation and earthworks to control erosion, socio-environmental mobilization actions, water quality monitoring with discussion in society, changing the form of public management to adaptive and inclusive management, in addition to strengthening water governance as a unique criterion for the sustainability and resilience of cities.

KEYWORDS: Sustainability. Governance. Action Plan.

Medidas de control operacional y monitoreo de riesgos de seguridad hídrica en la cuenca superficial del río Corumbataí en el municipio de Rio Claro (SP)

RESUMEN
Objetivo: Proponer medidas de control y monitoreo de la contaminación del nacimiento y la cuenca superficial del río Corumbataí, en el municipio de Rio Claro (SP).
Metodología: La investigación se basó en una revisión bibliográfica y un análisis exploratorio del área de estudio con indicadores de sostenibilidad y la priorización de la matriz de riesgos para proponer un plan de mejora basado en las recomendaciones de la Organización Mundial de la Salud y la norma NBR 17080.
Originalidad/relevancia: La priorización de los riesgos de contaminación del agua complementa el análisis de la calidad del agua. Sin embargo, los gestores públicos no adoptan el Plan de Seguridad del Agua (PSA) como instrumento de toma de decisiones para la gestión de los recursos hídricos y el abastecimiento local debido al desconocimiento de los requisitos de la Ordenanza Ministerial 888/2021 o a la falta de compromiso de la administración pública para abordar el tema. La originalidad de la investigación radica en la estructuración de un plan de medidas basado en eventos peligrosos, la identificación del grado de riesgo, el objetivo de control, las medidas de control y las estrategias de monitoreo.
Resultados - Entre los eventos peligrosos más agresivos, destacan: el transporte de contaminantes por escorrentía superficial; el vertido de efluentes debido a la limpieza de tanques; la erosión y los residuos de las operaciones mineras; y la presencia de fosas sépticas cerca de la toma de agua. Los indicadores de sostenibilidad con niveles insatisfactorios están más relacionados con el cambio climático que con el agua y el saneamiento, y la resiliencia climática ha demostrado ser el eslabón débil de esta adaptación.
Contribuciones teóricas/metodológicas - La metodología adoptada minimizó su subjetividad gracias a estudios previos y visitas de campo para recopilar datos primarios en las inmediaciones de la toma de agua, ubicada en una zona rural.
Contribuciones sociales y ambientales - Las principales indicaciones sociales y ambientales se refieren a la necesidad de reforestación y movimiento de tierras para controlar la erosión, acciones de movilización socioambiental, monitoreo de la calidad del agua con debate social, cambio de la gestión pública hacia una gestión adaptativa e inclusiva, además del fortalecimiento de la gobernanza del agua como criterio único para la sostenibilidad y la resiliencia de las ciudades.

PALABRAS CLAVE: Sostenibilidad. Gobernanza. Plan de Acción.

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GRAPHIC SUMMARY

Context

Water security depends on water quality, the monitoring system and the commitment of public managers to deal with this challenge, especially in the face of climate change.

Study Area

Surface catchment of the Corumbataí River in the municipality of Rio Claro (SP).

Methodology

Literature review
Sustainability indicators
Risk matrix
Improvement plan

Main Outcomes

- List of dangerous events related to the disposal of effluent and sewage, erosion and waste from mining operations and the existence of septic tanks near the water intake.
- Improvement plan template

Contributions/Originality

Field visits and preliminary studies to support personalized risk analysis.
Improvements in urban and territorial infrastructure associated with the public manager's commitment to adaptive and inclusive management ➜ strengthening water governance.

1 INTRODUCTION

The growing water scarcity represents a challenge, intensified by the effects of climate change and the increased demand stemming from population growth. In a worldwide scale, roughly 4 billion inhabitants face shortages at least one month per year (Mekonnen; Hoekstra, 2016; WHO, 2017), and approximately 33 million Brazilians lack access to treated water supply services (Instituto Trata Brasil, 2023).

In this sense, the adoption of a management program that guarantees the safe distribution of water to the population is recommended in the long term based on effective risk management supported by the Water Security Plan (WSP) (ABNT, 2023; WHO, 2023).

The WSP is a preventive methodological tool that makes it possible to identify the risks of water contamination throughout the Water Supply System (WSS). Covering everything from abstraction to the final consumer, the WSP is justified by the limitations of traditional approaches to controlling water quality for human consumption, with time-consuming methods for analyzing parameters and low alert capacity (Brazil, 2012; WHO, 2023), and it should have the following objectives (Brazil, 2023): (i) prevention of supply sources contamination; (ii) carry out treatment to eliminate or reduce the concentration of contaminants in the water, in order to meet established quality standards and (iii) prevent new contamination of the water during distribution, storage and distribution.

The PSA is based on the concept of multiple barriers to provide greater reliability to the tool, considering that the failure of the first barrier can be compensated by the existence of other underlying barriers along the SAA. This minimizes the probability of the contaminant spreading through the SAA and contaminating the end consumer (Brazil, 2012). Chart 1 shows the steps for preparing the PSA.

Chart 1 – Flowchart of the stages for drawing up the WSP

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STAGE 1
• Assembling the WSP team
• Elaborating the implementation schedule and responsibilities
• Elaborating the flowchart process
• Preliminary data collection, WSS analysis
• Identifying hazards and hazardous events
• Validating existing control measures and assess risks

⬇

STAGE 2
• Setting new critical limits
• Establishing control measures
• Establishing operational monitoring

⬇

STAGE 3
• Defining routine and emergency procedures
•Developing plans for WSP management
• Reviewing and updating the WSP

Source: Adapted from ABNT (2023) and Brasil (2012).

Initially, the operational control and planning team is formed, along with the action schedule, based on the general diagnosis of the WSS (step 1). Next, the critical limits of the parameters to be monitored are established to indicate control measures to prevent, eliminate or mitigate the risks to safe levels. Once done, operational, emergency and routine procedures for correction and prevention are defined (step 2). The plan involves training safety practices and adapting operational practices to mitigate the risks and/or prevent them from rising throughout the water supply system. Finally, it closes with a review of the WSP, performance achieved and new actions, as a continuous chain cycle of improvement (Brasil, 2012; ABNT, 2023).

Among the stages of risk identification and improvement proposal, the WSP approach also makes it possible to consider current levels and future climate change projections. Climate change is expected to alter the spatial distribution, duration and intensity of natural events, affecting the availability of drinking water in different ways (WHO, 2017).

Considering this, the Water Safety Plan Manual document addresses the possibility of climate change influencing the preparation of the PSA, since dangerous events involving water contamination (stages 1 and 2) can be aggravated by the climate and, therefore, the use of control measures and long-term monitoring is recommended to address climate change (WHO, 2023).

The relationship between climate change and PSA is directly linked to the achievement of the Sustainable Development Goals (SDGs), which aim to establish a global commitment towards a more just, equitable and sustainable future. Among them, SDG 13 (Action against climate change and its impacts) stands out, which assumes the strategic objective of mobilizing those responsible capable of promoting the necessary changes and preventing climate-related projections from becoming reality, and SDG 6 (Clean water and sanitation), which aims to

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address access to clean water, sanitation and hygiene, indicating that by 2030 billion people will not have access to services if further progress is not made (UN, 2023).

SDG 13 addresses the following objectives in combating climate change and its impacts: (i) strengthening resilience and adaptive capacity to climate-related risks; (ii) integrating climate change measures into national policies, strategies and planning; and (iii) improving education, raising awareness and increasing human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning (UN, 2023).

Silva et al. (2024) evaluated public policies in megacities (Brazilian and Mexican) and observed a setback in public policies due to changes in management as climate change worsened. In this context, Ventura et al. (2024) reinforced the idea of participatory governance in water resource management, so that the river basin committee becomes the place to discuss problems and formalize decisions with a view to addressing climate change and water scarcity.

In addition, municipalities can obtain resources to implement actions aimed at implementing the PSA, as commented by Ventura et al. (2023), by submitting projects to obtain financing through the State Water Resources Fund (FEHIDRO).

In this way, the PSA, as a preventive planning instrument for water contamination, plays a role in evaluating the system, identifying risks, control measures and prioritizing them, also contributing to achieving climate resilience in this system.

2 OBJECTIVE

The main objective was to propose control measures and operational monitoring of the risk of contamination related to the surface catchment area of the Corumbataí River, in the municipality of Rio Claro/SP, countryside of São Paulo.

3 METHODOLOGY

The research based on a literature review and exploratory analysis. The former consists of a procedure that seeks to gather information available in the literature on the subject (Creswell, 2007) and the latter is developed by describing the relationships between the characteristics of phenomena, facts and the observed environment (Marconi; Lakatos, 2003).
The stages of the research were the following: (i) analysis of the hazardous events in the study area and (ii) proposition of control measures and operational monitoring.

3.1 Analysis of the study area

The analysis of the study area covered local and regional characteristics, such as location, land use and occupation, and scenario regarding the achievement of the municipality's SDGs. To this end, technical reports from the PCJ Basin Agency Foundation (2020) and electronic documents from IBGE (2023) and IDSC-BR (2023) were consulted to obtain data.

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The hazardous events were collected in the vicinity of the surface catchment of the Corumbataí River through field visits, according to the research by Ventura, Ferro and Morais (2023).

These authors analyzed the characteristics of the surface catchment of the Corumbataí River and its surroundings by reading and interpreting technical reports and manuals such as Beuken (2008) and WHO (2023).

3.2 Control measures and operational monitoring

Based on information obtained in the field, photographic records and analysis of secondary data, a set of control measures and monitoring actions was structured, based on the study by Vieira and Morais (2005), the Water Safety Plan Manual (WHO, 2023) and NBR 17080 (ABNT, 2023). The criteria and classification scale are shown in Tables 2 and 3, while Table 1 presents the risk analysis for the present study.

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Chart 2 – Scale of probability of occurrence of hazardous events

Probability of occurrence	Description	Weight
Almost certain	Expected to happen once a day	5
Very likely	Will probably happen once a week	4
Likely	Will probably occur once a month	3
Not very likely	May occur once a year	2
Rare	May occur in exceptional situations (once in five years)	1

Source: ABNT, 2023.

Chart 3 – Scale of severity of consequences of hazardous events

Severity of consequence	Description	Weight
Catastrophic	Potential harm to the health of a large part of the population	5
Major	Potential harm to the health of a small part of the population	4
Moderate	Potential damage to a large part of the population	3
Minor	Potentially harmful to a small part of the population	2
Insignificant	No impact or not detectable	1

Source: ABNT, 2023.

Table 1 – Classification of risk levels for water safety in Water Supply Systems

Risk assessment	Risk Degree
Very high - immediate action required	> 15
High - need special attention	10 a 15
Medium - needs attention	6 a 9
Low - manageable with routine procedures	< 6

Source: Drafted by the authors based on ABNT, 2023.

4 RESULTS AND DISCUSSION

4.1 Characterization of hazardous events and sustainability in the study area

The Corumbataí River Basin, located in the central-eastern region of the State of São Paulo (Figure 1), is one of the five sub-basins that make up the Piracicaba, Capivari and Jundiaí River Basins (PCJ Basins). The Corumbataí River Basin covers nine municipalities and covers an area of 1,719.46 km² (Fundação Agência das Bacias PCJ, 2020), standing out for its relevance in agricultural and industrial development.

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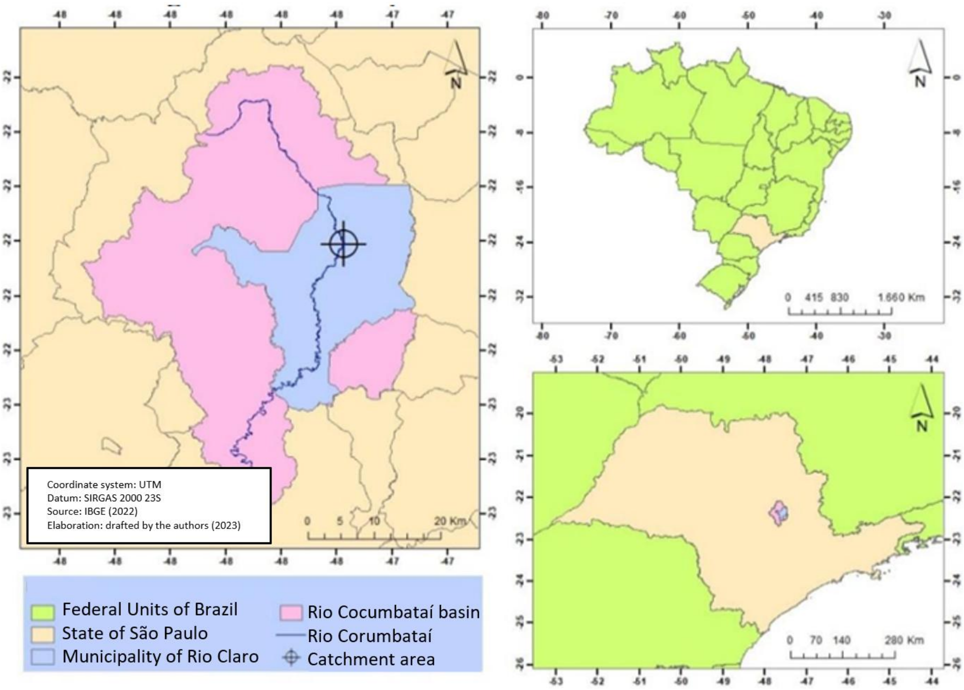
Figure 1 – Location of the Corumbataí River Basin



Source: Ventura, Ferro e Morais, 2023.

This Basin has 92% of its territory composed of rural areas and 8% of urban areas. In rural areas, 22% has vegetation remaining from the Cerrado and the Atlantic Forest, and 78% has land use and occupation in different forms (Fundação Agência das Bacias PCJ, 2020), however, it is concentrated in sugarcane, native forest and fields (Fundação Agência das Bacias PCJ, 2020). It is worth noting that sugarcane and pasture areas are activities that demand high water consumption and occupy more than 60% of the total area of the basin (Table 2).

The municipality of Rio Claro has 208,857 inhabitants (IBGE Cidades, 2025) and covers 28% of the total area of the Corumbataí River Basin, being responsible for supplying drinking water to its headquarters, as well as the districts of Ajapi and Batovi (Rio Claro, 2021).

Table 2 – Land use and occupation in the Corumbataí River Basin

Classes	Area (km²)	Area (%)
Urbanized Area	87,05	5,06%
Field	**285,17**	**16,59%**
Wet Field	31,89	1,86%
Sugarcane	**753,97**	**43,85%**
Water Bodies	6,97	0,41%
Permanent Farming	114,13	6,64%
Temporary Farming	3,72	0,22%
Native Forest	**391,15**	**22,75%**
Mining	8,48	0,49%
Other Uses	35,73	2,08%
Forestry	1,20	0,07%
Total (km²)	**1719,46**	

Source: Adapted from Fundação Agência das Bacias PCJ, 2020.

In addition to the risk of contamination generated by indiscriminate use and occupation, mortality rates related to diseases transmitted by water and food reflect the level of adequacy of safe sanitation and sources of contamination. In this field, the study by Moraes

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(2024) illustrated the deficiencies in public sanitation services and the mortality rate from diseases of this nature in each macro-region of the country, with emphasis on the north and northeast regions with the worst rates in these aspects.

The Sustainable Development Index of Rio Claro reached 56.5 on a scale of 0 to 100. The best SDGs were 6 (Clean Water and Sanitation), 7 (Renewable and Affordable Energy) and 13 (Climate Action), although the indicators with low performance of these SDGs were loss of treated water in distribution, percentage of the municipality deforested and average performance for “strategies for risk management and prevention of environmental disasters” (IDSC, 2024). Thus, the development of preventive systems to combat floods, inundations and flooding, as well as the improvement of sanitation services, increase the resilience of cities and, consequently, the quality of life of the population. It is worth noting that the loss of treated water (36.62%) (Brazil, 2024) exemplifies the need for urgent adjustment in the operational system, as it increases the cost of water for consumers, as this index is above that estimated in Plansab for the year 2033 (31%) (Brazil, 2023), indicating that Rio Claro has not achieved universalization of the service to date.

On the other hand, poor performance was seen in the high rate of femicide and homicide and deaths by firearms and low investment in urban infrastructure and public resources, negatively interfering with SDGs 5 (gender equality), 9 (industry, innovation and infrastructure), 16 (peace, justice and effective institutions) and 17 (partnerships for the implementation of the goals). In other words, there is a need to improve public safety and urban facilities to ensure a better quality of life for the population.

The municipality of Rio Claro is supplied with surface water from surface catchments in Ribeirão Claro and Rio Corumbataí. The catchment from the Corumbataí River contributes 1.5 million m3 per month to supply 60% of the municipality's population (Rio Claro, 2021).

Chart 4 describes the hazardous events identified by Ventura, Ferro and Morais (2023) and their respective hazard (P) and severity (S) ratings.

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Chart 4 - Prioritization of hazardous events in and around the surface catchment area of the Corumbataí River

	Hazardous events	P	S	Risk <6	Risk 6-9	Risk 10-15	Risk >15
1	Loading of contaminants by surface runoff	5	4				20
2	Heavy rainfall with increased water turbidity	3	5			15	
3	Contamination from direct contact with excess manure and agrochemicals from agricultural activities	3	5			15	
4	Interruption of power supply and system failure due to storms, defects, accidents or vandalism	3	5			15	
5	Discharge of treated sewage from a sewage treatment plant near the catchment	5	3			15	
6	Slaughter of animals around the catchment area or on the river banks	4	3			12	
7	Discharge of effluents due to cleaning of water reserve tanks, fish farming etc.	4	3			12	
8	Erosion and presence of contaminants due to mining operations	4	3			12	
9	Inadequate sewage disposal near the catchment	3	4			12	
10	Oil deposited on roads due to emissions, leaks or spills, being transported by surface runoff	4	3			12	
11	Presence of latrine (black pit) within 30 meters of the catchment; fecal contamination through leaching of human or animal waste	3	4			12	
12	Spillage of pollutants on the highway due to a vehicle accident, which could reach the water source	2	5			10	
13	Existence of another source of pollution within 10 meters of the catchment	3	3		9		
14	Overflow from cesspits in places not covered by the public sewage system	3	3		9		
15	Siltation and contamination due to the use of the banks for recreation	4	2		8		
16	Disposal of solid waste around the source and its leachate	4	2		8		
17	Erosion caused by dredging and sandblasting around the source	2	4		8		
18	Occurrence of drought and/or prolonged flooding, making it impossible to collect water	2	4		8		
19	Contamination by wild animal excrements	5	1	5			
20	Chemical contamination due to accidents (such as industrial or forest fires)	1	5	5			
21	Clogging and/or siltation in the catchment area due to the presence of solid waste	2	2	4			

Source: Ventura, Ferro and Morais, 2023.

This prioritization matrix has a certain subjectivity due to the nature of the method, but it can be minimized through interviews or visits to superficial collections. In this sense, the same method was developed by Silva, Ventura and Padrin Filho (2025) in the municipality of Dois Córregos (SP), whose risk prioritization shade indicated serious and very serious severity that can compromise water quality in the Lajeado Stream Basin, such as constructed risks (changes and/or rectifications in the shape of the watercourse; irregular occupation/constructions in the surroundings; Increased soil waterproofing in the area of contribution of the hydrographic basin. disposal and accumulation of solid waste in general), natural risks (points with erosion processes along the watercourse) and social risks (illegal occupation and constructions in the surroundings) with risk level 20.

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This material can support decision-making regarding water supply and water resource management in the municipality, as well as promote public policies to make the city more resilient in facing climate change regarding the prevention of dangerous events.

4.2 Proposed control measures and operational monitoring

The Improvement Plan includes the hazardous events identified as having the highest risk, the objective of controlling this event, strategies for operational monitoring and control measures (Tables 5 to 8).

The most critical point of the analysis refers to the transport of contaminants by surface runoff that triggers diffuse pollution, which is difficult to monitor and supervise operationally (Table 5). This scenario may occur if this event is inherent to the occurrence of the others (discharge of treated sewage upstream of the collection point); Discharge of effluents due to the cleaning of water reserve tanks, fish farming and similar activities; Erosion and waste due to the action of mining companies; Inadequate discharge of sewage near the collection point; Presence of a latrine/cesspit up to 30 meters from the collection point; Fecal contamination through leaching of human waste; Oil deposited on highways by emission, leakage or spillage, transported by surface runoff; Cargo spillage on the highway due to a vehicle accident, which may reach the water source, which may increase the adverse effects (Table 6).

In this sense, Ventura et al. (2023) developed guidelines for the formulation of public policies for the Tietê-Jacaré River Basin Committee that can serve as a basis for local discussions. Among them, the following stand out: the encouragement of green-blue technologies with the principle of Nature-Based Solutions (NbS) and sustainable mechanisms that guarantee water infiltration into the soil and contribute to the hydrological cycle for training the technical staff of city halls; the use of water security assessment instruments, based on NBR 17080, connected to the use of land and the surroundings of catchments and the source; use of technologies or renovation of the water distribution network to reduce losses; use of indicators that assess water governance for climate resilience, information systems and connectivity of information with the population of the basin, in addition to other contributions by the authors.

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Hazardous events (Ventura, Ferro and Morais, 2023)	R*	Improvement plan		
		Goal	**Operational monitoring**	**Control measures**
Carrying of contaminants by surface runoff	20	Recovering native vegetation, especially on the river banks to reduce the impact of heavy rainfall; monitoring the area, predicting and overseeing hazardous events	• Standardization of operations while heavy rainfalls take place • Monitoring the use and occupation of the land and activities at the water source, with emphasis on the preservation areas and locations close to the catchment area • Development of a list of materials and compounds which are likely to contaminate the catchment area due to the use and occupation of the land • Definition of monitoring locations and their operations	• Restoration of the canal banks to distance the river from sources of contamination, increase soil permeability and structural stability: - reforestation with native plants (initially fast-growing) - earthworks (embankment and cutting)

Chart 5 - Improvement plan for very high risks at the surface catchment of the Corumbataí River and its surroundings

R*: Ventura, Ferro e Morais, 2023.

Source: Drafted by the authors, 2024.

Chart 6 - Improvement plan for high risks at the surface catchment of the Corumbataí River and its surroundings

Hazardous events (Ventura, Ferro and Morais, 2023)	R*	Improvement plan		
		Goal	**Operational monitoring**	**Control measures**
Heavy rainfall with increased water turbidity	15	Recovering native vegetation, especially along the river banks to reduce the impact of heavy rainfall; monitoring the area, predicting and supervising hazardous events	• Standardization of operations while heavy rainfalls take place • Monitoring the use and occupation of the land and activities at the water source, with emphasis on the preservation areas and locations close to the catchment area • Development of a list of materials and compounds likely to contaminate the catchment area due to the use and occupation of the land • Definition of monitoring locations and their operations	• Restoration of the canal banks to distance the river from sources of contamination, increase soil permeability and structural stability: - reforestation with native plants (initially fast-growing) - earthworks (embankment and cutting)
Contamination from direct contact with excess manure and agrochemicals from farming and cattle breeding	15			
Slaughter of animals around the catchment area or on the river banks	12			
Interruption to the power supply and system failure due to storms, faults, accidents or vandalism	15	Simultaneous control of the areas	• Drawing up contingency plans • Carrying out security patrols • Camera surveillance	• Restrict access to the area with fencing

R*: Ventura, Ferro e Morais, 2023.

Source: Drafted by the authors, 2024.

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Chart 6 - Improvement plan for high risks at the surface catchment of the Corumbataí River and its surroundings (continued).

Hazardous events (Ventura, Ferro and Morais, 2023)	R*	Improvement plan		
		Goal	Operational monitoring	Control measures
Discharge of treated sewage from a sewage treatment plant near the catchment	15	Propose the supervision of effluents and communication between system operators (WTP and STP)	• Establishing communication between operational teams • Defining monitoring places and their respective operations • Drawing up contingency plans	• Carrying out a diagnosis of the STP and interventions in the unit, if there are effluents with parameters that do not comply with CONAMA resolution 430/2011 (Brasil, 2011)
Discharge of effluents due to the cleaning of water reserve tanks, fish farming	12	Avoiding the construction of new tanks and regularizing existing ones	• Definition of monitoring locals and respective operations • Inspection of existing tanks	• Carrying out awareness campaigns about the consequences of discharging effluents into the river
Erosion and presence of contaminants due to mining operations	12	Monitoring the activities carried out and their consequences	• Establishing contact with those be held accountable • Defining monitoring spots and their respective operations	• Diagnosing the units and assessing the consequences for water quality
Inadequate sewage disposal near the catchment	12	Identifying hazardous spots and providing suitable ways of collecting and treating sanitary sewage	• Inspection of sewage systems in areas that are near to the catchment area • Monitoring illegal dumping of untreated sewage into the river	• Expanding the existing sanitary sewage systems, prioritizing areas that are near to the catchment area
Presence of latrine (black pit) up to 30 meters from the catchment; fecal contamination through leaching of human waste	12			
Oil deposited on roads by emission, leakage or spillage, being transported by surface runoff	12	Dealing with risks related to means of transportation and transport routes	• Definition of monitoring spots and respective operations • Drawing up contingency plans • Camera surveillance of the roads near the river	• Carrying out works, such as ditches and detention reservoirs, to avoid direct contact of contaminants and the river
Cargo spillage on the highway due to vehicle accidents, which can reach the water source	10			

R*: Ventura, Ferro e Morais, 2023.

Source: Drafted by the authors, 2024.

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Chart 7 - Improvement plan for medium risk at the surface catchment of the Corumbataí River and its surroundings

Hazardous events (Ventura, Ferro and Morais, 2023)	R*	Improvement plan		
		Goal	Operational monitoring	Control measures
Overflow from cesspools in places not covered by the public sewage system	9	Identifying hazardous spots and providing suitable ways of collecting and treating sanitary sewage	• Inspection of sewage systems in areas that are near to the catchment area • Monitoring illegal dumping of untreated sewage into the river	• Expanding the existing sanitary sewage systems, prioritizing areas that are near to the catchment area
Existence of another source of pollution within 10 meters of the catchment	9	Dealing with new sources of pollution near to the catchment area	• Inspection in order to know the characteristics of the area within a 10-meter radius from the catchment	• Promoting adequate ways of treating and containing polluting sources
Siltation and contamination due to use of the banks for recreation	8	Avoiding improper use of the river banks	• Monitoring the correct use of the land	• Carrying out awareness campaigns about the consequences of activities carried out on the river
Erosion caused by dredging and sandblasting in preserved areas	8	Monitor the activities carried out and their consequences	• Establishing directly communication with those to be held accountable • Defining monitoring locals and their respective operations	• Carrying out a diagnosis of the unit and monitoring consequences in terms of water quality
Disposal of solid waste around preserved areas and its leachate	8	Avoid irregular disposal and provide adequate ways for solid residues disposal	• Supervision of the final disposal of solid waste	• Expansion of solid residues collection system • Expansion of solid residues management system
Occurrence of drought and/or prolonged flooding, making water collection unfeasible	8	Predicting the occurrence and controlling the consequences of natural events that could damage the river's water quality	• Drawing up contingency plans • Definition of monitoring locals and respective operations	• Construction of a reservoir to reserve water and stabilize the quality of the raw water in the event of heavy rainfalls

R*: Ventura, Ferro e Morais, 2023.

Source: Drafted by the authors, 2024.

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Chart 8 - Improvement plan for low risks at the surface catchment of the Corumbataí River and its surroundings

Hazardous events (Ventura, Ferro and Morais, 2023)	R*	Improvement plan		
		Goal	Operational monitoring	Control measures
Chemical contamination due to accidents (such as industrial or forest fires)	5	Control and define strategies to guarantee water safety during hazardous event	• Definition of monitoring spots and respective operations • Camera surveillance • Establishing contact with those responsible for places that may pose a risk • Drawing up contingency plans	• Study of critical locations and establishment of systems to combat accidents
Clogging and/or siltation in the catchment area due to the presence of solid waste residues	4	Avoid irregular disposal and provide adequate ways for solid waste disposal	• Supervision of the final disposal of solid waste	• Expansion of solid residues collection system • Expansion of solid residues management system
Presence of animal carcasses around preservation areas	4	Simultaneous control of the areas	• Drawing up contingency plans • Carrying out security patrols • Camera surveillance	• Restricting access to the area in question with the placement of fences

R*: Ventura, Ferro e Morais, 2023.
Source: Drafted by the authors, 2024.

Pestana et al. (2024) illustrated the aspects that reinforce water governance in a fair, transparent and equitable manner to achieve resilience and sustainability in tackling climate change, especially the need for adaptive management to deal with urban challenges and the proposal of a governance planning and operation structure, as also highlighted by Ventura et al. (2023). The use of geoprocessing assists urban planning and trains technical agents of the public authorities in generating data and collecting evidence for decision-making and formulating public policies for sanitation, land use and occupation, and monitoring risks to water contamination. Access to financial resources through FEHIDRO, for example, can favor the implementation of works and non-structural measures and, thus, seek to engage and change the behavior of the population through short courses on the benefits of these initiatives for the environment and society in general.

Another way is to build public policies supported by intersectoral integration (water, energy, food) and a systemic vision to achieve long-term water resilience and sustainability (Pestana et al., 2024).

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5 CONCLUSION

The Water Safety topic is little discussed or known by public managers who are unaware of the need to have a PSA, according to Ministerial Ordinance 888/2021, which establishes the responsibility for providing safe water, both through the distribution network and alternative forms of supply to isolated communities. This research provided a preliminary diagnosis that can be monitored over time, due to climate interference and city expansion. Thus, the PSA becomes a collaborative instrument for urban master planning, sanitation and even the river basin plan.

This research adopted a method recommended by the World Health Organization (WHO), which is based on the analysis of dangerous events and prioritization of risk to contamination of water supply sources and, thus, made it possible to achieve the main objective. However, to reduce the subjectivity factor, the authors resorted to field visits and previous studies in the study area to increase the robustness of the methodology and make the diagnosis reliable to what was found in the study area.

The analysis established a relationship with the SDGs, but it is important to monitor the indicators that comprise them to verify their evolution, both in improving the population's quality of life and urban services, according to NBR 17080.

The most critical hazardous event was the “carrying of contaminants by surface runoff”, whose dissipation flows through diffuse pollution and depends on continuous and efficient monitoring and supervision. However, there are hazardous events relevant to the medium risk that deserve unified action with this first, such as the discharge of effluents from cleaning agricultural services in the region; the existence of erosion and waste due to the action of mining companies; inadequate discharge of sewage near the collection point; the existence of septic tanks near the collection point, among others, to avoid the potential contamination of human health and the environment as a whole.

Considering that most of the occupation in the Corumbataí River basin is represented by sugarcane (44%) and the indicators at unsatisfactory levels are more related to climate change than to water and sanitation, indicating that climate resilience represents the weak link in this adaptation. Therefore, strategies can be implemented to contribute to water security, such as studying and discussing the relationship between the SDGs and climate resilience, adaptive planning and preparing for changes in the near future and involving local institutions and water resource users in the design of the PSA, among others.

Making these actions tangible, the improvement plan is one of the instruments that can support the monitoring of dangerous events and their respective risks, as well as corroborate the transparent governance of the public administrator and ensure the participation of agents for this improvement, which can be triggered by partnerships with research institutions or by providing digital technology for monitoring dangerous events through agreements with private companies.

The water security challenges persist, and the public authorities can seek technological, scientific and popular support integrate knowledge and promote initiatives shared among different social actors. Therefore, the change in posture in public management regarding the form of planning, knowledge and use of indicators to support decision-making, as well as the preparation and provision of a water safety plan in digital media, identify the commitment of the local manager to the sustainability and resilience of cities.

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STATEMENTS

CONTRIBUTION OF EACH AUTHOR

Luiz Henrique Rosolen Ferro: Study conception and design, data curation, formal analysis, investigation, methodology, writing initial draft.

Katia Sakihama Ventura: Study conception and design, formal analysis, methodology, critical review, review and final editing, supervision.

Paulo Vaz Filho: Study conception and design, formal analysis, critical review, review and final editing.

DECLARATION OF CONFLICTS OF INTEREST

We, **Luiz Henrique Rosolen Ferro, Katia Sakihama Ventura and Paulo Vaz Filho**, authors of the manuscript **Operational control and monitoring measures for water safety risks in the surface catchment of the Corumbataí River in the municipality of Rio Claro (SP),** declare:

1. Financial Relationships: We have no financial relationships that could influence the results or interpretation of the work.

2. Professional Relationships: We have no professional relationships that could impact the analysis, interpretation or presentation of the results.

3. Personal Conflicts: We have no personal conflicts of interest related to the content of the manuscript.
