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Scientific Paper

Identification of potential hazards in rural alternative collective water supply solutions for the preparation of Water Safety Plans: an adaptation proposal

Identificação de perigos potenciais em soluções alternativas coletivas rurais de abastecimento de água para a elaboração de Planos de Segurança da Água: proposta de adaptação

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ABSTRACT

The drinking-water safety framework presented by the World Health Organization and included in Brazilian legislation is based on the management of health risks, with the preparation of Water Safety Plans (WSP). In Brazil, about 29.9 million people live in rural locations, of which 72.7% depend on alternative supply solutions. Despite existing efforts in applying WSPs in small communities, there is still a gap in official materials directed to small-scale supply systems. This study contributes to fulfill this gap with a methodological framework to adapt existing evaluation tools aimed at improving WSPs to assess risk in the context of Brazilian alternative collective solutions (SACs) located in rural areas. The adapted proposed methodology identifies potential hazards having a SAC in the municipality of Travesseiro (state of Rio Grande do Sul, Brazil) as a case study. The results of this process highlighted the importance of evaluating small SACs, where insufficient data on the supply infrastructure, scarcity of implemented control measures and the absence of monitoring at all levels are still common. We also explore how improvement planning within the scope of the construction of simplified WSPs can be integrated to produce data to support the instruments of water resources management and investments in sanitation. Finally, the results also support the creation of a national database to identify potential hazards and the argument for the extension of the assessment to the entire supply coverage, allowing such hazard mapping to inform decision-making.

Keywords: risk assessment; rural sanitation; small-scale drinking water supply.

RESUMO

A estrutura de segurança da água para consumo humano proposta pela Organização Mundial da Saúde e incluída na legislação brasileira baseia-se na gestão de riscos à saúde, com a elaboração de Planos de Segurança da Água (PSA). No Brasil, 29,9 milhões de pessoas residem em localidades rurais. Delas, 72,7% dependem de soluções alternativas de abastecimento e, embora existam iniciativas de aplicação de PSA em pequenas comunidades, permanecem lacunas de materiais oficiais direcionados a sistemas de pequeno porte. Este trabalho tem como principal contribuição a adaptação das ferramentas metodológicas que compõem a elaboração dos PSA à avaliação de riscos no contexto das soluções alternativas coletivas (SAC) localizadas em áreas rurais. Foi aplicada uma metodologia adaptada de identificação de perigos a uma SAC do município de Travesseiro (RS). Os resultados evidenciaram a importância da avaliação de sistemas desse tipo refletida na insuficiência de dados sobre a infraestrutura de abastecimento, a escassez de medidas de controle implementadas e a ausência de sistemas de monitoramento em todos os níveis. Destacou-se a potencialidade do planejamento de melhorias no âmbito do desenvolvimento de PSA simplificados e da produção de subsídios para os instrumentos de gestão de recursos hídricos e investimentos em saneamento. Finalmente, os resultados substanciam a construção de banco de dados nacional para a identificação de perigos e de que a avaliação seja estendida a toda a cobertura de abastecimento, permitindo que o mapeamento de perigos informe a tomada de decisões.

Palavras-chave: avaliação de riscos; saneamento rural; abastecimento de água de pequeno porte.

INTRODUCTION

Access to reliably safe drinking-water is globally considered a human right, thus being recognized by the United Nations (UN) in 2010, and its universalization has been among the organization's Sustainable Development Goals since 2015 (WHO, 2017). The World Health Organization (WHO) considers safe drinking--water management to be composed of a locally accessible service, available

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when needed and free from contamination; until 2017, 53% of the world's rural population had supply coverage that complied with those criteria, with the gap between rural and urban services decreasing 15%. Meanwhile, in Brazil, 8% of the rural population (over 2,3 million people) still lacked improved access to water supply (WHO/UNICEF, 2019).

The supply structures described within Brazilian legislation are categorized as either water supply systems (*sistema de abastecimento de água* — SAA), alternative collective solutions (*solução alternativa coletiva* — SAC) or alternative individual solutions (*solução alternativa individual* — SAI); both SAAs and SACs being of collective use and differing in the existence or not of a distribution network, absent in SACs.

According to the 2010 Demographic Census, about 29.9 million people live in rural areas, of which 72.7% depend on alternative supply solutions (IBGE, 2012). Rural SACs in the state of Rio Grande do Sul face challenges such as lack of economic self-sufficiency, distrust of the population in relation to chlorination processes and limited technical and administrative municipal resources (HÄGGQVIST; LARSSON, 2020).

The WHO's drinking-water safety framework is based on health risk management and includes the establishment of health goals by governmental agencies, the preparation of Water Safety Plans (WSPs) by suppliers and independent monitoring upon final samples (WHO, 2023). In general terms, WSPs are instruments that seek to identify and prioritize hazards and risks in a supply system, from the source to the consumer. Based on this identification, the plan establishes control measures and preventive management procedures to reduce or eliminate risks (BRASIL, 2013).

Since the challenges in introducing the methodology in communities served by small supply systems, possibly in situations of social vulnerability, are different from those faced in other conditions, case studies have been carried out in several contexts of this category (HASAN; HICKING; DAVID, 2011; LANE *et al.*, 2022; LI *et al.*, 2020; MUREI *et al.*, 2022) and simplified operating manuals have been published (WHO, 2012; RICKERT *et al.*, 2014).

Brazilian general guidelines for WSP preparation were first published in 2012 by the Ministry of Health, with a focus on urban and medium to large scale supply systems (BRASIL, 2013). The methods of identifying potential hazards as a step in a semi-quantitative risk assessment are of low complexity and require the participation of people acquainted with the system. Approaches such as brainstorming sessions, collection of data from past experiences, checklists of specific hazards and potential accident scenarios or a combination of strategies may be applied (BEUKEN *et al.*, 2008).

Ventura, Vaz Filho and Nascimento (2019) described the adaptation of the methodology to a Water Treatment Plant in São Paulo and identified the existence of similar projects in several municipalities in the south and southeast of the country. Although there have been Brazilian initiatives focusing on small communities (CORRÊA; VENTURA, 2020; BARACHO; NAJBERG; SCALIZE, 2023), there are still gaps in official materials aimed at small systems, isolated communities or collective alternative solutions with groundwater sources (BRASIL, 2013); such documents must take under consideration the specificities of the target group, and its circumstances (FERRERO *et al.*, 2019).

Considering the gaps in WSP for small systems and the importance of these systems in the national and state contexts, the present work aims to contribute to the adaptation of the WSP national guidelines considering the specific challenges of small supply systems. This result should aid operational monitoring protocols and improvement planning within the scope of the development of simplified WSPs. The guiding question for the development of this project, therefore, was: How to adapt the methodological tools that make up the preparation of WSPs to risk assessment in the context of SACs located in rural areas?

METHOD

A WSP methodology following the Brazilian guidelines (BRASIL, 2013) was adjusted to the target of this study. Whenever necessary, the Water Safety Planning for Small Community Water Supplies (WHO, 2012) was consulted. The target area of the study was the rural water supply run by Associação Três Saltos e São João, in the municipality of Travesseiro (state of Rio Grande do Sul — RS).

The research work steps followed were:

- analysis of the WSP method in view of the SACs particularities and identification of relevant alterations;
- employment of the altered method in a study site which encompasses the peculiarities of the SACs;
- discussion of the benefits and limitations of the approach and proposal of adaptations.

Analysis of the Water Safety Plan method in view of the peculiarities of the alternative collective solutions and identification of relevant alterations

The flowchart for the development of a WSP suggested by the Ministry of Health was adapted for the execution of this project; as illustrated by Figure 1, the guideline's preliminary and system assessment steps were taken into account, the latter of which had two following substeps suppressed (here depicted in light gray). As one of its source materials, Portugal's guidelines published by Vieira and Morais (2005) were taken into account for the system descriptions. Based on the descriptions of the SAC, flow diagrams were constructed illustrating the stages of the system. The primary local documents consulted included the municipal basic sanitation plan (TRAVESSEIRO, 2019) and the technical reports on which the current Watershed Management Plan (RIO GRANDE DO SUL, 2012) was based.

Due to the absence of consolidated models and specific guidelines for this stage, the identification of hazards and hazardous events was performed using the checklist methodology by Beuken *et al.* (2008), of which the Techneau Hazard Database (THDB) is a product. The checklist's items include the subsystems from the water source to the consumer's tap, the organization of the system as a whole and the anticipation of future problems.

Employment of the altered method in a study site

The selection of the study site was based on data collected by the 2010 Census (IBGE, 2012) and data from the Brazilian Drinking-water Quality Surveillance Information System (Sisagua), available through the government's transparency portal (BRASIL, 2020b). Municipalities covered by the health surveillance team of the 16th Regional Health Coordination Office that met at least two of the criteria were selected: a high proportion of population residing in rural areas (over 50%); one or more SACs with groundwater sources distributed without treatment; irregular samples according to the standards of current legislation analyzed in 2020.

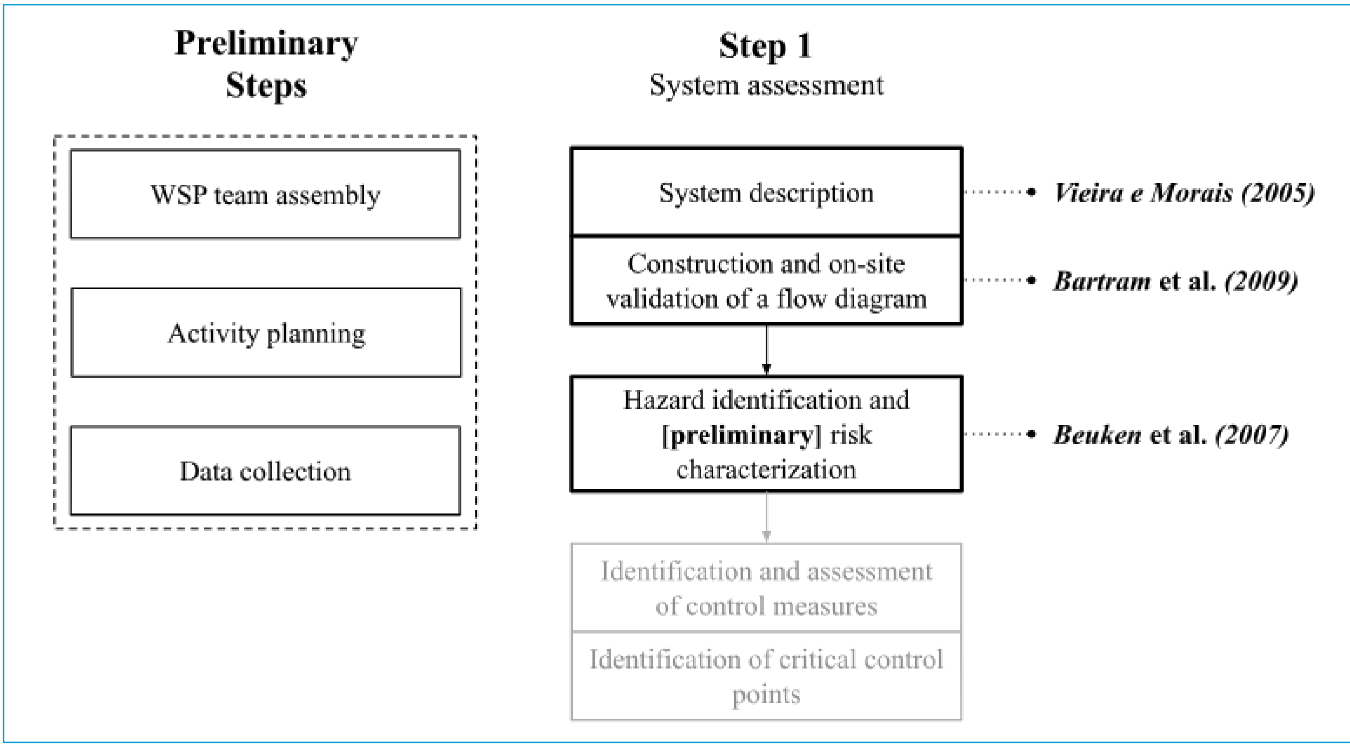

Figure 1 – Adapted flowchart for the identification of potential hazards.

The study focuses on the SACs located in the rural areas of the municipality of Travesseiro/RS (29°17'S, 52°03'W). The entire extension of the municipality is part of the Arroio Forqueta basin, and is therefore covered by the Taquari-Antas Watershed Committee. Travesseiro has a current estimated population of 2,334 inhabitants, 61.7% of which live in rural areas, whose water supply is entirely managed by community associations (TRAVESSEIRO, 2019). Taking into account the project development time and the limitations imposed by the COVID-19 pandemic, the study site was restricted to a single rural SAC presenting irregularities in the surveillance analysis results (Associação Três Saltos e São João).

RESULTS AND DISCUSSION

Analysis of the Water Safety Plan method in view of the peculiarities of the alternative collective solutions and identification of relevant alterations

Vieira and Morais (2005) suggest the employment of three information sets: set A, comprised of information related to the river basin and water source; set B, of data related to the catchment and treatment units; and set C, of data relating to storage and distribution systems.

The hazard identification methodology by Beuken *et al.* (2008) was altered taking into account the study context and the WHO recommendations for the development of WSPs in small communities, resulting in the suppression of bottom-up steps which would result in an initial hazard list based on the opinions of experts in the system. After selecting the THDB sections to be applied in the identification session, the items were categorized according to the sets of information proposed by Vieira and Morais (2005) as employed in the system description.

The methodology allows for a preliminary qualitative prioritization of risks through the use of checklist alternative markings; the chosen symbols, colors and their definitions were applied as depicted in Chart 1. The definitions employed here were selected based on the Brazilian WSP guidelines, in a simplification of risk management terminology: any hazard presenting a high probability of occurrence or significant severity of consequences was categorized as likely high risk, while other less pressing hazards that were present but still unrecognized by the supplier were categorized as likely low risk.

Employment of the altered method in a study site

In the system description stage, a distinct lack of publicly available information about the supply infrastructure was detected. Difficulties in WSP implementation, as highlighted by Tsitsifli and Tsoukalas (2021), such as inadequate documentation, absence of monitoring, lack of staff experience were encountered during this process.

When identifying hazards already recognized by the supplier, two types of barriers were considered control measures in operation: the monitoring of surface water quality and strategies to improve the classification of watercourses established in the Taquari-Antas Watershed Management Plan; and the monitoring of water quality carried out by the company responsible for the system's technical operation.

A total of 152 items were evaluated, distributed among the three sets of data and five classifications used, as illustrated in Figure 2 for a better visualization of the contrast between each set. Approximately one third of the potential hazards were considered irrelevant for this system; among the potential hazards identified, most (approximately 72%) were considered likely to be high risk, while only three had a barrier in place; in addition, the 15 items that could not be classified due to lack of data were part of the datasets referring to the SAC structure itself.

Chart 1 – Markings adopted in the identification of potential hazards.

Symb.	Color	Definition by Beuken *et al.* (2008)	Definition by the Brazilian Health Ministry (BRASIL, 2013)
	Blank	Non-existent hazard or hazard with negligible risk.	-
1	*Green*	Hazard recognized by the supplier; control measures are already in place.	Tolerable risk hazard to be controlled by routine procedures.
2	*Yellow*	Likely low risk hazard that still demands attention.	Moderate risk hazard that requires the adoption of control measures and, when necessary, specific monitoring procedures.
3	*Red*	Likely high risk hazard.	High risk hazard that requires the adoption of control measures and, when necessary, specific monitoring procedures.
X	*Blue*	Insufficient data.	-

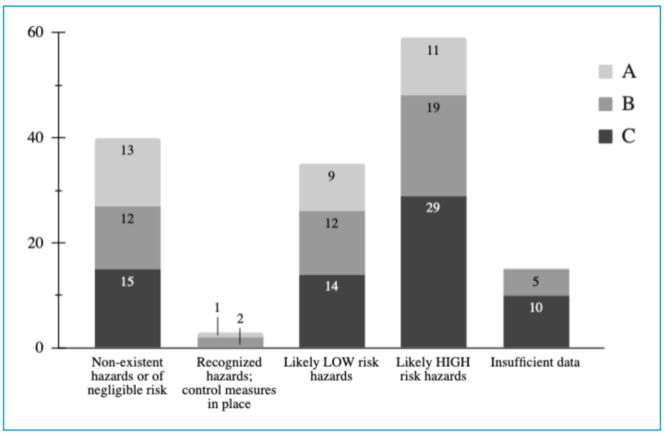

Figure 2 – Distribution of hazards as identified through the supply system's stages: (A) hydrographic basin and aquifer, (B) catchment and (C) treatment systems and storage and distribution systems.

Since there was no identification of potential hazards to the system that were not somehow contained in the THDB, the listing was considered comprehensive enough for application in similar systems; it is possible, however, that additional items may be surveyed when there is enough data to describe the structures in detail. Nonetheless, it is preferable that the methodology be adaptable to the lack of technical data in the case of small supply systems, which is a frequent challenge (WHO, 2012).

As a result of the lack of information available for the system description, the assessment of 15 potential hazards was considered infeasible due to insufficient data. A low proportion of hazards already recognized by the supplier was observed throughout the system, which originates from the scarcity of control measures in operation; currently the main barrier to contamination is the disinfection process, about which no information is available to the public, which is a hindering factor also observed in other countries (GUNNARSDOTTIR *et al.*, 2020).

Due to the absence of raw water monitoring systems at the source and catchment unit, hazards related to failure at these points were considered nonexistent. Monitoring carried out by the technical managers, which must be fed into Sisagua by the outsourced company in the case of SACs, is also absent in most cases (OLIVEIRA JÚNIOR *et al.*, 2019; BRASIL, 2020b), and this information is a vital part of the WHO's water safety framework (WHO, 2023). The lack of effective monitoring of water quality is frequently observed in the case of small systems, given the low sampling frequency due to labor restrictions (VIEIRA, 2011; LI *et al.*, 2020).

The results allowed for two main routes of discussion: the applicability of the methodology as a step in the preparation of WSPs and the relevance of the data produced by the analysis in the contexts of water resources management and basic sanitation. Finally, the discussion led to the proposal of adaptations to the current guidelines related to risk management in SACs.

Numerous likely high risk hazards were checked in datasets B and C, which represent priorities for risk analysis and identification of critical control points in a WSP; similar distributions have been observed in other peripheral countries such as China and Colombia (LI *et al.*, 2020; PEREZ-VIDAL; ESCOBAR-RIVERA; TORRES-LOZADA, 2020). In the case of Travesseiro, the municipal basic sanitation plan admits the absence of preventive maintenance as a threat to water safety (TRAVESSEIRO, 2019).

Rural sanitation in the area faces challenges such as lack of economic autonomy of supply associations, insufficiency of municipal funds for water supply and sanitary sewage projects and limitation of technical and administrative resources (HÄGGQVIST; LARSSON, 2020); the absence of financial resources and time availability are the most cited challenges to WSP implementation, according to Baracho and Scalize (2023). The implementation of WSPs in small water supplies usually requires external hydrological and meteorological advising, especially when dealing with climate change adaptations (RICKERT *et al.*, 2019), which can have a significant impact on water safety planning in periphery countries (SHAMSUZZOHA; KORMOKER; GHOSH, 2018).

Considering that 10.4% of the state of Rio Grande do Sul uses alternative supply solutions (BRASIL, 2020a) and that currently no SAC in operation has a WSP in place, there is an information gap between sanitation and water resources management that needs to be addressed. By mapping the hazards throughout the collective supply coverage, data is generated that supports the improvement of water management instruments (such as water permits, classification of water bodies, water charges, pollution charges and watershed plans), as well as their integration with investments in sanitation. So far actors implementing WSPs in Brazil have not been able to establish a relationship with the organizations responsible for such instruments (BARACHO; NAJBERG; SCALIZE, 2023).

Improved collaboration between supplier, health and basin agencies has been noted as a benefit of WSP implementation (KAYSER et al., 2019). Identification of more vulnerable areas that would require higher quality standards for raw water quality (through classification of water bodies); tighter control on water permits and pollution charges to curb point source pollution are some examples of a potential intersection between water safety and water resources planning (BARACHO; NAJBERG; SCALIZE, 2023).

Baracho, Najberg and Scalize (2023) have pointed out the absence of a database covering WSP implementation in Brazil as a hindering factor; with that in mind, it is recommended that a national database of potential hazards be built based on the THDB, as also suggested in studies focused on similar community-managed supplies (GUNNARSDOTTIR *et al.*, 2020; LANE *et al.*, 2022; LI *et al.*, 2020). Such a list should be reviewed periodically, including exchanges between the different levels of governance (municipal, state, watershed committee), so that the database be specialized considering the common hazards in each region.

Finally, with the data resulting from the hazard assessment, it is proposed that the mapping of hazards and prioritization of risks, when performed for the entire supply coverage, inform the technical diagnosis in the preparation of different management plans, such as the municipal and state Basic Sanitation Plans and the Watershed Management Plan. It will be thus possible to ensure the use of management instruments so that the demands of the small systems can also be met.

CONCLUSIONS

The research was successful in its objectives by performing an adaptation of the guidelines for the preparation of WSPs to the context of small-scale supply in rural areas, taking into account the peculiarities of the SACs. The research methodology provided satisfactory results, which enabled the discussion.

The methodology for identifying potential hazards adapted to the context of the SACs was considered effective despite the lack of publicly accessible information on the supply infrastructure, and the THDB was considered sufficiently comprehensive for similar systems. The products of the evaluation highlight the challenges faced by small-scale supply, especially with regard to the scarcity of control measures and the absence of operational monitoring of water quality.

In addition, it was possible to justify the preparation of WSPs as a source of technical data and as a record of the demands of small systems within the scope of prioritizing investments in sanitation planned at municipal, state and watershed management levels.

AUTHORS' CONTRIBUTIONS

Fagundes, I.C.: Conceptualization, Data curation, Methodology, Writing – original draft. Marques, G.F.: Supervision, Writing – review & editing.

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