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Environmental Management

SWOT Matrix as a tool for diagnosing the municipal water supply system of a small city: a case study

Matriz SWOT como ferramenta de diagnóstico do sistema de abastecimento de água municipal de uma cidade de pequeno porte: um estudo de caso

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ABSTRACT

Small municipalities often face challenges related to their water supply systems, such as limited financial resources, low population densities and limited organizational capacity. In this context, this study aimed to diagnose the water supply system in the city of Quatro Pontes - PR, which serves 2,628 economies, through SWOT analysis. This analysis consisted of determining the strengths, weaknesses, opportunities and threats of the system, listed based on reports from employees and visual inspections. It was found that the system presents factors already documented for small municipalities with autonomous services, such as the strengths "good water quality" and "easy maintenance", as well as the weaknesses "few financial resources applied" and "outdated pricing policy". In addition, opportunities were mentioned, such as technological innovations in the sector, and threats related to water waste and contamination by pesticides. The results presented depict the water supply system of the municipality and can direct managers to take advantage of opportunities and mitigate system threats.

Keywords: Sanitation; Small size municipalities; Strengths and weaknesses; Opportunities and threats

RESUMO

Municípios de pequeno porte geralmente enfrentam desafios relacionados a seus sistemas de abastecimento de água, como recursos financeiros limitados, densidades populacionais reduzidas e restrita capacidade organizacional. Neste contexto, este trabalho teve como objetivo verificar diagnosticar o sistema de abastecimento de água do município de Quatro Pontes – PR, que atende 2.628 economias, por meio da análise SWOT. Esta análise consistiu na determinação das forças, fraquezas, oportunidades e ameaças do sistema, elencadas com base em relatos dos colaboradores e inspeções visuais. Constatou-se que o sistema apresenta fatores já documentados para pequenos municípios com serviços autônomos, como as forças "boa qualidade da água" e "manutenção facilitada", bem como as fraquezas "poucos

recursos financeiros aplicados" e "política de preços defasada". Além disso, foram citadas oportunidades, como inovações tecnológicas no setor, e ameaças relacionadas ao desperdício de água e à contaminação por agrotóxicos. os resultados apresentados retratam o sistema de abastecimento de água do município e podem direcionar os gestores para usufruir das oportunidades e mitigar as ameaças do sistema.

Palavras-chave: Saneamento; Municípios de pequeno porte; Forças e fraquezas; Oportunidades e ameaças

1 INTRODUCTION

Water is an essential resource for the development and maintenance of life and most human activities (AL-WASHALI *et al.*, 2019). According to Tzanakakis *et al.* (2020), the domestic use of water has increased in recent years, mainly due to population growth, increases in living standards and temperature rise. Considering the limited availability of this resource, in a proper form for catchment and subsequent human uses, in addition to the increasingly severe and constant water crises (CLAUDINO *et al.*, 2021), the efficient management of drinking water is a crucial element for the well-being and development of a community (KUSTERKO *et al.*, 2018; AL-WASHALI *et al.*, 2019).

In this context, the major objective of a water supply system is to provide this product (drinking water) in the quantity and quality necessary to maintain the health and welfare of the served population (CAMILO ROSADO *et al.*, 2020). According to Martins (2019), this service can be provided directly by the government, through the decentralization and transfer of these activities to a separate legal entity, through the creation of a municipal authority or by the private sector. Moreover, according to the authors, these decentralizing actions are usually adopted to speed up and make the provision of sanitation services more efficient, without losing the authority that has an "arm of the state", which has greater autonomy in decision-making, with patrimony and own recipes.

According to Pavón *et al.* (2018), water governance in a given location is not static, being under the influence of dynamic processes such as social, urban and economic changes, related to globalization, technological advances and even perceptions about this resource. Because it is a complex activity, managers of water supply systems also face complex problems. Among the main challenges faced by entities in the sector, par-

ticularly in the case of small municipalities, we can mention the limited financial resources, less qualified human resources, lower per capita income, reduced population densities and little organizational capacity (MUGABI; NJIRU, 2006), in addition to problems related to controlling and combating water losses (BARROS; LIMA, 2020; GORZONI *et al.* , 2019) and maintaining its quality (GUNNARSDOTTIR *et al.* , 2017; SMIRNOV; POMOGAEVA; SHLYCHKOV, 2019).

According to Bezerra *et al.* (2018), the evaluation of supply systems from the perspective of efficiency and effectiveness is necessary before decision-making, to ensure the availability of water and the sustainability of services in the medium and long term. Also, it is important to emphasize that the New Legal Framework for Sanitation (BRAZIL, 2020a) determines that companies providing sanitation services, regardless of the spectrum of coverage, be economically sustainable. Therefore, the adoption of adequate tools for the diagnosis of systems can be beneficial to managers. An example of a tool with these characteristics is the SWOT analysis.

SWOT analysis is a strategic planning tool used to analyze a given organization in order to build a strategy for it (ZIMA; PLEBANKIEWICZ; WIECZOREK, 2020). It is used to diagnose the situation in which the organization finds itself, dividing it into two environments: internal and external. The internal environment is characterized by strengths (S) and weaknesses (W), while the external environment, is by opportunities (O) and threats (T) (LEIGH, 2009).

SWOT analysis was developed in the 1960s by researchers at the Harvard Business School, seeking to recognize the potential of a company within the market, through its strengths and weaknesses and the goals to which it aspired. The methodology as a strategy was consolidated in the 1965 book Business Policy: Text and Cases (LEIGH, 2009). It is a simple and efficient tool to determine and assess the organization's capabilities. SWOT analysis applied to water resources management can be found in recent research. Monteiro and Cabral (2018) can be cited, who used it to compose the groundwater management scenarios in the Brazilian state of Piauí; Pereira and Marques (2020), who applied the tool to analyze tariffs for irrigation water in Portugal;

Petousi *et al.* (2017), who used it to define priority measures for the management of water resources in the Island of Crete, Greece and; Nagara *et al.* (2015), who applied it to make a comparison between the technological solutions for water management employed in Asia and Africa.

In face of the above, it can be noted that it is common for small municipalities to face a series of problems and challenges related to their water supply systems (SILVA, 2018). Hence, considering the applicability of the SWOT analysis in issues related to the management of water resources, this work aimed to apply this management tool, aiming at the diagnosis of the water supply system in the municipality of Quatro Pontes - PR, listing its strengths, weaknesses, opportunities and threats. The SWOT Matrix can lead managers to take advantage of opportunities and mitigate the system threats.

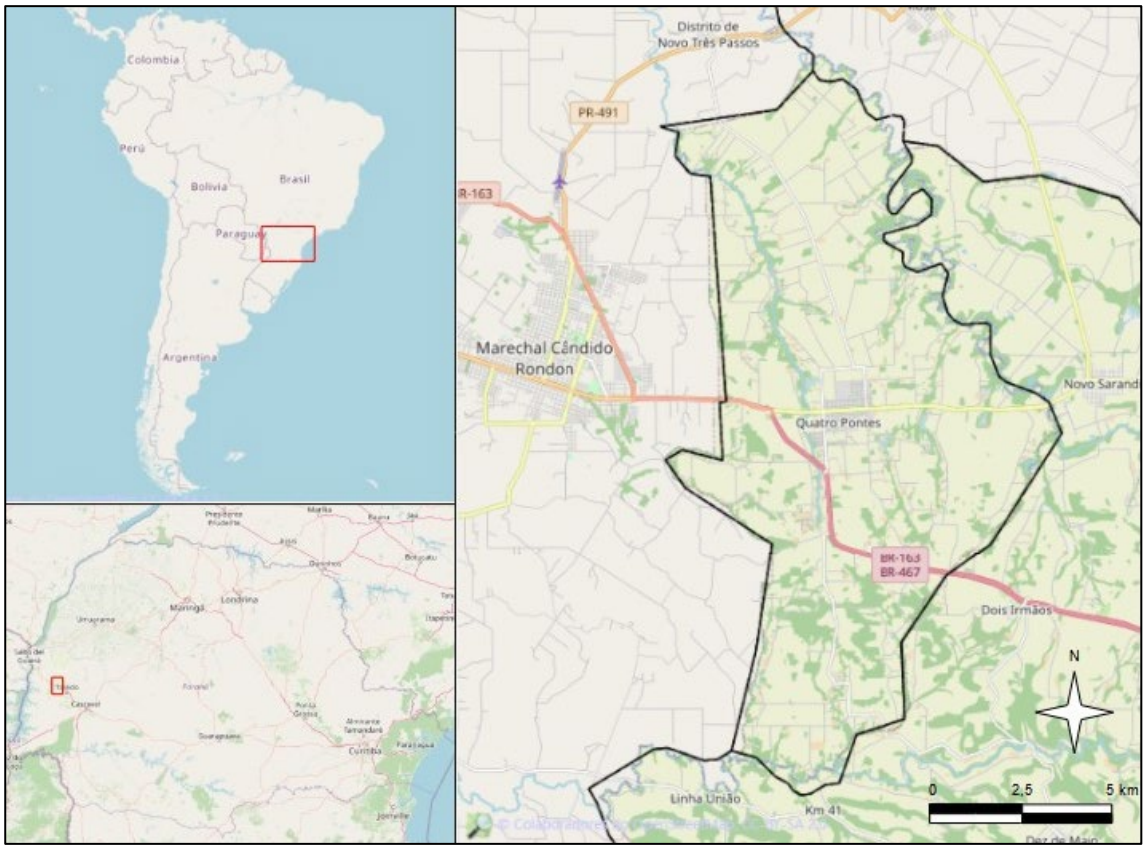
2 MATERIALS AND METHODS

2.1 Characterization of study area

The municipality of Quatro Pontes is located in the west of the state of Paraná, at the geographic coordinates 24º34'30'' S and 53º58'37'' W. It is located in the Paraná 3 watershed, limited to the north by the municipality of Nova Santa Rosa, to the south and east by the municipality of Toledo and to the west by the municipality of Marechal Cândido Rondon (QUATRO PONTES, 2016). Figure 1 presents the geographic position of the municipality in relation to the country and state.

According to the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese) (2021), Quatro Pontes had an estimated population of 4,029 inhabitants for the year 2020. Moreover, according to the demographic census carried out in 2010, 64.04% of the population lived in urban areas, and 35.96% in rural areas (IBGE, 2017). The area of the territorial unit is 115,681 km² and, according to the National Information System on Sanitation (SNIS, in Portuguese) (BRAZIL, 2020b), in 2020, the urban service rate of the water distribution system was 100%.

Figure 1 – Map of the study site



Source: Adapted from OpenStreetMap© Contributors (2021)

In 2020, 22.10% of the establishments in Quatro Pontes carried out activities related to agriculture, 21.57% carried out activities related to the retail trade and 13.16% related to transport and communications. Regarding the fiscal value added of the municipality, 80.34% came from primary production, 12.70% from industry, 6% from commerce and services and 0.94% from notices of infractions, resources and challenges from the City Hall. In the agricultural field, poultry (847,400 heads) and swine (155,050 heads); and soybean (29,363 ton) and corn (19,449 ton) production stood out (PARANÁ INSTITUTE FOR ECONOMIC AND SOCIAL DEVELOPMENT, 2022).

In the city, the water supply service is provided by the Quatropontense Water System (SQPA, in Portuguese), an agency under the care of the Water Supply Division of the Municipal Department of Works, Urbanism and Transportation. This has the duties of operating, maintaining, conserving and exploring the water supply service, as

stated in the Municipal Basic Sanitation Plan of Quatro Pontes - PR (QUATRO PONTES, 2016). In the rural area of the municipality, there are associations of residents of the localities that manage the distribution of water, in partnership with the public sector, and have their own tariffs. Rural areas are not part of the scope of this work. Public sewage collection and treatment services are not operated in the municipality.

Water for urban supply is extracted from mines and deep wells, being conducted by raw water pipelines, made up of cast iron pipes with a nominal diameter of 100 mm, to four reservoirs located in the city center. In these, the treatment step by simple disinfection takes place, due to the characteristics of water from the springs. Finally, the water is distributed to the final consumer through the distribution network of polyvinyl chloride (PVC) pipes with a predominant nominal diameter of 50 mm. According to the Municipality of Quatro Pontes, in December 2020 there were 2,628 active connections at the urban area, in an extension of the water network of approximately 32,000 meters.

2.2 Research methods

The methodology used in this research had four phases. The first phase was the reading and analysis of publications related to the research topic. The second was the visit to SQPA facilities to collect data with employees involved in the system and also direct observations. The third consisted of the elaboration of the diagnosis using the SWOT analysis tool, while the fourth consisted of the analysis and discussion of the results.

To collect data from the system's employees, an adapted methodology from Nogueira and Silva (2017) was used: after explaining the concept of the SWOT analysis, the employees were asked to spontaneously cite up to four strengths, four weaknesses, four opportunities and four threats to the system. These were named 'factors'. They were also asked to assign a degree of importance to each factor listed, according to the Likert scale with three intervals, as follows: 1 (little important), 2 (medium important) and 3 (very important). In the event of two degrees of importance with different values

for the same factor, the highest of them was adopted. These factors were then classified into one of the following groups: Infrastructure, Management and Environment, in order to facilitate the diagnosis approach.

After data collection, the procedure adopted by Ferreira *et al.* (2019) was performed: as some factors may be more relevant than others for the same group, the author adopted a classification for the variables by multiplying the degree of importance by the magnitude, the latter being the number of times the factor was mentioned during the interviews.

3 RESULTS AND DISCUSSION

Data collection with employees of the Quatro Pontes water supply system was used to build the internal and external environments of the SWOT Matrix. Nine employees were interviewed, who occupied technical and administrative positions. The length of service of the interviewed employees ranged from six months to fifteen years of experience.

3.1 Strenghts

The factors mentioned by employees as strengths, cited by them spontaneously, are presented in the first column of Table 1. Each factor has a magnitude, which is translated by the number of times it was mentioned in the interviews and is presented in the second column. The third column presents the degree of importance that the employees attributed to each factor. In the fourth column, the final classification is presented, which is the magnitude multiplied by the degree of importance. Finally, the fifth column presents the group to which the factor was fit (Management, Infrastructure or Environment).

It can be observed that 10 factors were listed, with 3 elements in the Infrastructure group, 1 in the Environment group and 6 in Management one. It is noteworthy that

although most of the system's strengths are in the Management group, the three factors with the highest magnitude/classification are from the Infrastructure and Environment areas. Treatment with hypochlorite produced in the municipality itself, a quality product (drinking water) and small municipality: facilitated maintenance were the factors with the greatest magnitude, mentioned four times by employees. In addition, the three factors had an importance degree of 3 and classification of 12.

Table 1 – Internal environment - Strengths of the Quatropontense Water System

Factor	Magnitude	Degree of importance	Classification	Group
Treatment with hypochlorite produced in the municipality itself	4	3	12	Infrastructure
Quality product (drinking water)	4	3	12	Environment
Small municipality: facilitated maintenance	4	3	12	Infrastructure
Newly constructed catchment system	3	3	9	Infrastructure
Agility in the execution of maintenance services	2	3	6	Management
Hotline for emergencies and calls for maintenance	2	3	6	Management
Support of the municipal administration for the management of the system	1	3	3	Management
System management planning: there is no shortage of equipment and materials for maintenance	1	3	3	Management
All employees have qualifications in the sector	1	3	3	Management
Dedicated employees	1	3	3	Management

Treatment with locally produced sodium hypochlorite was cited as a strength, with a rating of 12. According to Pacheco *et al.* (2018), chlorine is the most used water disinfectant in Brazil and, among the available options, sodium hypochlorite produced through brine electrolysis (as in Quatro Pontes) is advantageous over the use of chlorine gas (Cl_2). Chlorine gas is more expensive, and its use carries risks in case of leaks, as it is asphyxiating, causes irritation to the nose, eyes and mouth, and has a strong

odor. Pacheco *et al.* (2018) evaluated usage of the two disinfection methods in the city of Uberlândia - MG. They observed that hypochlorite is efficient and its use results in water that meets Brazilian potability standards and is more accessible than chlorine gas. The costs of implementing this system pay off in a short time, in addition to ensuring the safety of employees and the resident population close to the treatment plant. Corroborating what has been reported, Smirnov *et al.* (2019) propose the transition from chlorinated water disinfection systems to systems using sodium hypochlorite, as a measure to modernize and develop water supply systems in small municipalities. In this way, it is understood that the technology used by the municipality can be considered a strength.

Good water quality, cited as a strength in this work with classification 12, was also considered a strength in the SWOT analysis performed by Petousi *et al.* (2017) for the management of water resources in the Island of Crete, Greece and, by Pereira and Marques (2020), in the analysis of water tariffs for irrigation in Portugal. Considering the extraction of water by wells (as carried out in Quatro Pontes). Nagara *et al.* (2015) pointed out as a strength the fact that this technology produces water of moderate to high quality, with low energy consumption and cost, in a SWOT analysis for solutions in water resources in Africa and Asia. It is thus observed that water quality is frequently cited in SWOT analyses related to water resources, as was also verified in this research.

Another strength mentioned is related to the size of the municipality, with classification 12, which, because it is small, is easy to had the system maintenance done. The reduced territorial and network extension, in addition to the simplicity of the system (compared to larger municipalities) allow maintenance activities to be carried out in a less complex and more agile way. The strengths “hotline for emergencies and calls for maintenance” and “system management planning: there is no shortage of equipment and materials for maintenance” can also contribute to the agility in the necessary repairs. System employees are quickly contacted, and materials needed for repairs are usually in stock. In that regard, Pereira and Morais (2020) also cited the rapid interaction between consumers and the water utility, and the monitoring of the rate of use and

inventory control of materials and equipment as examples of strategic measures for improvements in water distribution systems, being the SQPA in line with these recommendations.

The newly constructed catchment system was also considered a strength of the system (classification 9). In general, systems with younger ages have less need for maintenance and repairs, mainly of a corrective nature. In this way, the new reservoir results in a simplified maintenance policy with reactive management strategies. As the pipeline ages and the failure episodes become more constant, maintenance management becomes more complex (HERNÁNDEZ *et al.*, 2018).

Cited as a strength with classification 3, the support of the municipal administration for the management of the system is fundamental, not only in the economic aspect but also in the creation of public policies that promote the preservation of this resource. According to da Silva *et al.* (2019), these policies can be tax incentives, thus encouraging other organizations to act in favor of these works.

Also mentioned as strengths were the qualification of employees when they joined the system, and their dedication, both with a rating of 3. Toledo *et al.* (2020) evaluated the influence of professional qualification when getting a job in the municipality of Santana do Livramento - RS. The authors concluded that qualification at this time is a positive point for professionals, as many companies prefer not to train employees, as this action takes time and financial resources. According to Fernandes and De Souza (2022), when studying the motivation and recognition of employees in an educational institution, they found that motivation and commitment directly influence the performance of the professional. These factors determine how employees will strive to achieve their professional goals. To encourage dedication, the authors suggest opportunities for promotion and ensure adequate working conditions. In this way, it is understood that the qualification and dedication of employees are positive factors of the SQPA, contributing to the quality of the service provided.

3.2 Weaknesses

Table 2 presents the factors listed by employees for the weaknesses, still in the internal environment of the system. The group of weaknesses presented the greatest number of elements: about 35% of all factors listed. This is due to the greater diversity of elements presented by the interviewees, and also due to the adjustments that the researchers made, repositioning factors in the group of weaknesses that had been cited as belonging to other groups. This is necessary because, according to Dutra (2014), the factors must be correctly positioned for the best efficiency of the SWOT analysis.

Regarding the weaknesses of the system, the group that presented the greatest prominence was Management, with 10 elements mentioned, followed by Infrastructure and Environment, with 6 and 1 elements, respectively. The single factor for the Environment group may indicate that the system is in line with good environmental practices at the moment. The factor that presented the highest classification was the one that mentions the few financial resources applied to the sector (magnitude 4, degree of importance 3), followed by the factor that deals with the absence of an exclusive team for maintenance (magnitude and degree of importance 3), and the outdated pricing policy (magnitude and degree of importance 3), all of which belonging to the Management group.

According to Pavón *et al.* (2018), problems such as economic restrictions and lack of qualified personnel to manage water supply systems, especially in smaller cities, end up encouraging the entry of the private sector. It is noteworthy that the authors carried out the investigation in a city with a tourist character. Mugabi and Njiru (2006) also drew attention to the same structural disadvantages of these systems in small towns; however, they state that small cities are usually too large for community management approaches to be applied, and too small to attract investment from the private sector. In this work, weaknesses related to the aforementioned problems can be observed: few financial resources applied to the sector (classification 12), absence of an exclusive team for maintenance (classification 9), lack of equipment in the laboratory (classification 8), lack of training for employees (classification 8), lack of space in the laboratory

(classification 6), among others. Currently, the system has only one technical employee with the function of performing system maintenance, connecting new points, cutting supplies, planning and purchasing maintenance materials, which not only serves the municipality's urban areas but also the rural ones. Hence, there is no personnel with exclusive functions to perform the necessary maintenance.

Table 2 – Internal environment - Weaknesses of the Quatropontense Water System

Factor	Magnitude	Degree of importance	Classification	Group
Few financial resources applied to the sector	4	3	12	Management
Absence of an exclusive team for maintenance	3	3	9	Management
Outdated pricing policy	3	3	9	Management
Lack of equipment in the laboratory	4	2	8	Infrastructure
Lack of training for employees	4	2	8	Management
Poor communication between SQPA sectors	3	2	6	Management
Lack of space in the laboratory	3	2	6	Infrastructure
Lack of assessment of production losses	2	3	6	Infrastructure
Divergent information among managers (outdated files, only one employee knows the pipe mapping)	2	3	6	Management
Old plumbing; and employees with no knowledge of where they are or their status	2	3	6	Infrastructure
Small work team: accumulation of functions/overloaded	2	3	6	Management
Attention given to the system only when failures occur: lack of preventive maintenance	2	3	6	Management
Reservoir with pathologies	2	2	4	Infrastructure
High maintenance costs	1	2	2	Infrastructure
Centralized treatment system	1	2	2	Infrastructure
Devaluation of the work provided to the city hall and population	1	2	2	Management

Regarding the price policy gap (classification 9), according to the data provided by the municipality, in 2019, the financial result of the SQPA was negative by R$ 414,940.22. In 2020, the deficit was reduced to negative R$ 268,764.40. Thus, it is noted that the revenues are not enough to balance the costs of the system. As an example, the minimum municipal water tariff in 2021, referring to 10 m³, was R$ 35.20. As a comparison, the main sanitation agency in the state of Paraná, Companhia de Saneamento do Paraná - Sanepar, charged a normal minimum residential tariff of R$ 43.11, referring to 5 m³ (Regulatory Agency for Delegated Public Services of Paraná, 2021), higher value by half the volume supplied. Drinking water must have, according to Ghinis *et al.* (2020), a price that highlights its importance as an essential resource that is likely to be scarce, without becoming excessively expensive, restricting access for part of the population. In this sense, the system's outdated pricing policy can be considered a weakness, because, in addition to not making the system financially sustainable, it may not induce the population to use it rationally, which can generate waste. The values mentioned above also contradict the factor “few financial resources applied to the sector”, as they illustrate the high annual expenses of the municipality with the maintenance of the system. What is observed, however, is that the municipality needs to cover the annual losses generated by the system, which is inefficient in recovering the amount invested through invoices. Mugabi and Njiru (2006) observed the same behavior in their work when assessing the challenges of water management in small towns. Thus, there are no resources left to invest in improvements and innovations. This highlights the need to adjust the applied pricing policy so that the system becomes financially sustainable and resources can be invested in improvements.

Another factor that deserves attention is the lack of assessment of production losses (classification 6). According to Ociepa *et al.* (2019), this - along with the resulting financial losses - has been one of the main problems of water supply systems around the world. Globally, according to AlDairi and Badr (2021), 20 to 30% of all produced water is lost in distribution. In Brazil, this ratio was around 40% for the year 2020 (BRAZIL, 2020b), which is more expressive than the global average. In Quatro Pontes, the

reported loss rate in distribution was 8.59% in 2020, according to the SNIS (BRAZIL, 2020b), however, the real representativeness of this value can be questioned, since the system does not perform the macro-measurement of the total water produced. Furthermore, it should be noted that other weaknesses mentioned may contribute to losses, such as aged pipes and reservoir pathologies, as stated by Pereira and Marques (2020).

Problems related to the transfer of data between authorities involved in water quality monitoring were pointed out as a weakness in the SWOT analysis of the water resources management system of the Island of Crete, Greece (PETOUSI *et al.* , 2017). In Quatro Pontes, similar weaknesses were cited, notably the poor communication between SQPA sectors (classification 6) and divergent information among managers (classification 6). As an example, there are no physical or digital records of the location of new pipes installed, only one of the employees knows the such location. The problem worsens with regard to the old pipes, installed before Quatro Pontes had its own distribution system (the service was provided by a company from another municipality), in this case, none of the servers has exact knowledge of this network location. In this way, it can be understood that there must be an improvement in the registration and transfer of information between the actors involved in the system.

Bereskie *et al.* (2017) reported as a weakness, in the SWOT analysis for municipal water supply systems in Canada, untrained or poorly trained employees. In this work, lack of training (classification 8) for employees was also mentioned. It was found that employees with technical functions directly active in the sector enter the position with training or technical qualification. However, there is a lack of further training offered by the city hall and carried out for the specific activities in which they work, in order to allow the employee to deepen his knowledge and update himself on the new existing techniques. For example, the Dog Attack Prevention course is normally offered to meter readers of supply systems who are exposed daily to the risks of these incidents.

The devaluation of employees was also reported as a weakness of the system. Pereira and Morais (2020) listed as a strategic action to improve water distribution systems the investment in training and recognition of employees, in order to keep them

qualified and committed to their work, or to protect them from accidents. In this way, it is understood that continuous training/qualification and recognition of employees can be important improvements to be implemented.

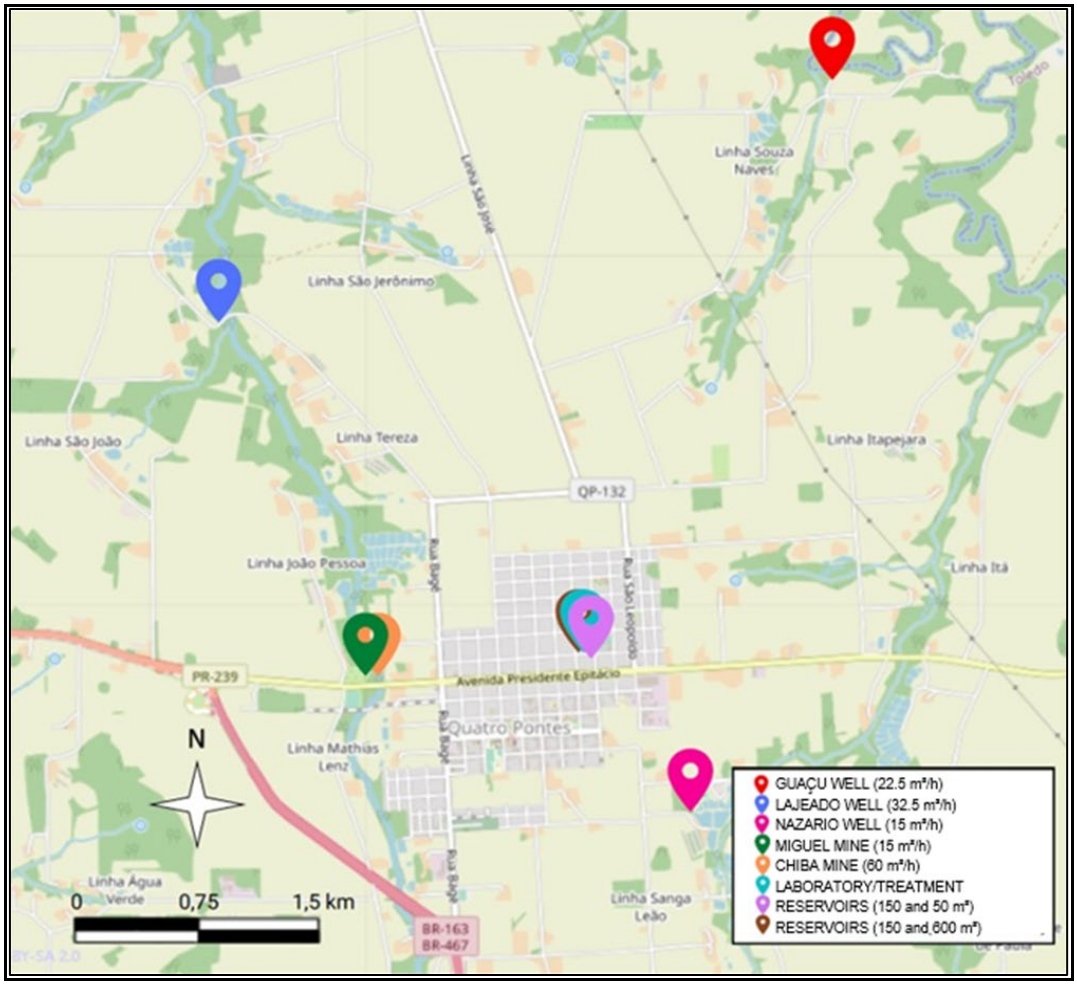
Although maintenance agility was mentioned as a strength in the previous topic, one of the weaknesses listed was the attention given to the system only when failures occur (corrective maintenance), with a lack of preventive maintenance (classification 6). Pereira and Morais (2020) state that when a maintenance program is not well planned and executed, it is susceptible to excessive uncertainties, which harm the system as a whole. Also, according to the authors, through detailed knowledge of the system and implementation of strategic plans, it is possible to reduce losses, minimize operating costs, increase consumer satisfaction and allow the prioritization of preventive maintenance. Gorzoni *et al.* (2019) reported that appropriate and periodic maintenance of the water distribution network of Altônia/PR (6,789 water service connections), along with installation of new water meters, pressure reduction valves and leakages monitoring led to losses reduction of 50%.

The factor "centralized treatment system" (classification 2) was cited as a strength by the system's employees. However, it was decided by the authors to place it in the group of weaknesses. According to Dutra (2014), these adjustments are necessary and beneficial for the SWOT analysis. Figure 2 shows the location of the points of water catchment, treatment and storage in the system.

According to Smirnov *et al.* (2019), in small municipalities, new wells are drilled as they expand and the water demand increases. These are connected to the existing water supply network, creating a centralized supply system with decentralized sources. In Quatro Pontes, the same situation can be seen (Figure 2). Also, according to the authors, there may be a centralized water treatment plant or several local treatment systems in each well, with decentralized systems being more economical and technologically viable. Pooi and Ng (2018) also mention high installation costs as a disadvantage of centralized treatment systems in developing countries and rural areas, because the low population density makes the cost-benefit of this type of structure reduced. Still,

Arora *et al.* (2015) point out that there are currently serious concerns about the long-term technical and environmental feasibility of conventional centralized water supply strategies. The authors state that new systems should invest in decentralized ways that use alternative sources of water, such as rainwater harvesting and recycled water, operating in parallel with conventional centralized water systems, including considering different water qualities, distributed according to the intended use.

Figure 2 – Location of the SQPA's water collection, treatment and reservation points



Source: Adapted from OpenStreetMap© Contributors (2021)

3.3 Opportunities

Table 3 expresses the factors listed by the interviewees to compose the group of opportunities, in the external environment. In this group, 10 factors were mentioned,

of which those belonging to the Management group stood out, which added up to 6 factors. The Environment and Infrastructure groups had 2 factors each. Despite the greater number of factors related to management, it is noteworthy that the factors with the highest classification were, respectively, the abundance of water in the Environment group and the possibility of harvesting rainwater in homes and public buildings, in the Infrastructure group.

The great availability of water was considered an opportunity by Monteiro and Cabral (2018), in the SWOT analysis for groundwater management in the Brazilian state of Piauí. In this work, the abundance of water was also considered as an opportunity, being the factor with the highest classification (18), cited 6 times, with importance degree 3.

Another opportunity mentioned cites the partnership between the municipality of Quatro Pontes and Itaipu Binacional (one of the largest hydroelectric dams in the world), which brings benefits to the supply system. The municipality is part of the Agreement of the Border Municipalities - Sustainable Cities, where Itaipu and the municipalities, together, allocate resources to promote sustainable development. One of the strategies is the implementation of Recycled Recycling Units (UVRs, in Portuguese), where actions that promote the correct destination of solid waste prevent them from contaminating the environment and the city's water sources, providing an environment of hygiene and public health, in addition to driving economic activity (BIESEK; WEBBER, 2018).

According to Athaydes *et al.* (2021), the National Health Foundation (FUNASA, in Portuguese) works in rural communities and municipalities with up to 50,000 inhabitants, being the main agency in the public sector to carry out activities aimed at improving basic sanitation in rural areas of Brazil. In Quatro Pontes, the Foundation has already helped in the creation of the SQPA, in the elaboration of the Municipal Basic Sanitation Plan and in the organization of the management of the system. Thus, since Quatro Pontes has about 4,000 inhabitants, the incentives offered by the entity can be raised, thus being cited as an opportunity for the SQPA.

Table 3 – External environment - Opportunities of the Quatropontense Water System

Factor	Magnitude	Degree of importance	Classification	Group
Abundance of water	6	3	18	Environment
Possibility of harvesting rainwater in homes and public buildings	5	3	15	Infrastructure
Agreement between municipalities bordering the Itaipu lake	4	2	8	Management
FUNASA incentives	4	2	8	Management
City with enough financial resources	3	2	6	Management
Creation of an autarchy	3	2	6	Management
New catchment sources (rivers)	2	3	6	Environment
Population awareness	3	2	6	Management
Existence of new technologies/trainings that can be applied to the SQPA	2	2	4	Management
Use of solar panels to reduce energy costs	1	2	2	Infrastructure

The factor “city with enough financial resources” was cited as an opportunity, however, one of the weaknesses of the system is “few financial resources applied to the sector”. According to Mugabi and Njiru (2006), the supply systems of small towns have limitations that negatively affect their operation. The limitation of investments and financing is one of them, in addition to the ineffectiveness in recovering the amount spent. According to the authors, the costs of implementing and maintaining water supply systems are high, which makes the maintenance of these systems for small towns - such as Quatro Pontes - financially unsustainable. In fact, the financial deficit observed in the SQPA illustrates the annual loss of the municipality with the maintenance of the system. This leads to the conclusion that more investments by the municipality would

only lead to a greater annual loss to it, since large investments do not pay for themselves due to the small consumer group of small cities, as warned by Mugabi and Njiru (2006).

As for the "creation of an autarchy" opportunity, it offers advantages, such as the financial resources that, collected through the water tariffs, would remain in the sector, and could be reinvested. In addition, an autarchy has administrative autonomy to carry out the actions it deems necessary and fulfill the objectives proposed by the administration (MARTINS, 2019). This action is, however, a decision that brings with it political issues to be considered, since the implementation of an autarchy could generate political friction due to the likely increase in the water bill. However, the issue of the negative financial results that the SQPA currently presents could be resolved. Still, with a salary policy of its own, tenders could be opened for the hiring of specialized technical personnel, with more attractive salaries. In addition, the system would still be linked to the city hall, and the administration would be local, maintaining the ease of communication and proximity that consumers have with the administrative sector.

According to Guimarães *et al.* (2007), the purpose of catchment is to create conditions for water to be extracted in a quantity capable of meeting the demand and, in a quality that requires the most simplified treatment possible. Also, according to the authors, to choose the source of supply, one must take into account, in addition to the quantity and quality of water, the costs, both installation and operation for the project period. In relation to supply sources, in Brazil, 43% of the cities are supplied exclusively by surface sources, 40% are supplied exclusively by underground sources and 17% have mixed supply. Despite relatively similar percentages, exclusively surface springs supply 49% of the population, while exclusively underground springs supply only 12% (National Water and Sanitation Agency, 2021), thus showing the lower capacity of the latter compared to the former, as corroborated by Shammas and Wang (2013), who reports that groundwater has better quality and lower associated cost, however, in general, it has a lower capacity. Currently, water abstraction for the SQPA is carried out via an

underground spring. In view of the above, considering future scenarios with a high demand for water, the capture of surface springs can be an option, so it was considered an opportunity in the SWOT Matrix elaborated.

In addition to surface and underground springs, water can be obtained through rainfall. Chaib *et al.* (2015) evaluated the possibility of rainwater harvesting in residential buildings in Belo Horizonte - MG, and concluded that the implementation of reuse systems such as cisterns is an effective alternative for reducing drinking water consumption in urban environments. Da Silva *et al.* (2021) studied, through simulations, the potential of harvesting rainwater in thirteen municipalities in the Brazilian state of Paraíba, concluding that this may be a viable alternative to reduce the demand for drinking water and consequently promote an increase in urban resilience in the region. Garcia *et al.* (2015) emphasize the need for awareness and individual responsibility of the population to play an active role in water conservation, to ensure the availability of this resource for future generations. In this work, the possibility of rainwater harvesting was cited as an opportunity with classification 15, the second highest, having a magnitude of 5 and importance degree 3.

The use of campaigns to raise awareness of the population regarding the rational use of water was cited as an opportunity with magnitude 3 and a degree of importance 2. Silva and Teixeira (2015) analyzed the influence of the use of collective awareness campaigns regarding the use of water in condominiums in São Paulo. By applying these campaigns, they observed positive results in the reduction of waste. These campaigns should be carried out in various sectors of society, and, according to Miranda *et al.* (2021), environmental education for children at school is the best alternative to make the population aware of the conscious use of water. In this way, it is understood that the execution of environmental education projects can be beneficial to the municipality.

As for the opportunity for new technologies and training that can be applied to the system, Ribeiro (2013) highlights the growing demand for innovation in processes and products, to increase the competitive capacity of organizations, in the sense of optimizing the services provided. Nagara *et al.* (2015) report as an opportunity, in a SWOT

analysis, that technological innovation has led to cheaper and better tubular wells and mechanical pumps. Smirnov *et al.* (2019) cited as examples of technological advances in water supply systems for small municipalities, the implementation of an integrated production process control system, modular treatment stations, ozonation and membrane filtration. In this way, it is believed that such advances can also be considered for application in the SQPA, if there is a need and economic feasibility.

According to Lee *et al.* (2017), the water-energy relationship, also called the water-energy nexus, is one of the key points for sustainable strategic planning. Water supply systems are one of the main consumers of electricity. Worldwide, 7% of all energy produced is spent on the water supply (GUANAIS; COHIM; MEDEIROS, 2017). Thus, attention is drawn to the factor that deals with the use of photovoltaic panels to reduce energy costs, of magnitude 1 and degree of importance 2. Aliyu *et al.* (2018) evaluated the use of photovoltaic panels for pumping water for irrigation and domestic use. They concluded that, although photovoltaic systems have a high initial investment, their use is economically viable, with low maintenance costs, in addition to being a clean and carbon-free energy source. The implementation of this technology can be an opportunity for the SQPA, especially if it results in economic gains, given the problem of the system's financial result.

In general, when the strengths are confronted with the opportunities of a system, there is a scenario of competitive advantages, where the strengths must be used to achieve the opportunities and highlight the system in the market. On the other hand, the confrontation of weaknesses with opportunities demonstrates a scenario of reorientation, where opportunities may be being lost due to internal failures (DUTRA, 2014).

Thus, in Quatro Pontes, opportunities such as the abundance of water in the region can be seen, which is enhanced by the quality water delivered to the population, resulting in a system that provides a quality service. The use of rainwater (opportunities) can be encouraged by the municipal administration, as in the municipality of Francisco Beltrão (GOIS; MELO, 2020), which can also install cisterns in its own buildings, using the strength of the support of the municipal administration with the system. The

Agreement signed with Itaipu Binacional and the incentives of FUNASA demonstrates the use of this same strength, also placing the SQPA in a prominent position with the use of strengths to seize opportunities. A need for reorientation lies in the existence of new technologies and training (opportunities) that are no longer taken advantage of due to the lack of training offered to employees (weaknesses). It is observed that few opportunities are not taken advantage of due to weaknesses, and that the use of strengths has been used to put the system in a position where it can be aggressive in its strategies.

3.4 Threats

Table 4 presents the factors cited by SQPA employees as threats to the system, and also in the external environment. In this group, 11 factors were mentioned, of which the Environment group stands out, with 5 factors. It is noticed that although there is only 1 factor related to the environment in the weaknesses, the scenario changes when migrating to the threats, a fact that deserves attention. The Management group presented 4 factors, and the Infrastructure group, 2 factors.

As can be seen in Table 4, the factor with the highest classification was the one that deals with the waste of water by population, from the Management group, followed by the one that cites the contamination of water by the use of pesticides and by the one that deals with the increasingly constant droughts - both from the Environment group.

Cunha and Guedes (2019) report the irrational use of water, in addition to poor distribution and pollution, as limiting factors to access to this natural resource. There is a great waste of water in the disposal of human waste, and the toilets are responsible for 14.9 to 49.8% of water consumption in a residence. The awareness of the population, mentioned in this work as an opportunity, is an essential instrument to change this scenario. There are saving technologies that can reduce wasted water, such as the use of dual flushes, which are independent of changes in users' habits (CUNHA;

GUEDES, 2019). Smirnov *et al.* (2019) propose the reduction of specific water consumption in the residential sector as a measure (among others) that leads to the modernization and development of the water supply system in small municipalities. Reuse of water also fights waste. Macedonio *et al.* (2012) claim that water reuse is essential nowadays, being widely used to supply water for irrigation, industrial processes, and groundwater recharge, and has been accepted as a method for indirect production of drinking water. In this way, it is observed that there are means that can be used to mitigate the threat related to the waste of water by the population.

The threat related to soil contamination by pesticides is quite relevant in the scenario in which the municipality fits, since, according to the Paraná Institute of Economic and Social Development (2022), there is considerable agricultural activity in the region. Almeida *et al.* (2019) point out that, in Brazil, little is invested in environmental education, which may justify the neglect of part of the population regarding these issues, leading to the use of these compounds often without proper care for the surrounding environmental resources. According to Silveira *et al.* (2020), while the national average pesticide use is 4 kg ha^{-1} $year^{-1}$, in the Paraná state, this value rises to 10 kg ha^{-1} $year^{-1}$. In the western region of the state, where Quatro Pontes is located, this value is even higher: 23 kg ha^{-1} $year^{-1}$. When released, the first destination of the active ingredients of pesticides is the soil. From there, they can percolate until they reach the reservoirs through fractures and pores, especially the principles that have more affinity with organic matter and dissolve more easily (STEFFEN; STEFFEN; ANTONIOLLI, 2011).

Table 4 – External environment - Threats of the Quatropontense Water System

Factor	Magnitude	Degree of importance	Classification	Group
Waste of water by the population	8	3	24	Management
Water contamination (pesticides)	7	3	21	Environment
Increasingly constant droughts	5	3	15	Environment

Clandestine connections	3	2	6	Management
Inappropriate legislation for small town	2	3	6	Management
Lack of sewage collection and treatment	2	3	6	Infrastructure
Too many new private wells	2	3	6	Environment
Decreased vegetation cover and carelessness with springs	2	2	4	Environment
Excessive increase in livestock production: which consume a lot of drinking water and contaminate the soil	1	3	3	Environment
Accelerated growth of the municipality	1	2	2	Infrastructure
Dismissal of dedicated employees	1	1	1	Management

Despite studies showing a low percentage of pesticides in groundwater, Steffen *et al.* (2011) point out that analyses carried out to detect pesticides in both groundwater and surface waters are often ineffective. This is due to the fact that only 20 of the more than 400 active principles distributed in the 700 brands of pesticides sold in the state of Paraná are monitored. Human exposure to pesticides can cause allergies, gastrointestinal, respiratory, endocrine, reproductive, neurological disorders, mental disorders, suicides, and cancer (RUTHS; RIZZOTO; MACHINESKI, 2019). Hence, soil contamination by pesticides can be considered a threat to the system. It is noteworthy that according to the collaborators, the analyzes regarding water quality are constant and the current results do not point to water contamination by pesticides.

As in this work, the concern with longer periods of drought was also cited as a threat in the SWOT Matrix developed by Petousi *et al.* (2017), being related to climate change. Mullin (2020) highlights droughts as a key factor in water insecurity. According to the author, droughts present numerous challenges to the management of water supply systems, such as the reduction of water availability and quality, with an increase in

the microbial rate and an increase in organic particles. Thus, the factor “increasingly constant droughts” cited as a threat to the system is justified.

The factor related to clandestine connections, mentioned 3 times by the collaborators, can also be considered a threat, since, according to Piechnicki *et al.* (2011), they can considerably contribute to water losses. Also, according to the authors, this type of connection consists of bypassing the water meter or by clandestine derivation in the network. On the other hand, Monteiro and Cabral (2018) considered as a weakness (rather than a threat) a large number of irregular users, in a SWOT Matrix designed for the management of groundwater in Piauí. In this way, it can be seen that the current threat, if not mitigated, can become a weakness in a future scenario.

The lack of sewage collection and treatment was also cited as a threat. Currently, there is no public sewage collection in the municipality, the inhabitants use individual solutions (septic tanks) in their homes. According to Oliveira and Von Sperling (2011), in these static treatment systems, after the process of sedimentation and anaerobic digestion, the effluent infiltrates the soil. Also, according to the authors, the percolated liquid contains a high number of microorganisms of fecal origin (which may include pathogens), nitrogen (converted to nitrate in the soil) and other salts. Thus, the groundwater that receives it may be contaminated, causing problems if it is used directly for supply. In addition, there is the possibility of contaminated groundwater entering the supply network itself, in the event of underpressure problems, which may compromise the quality of the water supplied. It is noteworthy that factors such as water level depth, soil type (mainly in relation to infiltration capacity) and the number of septic tanks in a given area can influence the aforementioned effects.

According to Macedonio *et al.* (2012), freshwater consumption increased six times between the years 1900 and 1995, more than double the population growth, drawing attention to the need for conscious use. Nagara *et al.* (2015) pointed out that the general availability of water resources can be affected if there are several wells in the same watershed. This aspect was considered a threat in the SWOT analysis of water resources solutions in Asia and Africa. In this work, the excess of new private wells was

also reported as a threat. Pereira and Marques (2019) cited population growth as a threat in a SWOT analysis for water management for irrigation in Portugal, in this work, the accelerated growth of the municipality was also cited as such.

The threat related to the reduction of vegetation cover and carelessness with springs also deserves attention, since, according to Donadio *et al.* (2005), the presence of remnants of riparian vegetation helps to protect water resources. In the authors' study, for springs with different uses and land occupation in the surroundings, those containing remaining natural vegetation had better water quality than springs with agricultural use around them. Lima *et al.* (2011) also pointed out that the preserved vegetation cover was able to mitigate negative effects on the quality of groundwater in the district of Tamoios, Cabo-Frio - RJ.

As previously reported, Quatro Pontes has significant livestock activity, with an emphasis on the raising of pigs, chickens and cattle (Paraná Institute for Economic and Social Development, 2022). The increase in animal production was cited as a threat in this work. These animals produce waste during their life cycle, which, when disposed of without treatment, can compromise water sources due to chemical and bacteriological contamination. These contaminations are not restricted only to the place of release, since these water bodies can cross several municipalities (NOLASCO; BAGGIO; GRIEBELER, 2005). It is noteworthy that there are local laws that regulate the disposal of this waste, such as Resolution SEDEST No. 15 (PARANÁ, 2020a) and SEDEST No. 16 (PARANÁ, 2020b). However, there is a possibility that some producers do not respect them, thus configuring a threat to the system.

The analysis of threats confronted with system strengths leads to the emergence of defense mechanisms that must be used to avoid and minimize existing threats. When threats are confronted with weaknesses, you have a negative scenario for the organization. Weaknesses must be minimized or even eliminated, and threats must be prevented and kept away (DUTRA, 2014).

Defense mechanisms against the lack of water resulting from droughts (threats) can be found in the agility of the execution of maintenance services (strengths), combined with planning so that there is no shortage of materials for maintenance (strengths), as well as the fact that the maintenance is facilitated (strengths), the catchment system is newly built (strengths), with less risk of failure, and the hotline for emergencies and calls for maintenance (strengths). All these mechanisms reduce the volume of water lost in the event of a rupture, minimizing the aforementioned threat. On the other hand, the lack of assessment of production losses (weaknesses) enhances this threat, so this weakness must be eliminated by performing macro measurements of all produced water. The waste of water by the population (threats) results in a negative scenario when related to the outdated pricing policy (weaknesses). In this case, it is up to the system to mitigate this weakness, updating its pricing policy to an economically viable value, and thus minimizing waste.

4 CONCLUSIONS

Based on the results obtained, this work achieved the proposed objective: to present the diagnosis of the water supply system in the municipality of Quatro Pontes - PR through SWOT analysis. This analysis methodology was proved to be a useful tool to evaluate an organization, starting from the mapping of its internal and external environments.

The analysis was based on the determination and discussion of the factors that make up the strengths and weaknesses in the internal environment, and opportunities and threats in the external environment of the system. These factors covered the areas of supply system infrastructure, management and labor, in addition to aspects related to the environment. As for the number of factors identified, 10 strengths, 16 weaknesses, 10 opportunities and 11 threats to the system were listed. The number of weaknesses stands out from the others, suggesting that greater attention should be paid to minimizing these factors.

Internal and external environments were interrelated for the development of improvement suggestions, which can be used in the elaboration of a strategic plan that

aims to mitigate weaknesses and threats, and boost strengths by taking advantage of the aforementioned opportunities. The outstanding factors include, among the strengths, the treatment with hypochlorite produced in the municipality itself, the quality of the water produced and the ease of maintenance, mainly due to the small size of the municipality. Among the weaknesses, the few financial resources applied to the sector, the absence of an exclusive team for maintenance and the outdated pricing policy were highlighted. As for opportunities, the most important were the abundance of available water and the possibility of capturing rainwater. Finally, for threats, the waste of water by the population and the contamination of this resource by pesticides stood out.

With this work, it was possible to verify the benefits of the SWOT analysis, such as its efficiency and ease of application, being the tool capable of raising relevant information for a public organization such as the SQPA, revealing the problems and challenges faced so that the administration can work in the decision-making about them.

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