

Technique proposal and application for risk assessment in collective basic sanitation system in rural areas

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ABSTRACT

Nowadays, apply risk assessment processes, from health perspective in all basic sanitation components (water supply, sanitary sewage, solid waste and rainwater management), in order to follow the Resolution 64/292 it is a reality. In this context, this article aimed to propose a risk assessment process (RAP) for collective basic sanitation structures and apply it on a riverside community in Goiás state of Brazil. The steps used included scope definition, technique selection for risk assessment and RAP approach and application. The community studied was Arraial da Ponte, which has collective systems for water supply, solid waste and rainwater management. The selected technique was the probability/consequence matrix, according to the criteria established in NBR IEC/ISO 31010:2021 and proposal included identification stages of RAP risk factors, hazards, contamination route and hazardous events, as well as characterization and risk prioritization. It was based on the components of risk management process of NBR ISO 31000 and on World Health Organization recommendations described for water and sanitary sewage safety plan manuals. As result, health risks were identified in all basic sanitation components, with levels ranging from moderate to unacceptable. The risks showed need for greater attention from managers, as effective public policies implementation. Finally, the RAP managed to prioritize hazardous events and their associated risks, being able to help in the construction of plans and investments in the evaluated community.

KEYWORDS: Small community. Risk assessment. Rural sanitation. Water supply. Rainwater. Solid waste.

1 INTRODUCTION

Safe access to potable water and sanitation system is a human right, recognized by United Nations Resolution 64/292, and essential to improve public health ensuring waterborne diseases prevention and control (UN, 2010). In the world, two billion people need safe access to drinkable water, in addition to 3.6 billion to the sewage service (UN, 2022). In Brazil, beside water supply and sewage, basic sanitation includes solid waste and rainwater management, according Law n. 11,445 (BRASIL, 2007). Those services must be provided based on several principles, including safety, quality, regularity and continuity.

Contact with inadequate basic sanitation or its absence, result in physical, chemical and/or microbiological hazards exposure to population. The latter leads to the prevalence of infectious and parasitic diseases, which can result in health risk (BAZGIR et al., 2020).

According to the World Health Organization (WHO), water as an essential good for life, must be available adequately, including its quality. Appropriate and drinkable water is defined as one that does not offer significant risk to population health that consumes it, assessed by implementation of risk management processes, as essential (WHO, 2017).

In this context, risk assessment applied to water supply (WSS) and sanitary sewage (SSS) systems has been used as a tool in several countries over the world. Pundir et al. (2021) evaluated the risk of a WSS in a rural area based on statistical analysis of water quality parameters, finding relevant results to improve it. Another methodology is the decision tree used in Hazard Analysis and Critical Control Points (HACCP), where Tsitsifli and Tsoukalas (2021) highlighted the technique rigor, which may not be applicable to all basic sanitation systems.

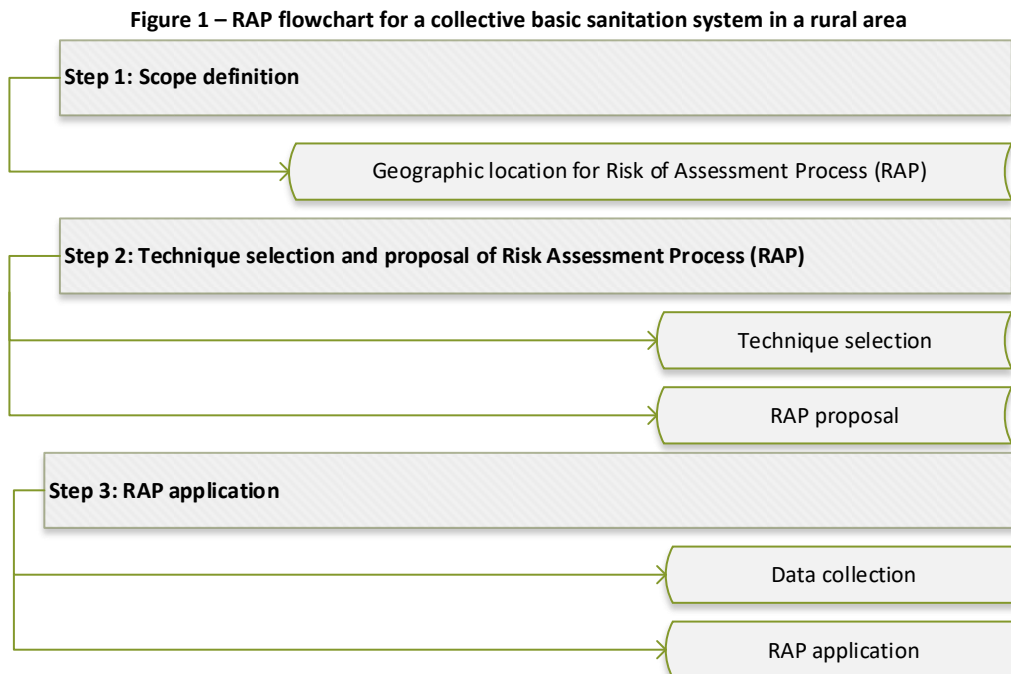
Risk assessment methodologies and processes are not applied exclusively to WSS. Based on the Water Safety Plan (WSP) methodology, WHO adapted them for sanitary sewage (WHO, 2016) and has been applied by Lane et al. (2021), who evaluated centralized and decentralized sanitation systems in Canada, concluding that it is possible to use this type of evaluation for decision-making, regarding management in SSS.

Regarding solid wastes, Lima and Paulo (2018) in their study applied at quilombola communities of Mato Grosso do Sul brazilian state, used preliminary analysis of hazards for management, reporting its adequate efficiency to define safe and sustainable alternatives.

However, the lack of information regarding risk assessment process application including all components of basic sanitation, is notorious. Hence, there is a need to propose a risk assessment process (RAP), from health risk perspective for all sanitation components (water supply, sanitary sewage, solid waste and rainwater management), in order to follow Resolution 64/292 (UN, 2010) and Brazilian legislation (BRASIL, 2021). In this context, this article aimed to propose a risk assessment process for collective basic sanitation structures and apply it in a rural community in the Brazilian state of Goiás.

2 MATERIAL AND METHODS

The risk management process described in the NBR ISO 31000 standard is structured as follows: i) definition of the scope, internal and external context and criteria; ii) risk assessment process (PAR), which integrates risk identification, analysis and assessment; iii) risk treatment; iv) monitoring and critical analysis; and v) registration and reporting (ABNT, 2018). This research included three stages foreseen in this process, the first defines the scope, the second is destined to the selection of the technique for risk assessment and the last one deals with the application of the PAR in a rural area (Figure 1).



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2.1 Step 1: Scope definition

The definition of the coverage area for RAP proposal in a rural area, considered four components of basic sanitation as provided in Law n. 11,445 (BRASIL, 2007), including water supply, sanitary sewage, solid waste and rainwater management. RAP can be applied in a given rural area with one or more basic sanitation components.

2.3 Step 2: RAP proposal and technique selection

The risk assessment technique was selected using NBR IEC/ISO 31010:2021 guidelines (ABNT, 2021): risk management – techniques for risk assessment process. This standard describes 42 risk identification, analysis and assessment techniques. It also provides guidance for selection and application of various techniques that can be used to improve the understanding of uncertainties during risk assessment process.

The basis for WSP elaboration were considered too, recommended on WHO Guidelines for drinking-water quality 4th Edition (GDWQ) (WHO, 2011), and the basis of manual for use and safe disposal of waste water, ash water and waste, called Sanitation Security Plan (SSP) (WHO, 2016), which in Brazil is defined as sanitary sewage. Thus, the adopted criteria were: i) the application; ii) scope; iii) time horizon; iv) need for information and data; v) risk assessment team knowledge and experience; vi) qualitative or quantitative method type; and vii) effort to apply (ABNT, 2021).

Therefore, it was crucial to define the phases for risks identification, analysis and assessment, allowing to develop the RAP proposal, based on risk management process of NBR ISO 31000 steps (ABNT, 2018) and on WHO basis described in the WSP and SSP manuals.

2.4 Step 3: Application of risk assessment process (RAP)

2.4.1 Study area

RAP application was accomplished in Arraial da Ponte riverside community, part of the Project *Saneamento e Saúde Ambiental em Comunidades Rurais e Tradicionais de Goiás* (SanRural Project - <https://sanrural.ufg.br/>), developed by Federal University of Goiás (UFG) and funded by National Health Foundation (FUNASA). The project was duly approved by Research Ethics Committee, CAAE 87784318.2.0000.5083.

The rural area is located 12.0 km away from the urban center of Água Limpa/GO (Figure 2). with 42 households, eight of which belong to the Ribeirinha Arraial da Ponte community, of which six were visited. This rural area was chosen because it has collective basic sanitation infrastructure.

Figure 2 – Geographic location of households belonging to Arraial da Ponte riverside community, Água Limpa-GO.



Font: Created by authors from IBGE (2016), Google Earth (2020), SanRural Project databases.

2.4.2 Data collection and risk assessment

The information used to assess health risks of population exposed to inadequate basic sanitation systems conditions followed methodological criteria published as products within *SanRural* Project scope, which adopted qualitative and quantitative approaches through descriptive, inferential and demography census research (SCALIZE et al., 2020a). Database contained community participatory technical diagnosis (PTD) information, based in: i) clinical health and its characteristics data (PAGOTTO et al., 2020; PAGOTTO et al., 2022); ii) sanitation characteristics (SCALIZE et al., 2020b); iii) water quality (SCALIZE et al., 2022); and iv) water availability (SCALIZE et al., 2021a). Then, the information was systematized, organized in electronic spreadsheets for RAP application, to be presented in tables containing risk factors, hazard, hazardous events and risk assessment.

3 RESULTS AND DISCUSSION

3.1 Scope and technique selection definition for risk assessment process

The scope selected in this research includes drinking water supply system, sanitary sewage, solid waste, and rainwater and drainage management. These criteria were selected regardless whether or not a particular basic sanitation component exists. Intradomiciliary practices that influence the community behavior must be taken into account for risk assessment. For example: improperly disposing of solid waste instead of using the collective collection service when available.

Considering the criteria adopted for selecting risk assessment techniques from ISO/IEC 31010, the probability/consequence matrix was selected as a way to combine qualitative or semi-quantitative classifications of consequences and probabilities, allowing to obtain risk level or classification. This technique is considered a decision-making tool for collective basic sanitation infrastructure (public or private) management, whether in urban or rural areas, where the format and definitions applied to it depend on selected scope. It requires data and information availability of rural sanitation conditions, the knowledge and experience of the team involved, mainly the dedication to apply this technique *in situ*. According to Brasil (2019), it is necessary to understand the ways in which rural, countryside, forest and water populations are organized in their territory. It is also necessary to know its cultural diversity, popular knowledge, manners and traditions and its implication in understanding environmental basic sanitation practices locally adopted and its relationship with health (SCARATTI; BEZERRA, 2020).

In this sense, a semi-qualitative risk assessment technique was chosen, recommended by WHO (WHO, 2011; WHO, 2012; WHO, 2016) and the Brazilian Ministry of Health (BRASIL, 2012). Standards and proposition studies (BARTRAN et al., 2009; ABNT, 2018; ABNT, 2021; BEZERRA, 2018), applied in urban (GODFREY et al.; 2005; BAZGIR et al., 2020) and in rural areas (PUNDIR et al., 2021; MILLER; WHITEHILL; DEERE, 2005; LANE et al., 2021).

3.2 RAP proposal

RAP for health of population exposed to inadequate conditions of collective basic sanitation systems had two steps: i) identification of risk factors, hazards, contamination route and hazardous events; and ii) risk characterization and prioritization.

3.2.1 First phase: Identification of risk factors, hazards, contamination route and hazardous events

To identify risk factors, must be known their sources and their exposure levels. The risk factor concept was based on the epidemiological risk model, which corresponds to some exposure (change in water quality due to reservoirs phytosanitary conditions) that increases the probability of disease or health problem occurrence, which can be part of the causal chain (BARBOSA; MACHADO, 2013). Identification risk factors helps to determine hazardous events and its respective hazard and, consequently, to estimate the probability of these events to be a risk to the exposed population. In this sense, RAP can also contribute to identify and improve the actions and assist managers to define early warning indicators and detect its reference limits (ABNT, 2021).

Therefore, in this phase, RAP begins with risk factors identification for each stage of the basic sanitation components, the hazards (physical, chemical, microbiological and radiological) that can cause damage to human health (BARTRAN et al, 2009; WHO, 2011; WHO, 2016) and its contamination route (ATSDR, 2005; WHO, 2016), as hazardous agent movement from the contamination source to the exposed population. According to ATSDR (2005) the contamination route includes the polluted source, the route of contaminant circulation, the receiving source (point of exposure), the route of exposure and the exposed population.

Hazardous event is an incident or situation, which introduces a hazard to the environment in which humans live or work. According to WHO (2016) it can be identified as follows: a situation “X” occurring due a situation “Y”, where “X” can happen and “Y” is how it can happen. An identified and well-described hazardous event will include a brief commentary, indicating how the hazard might be introduced (what could happen?) and its cause (how can it happen?). As an example, the hazardous event can be described as follows: Exposure of populations to animal excreta in backyards (what?) due to lack of confinement and proper disposal of effluents (cause, reason).

3.2.2 Second phase: risk characterization and prioritization

For each hazardous events identified on first step, the risk level for a population exposed to inadequate collective basic sanitation systems conditions, and its relationship with health is determined producing a list containing the prioritization of risks.

Depending on the risk assessment objective, matrices with different amounts of descriptors (2x2, 3x3, 4x4, 5x5 etc) can be created (BARTRAN et al, 2009; ABNT, 2018; WHO, 2016). In this study, a 5x5 matrix was adopted (Table 1), where one axis contains five (5)

descriptors of the frequency of exposure of humans to a hazardous event; and the other axis with five (5) severity descriptors dealing with the impact on the population health.

The risk assessment procedure for each hazardous events begins determining the frequency (values from 1 to 5) as a function of severity (values from 1 to 10,000), which results in the “risk score”, a semi-quantitative assessment of the risk, calculation by Equation 1.

$$Risk = event\ frequency \times event\ severity \quad (Equation\ 1)$$

Table 1 – Probability/consequence matrix to compute health risks in rural areas

Frequency		Severity				
		1	10	100	1.000	10.000
		No effect	Insignificant	Moderate	High	Critical
5	Daily	Tolerable (5)	Moderate (50)	Unbearable risk (500)	Unbearable risk (5000)	Catastrophic (50000)
4	Weekly	Tolerable (4)	Moderate (40)	Unbearable risk (400)	Unbearable risk (4000)	Catastrophic (40000)
3	Monthly	Tolerable (3)	Moderate (30)	Moderate (300)	Unbearable risk (3000)	Catastrophic (30000)
2	Annually	Tolerable (2)	Tolerable (20)	Moderate (200)	Unbearable risk (2000)	Catastrophic (20000)
1	Over 5 years	Tolerable (1)	Tolerable (10)	Moderate (100)	Unbearable risk (1000)	Catastrophic (10000)

Legend:

Value	Descriptor	Severity meaning
1	Minimum	Adequate conditions of collective basic sanitation systems, regulated and supervised, provided universally, comprehensively and continuously, with quality and without impact on health and the environment
10	Low	Partially adequate conditions of collective basic sanitation systems and minimal impact on health and the environment
100	Moderate	Partially inadequate conditions of collective basic sanitation systems and moderate impact on health and the environment
1000	High	Inadequate conditions of collective basic sanitation systems and high impact on health and the environment
10000	Critical	Inadequate conditions of collective basic sanitation systems with notification of diseases related to inadequate environmental sanitation (DRSAI) that lead to morbidity and mortality

Risk analysis:

Tolerable risk (RT): $RT \leq 20 \Rightarrow$ maintain current control measures.

Moderate risk (RM): $21 < RM \leq 300 \Rightarrow$ level of attention, it is necessary to **PLAN** the adoption of control measures to reduce the risk to tolerable levels.

Untolerable risk (RNT): $301 < RNT \leq 5000 \Rightarrow$ necessary to **PRIORITIZE** the adoption of control measures to reduce risk to tolerable levels.

Critical risk (CR): $RC > 5000 \Rightarrow$ situations with morbidity and mortality for which the **IMMEDIATE** adoption of control measures and/or an emergency plan are necessary to reduce the risk to tolerable levels.

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Frequency and severity identification of health risk level must be developed for each hazardous event. Severity corresponds to the health impact level if the hazardous event occurs (WHO, 2016). Thus, it refers to the ability of a particular hazardous events to cause adverse effects on exposed population health, which can lead to death. It can be measured based on knowledge of adverse health effects, taking as an example the indicator Disability Adjusted Life Years (DALY), which allows to assess health status of a population due to a disease or injury, as it considers the years of life lost due to premature death (mortality) and the years of equivalent healthy life lost (morbidity) due to living in less complete health areas (MURRAY; LOPEZ, 1996).

DALY values can be obtained through research at the Institute for Health Metrics and Evaluation (GBD, 2021), in addition to epidemiological studies of diseases lethality, incidence and severity (ALI et al. 2012; ANDERSON et al., 2019; ARAÚJO et al., 2017; BRASIL, 2020a; BRASIL, 2022a; BRASIL, 2020b). This information help defining the sanitation-related diseases severity, most commonly diagnosed in terms of severity. It has been used at national level, characterized by the lack of health data of rural areas, due to the difficulty in accessing health services.

In order to analyze the degree of severity for each previously identified hazardous events, the questions listed in Table 2 must be answered using the primary data referring to the information collected for each basic sanitation component and the information on the main diseases related to inadequate basic sanitation according to the rate of incidence, lethality, severity and DALY; obtained in literature.

Table 2 – Guiding questions to assess severity of each hazardous event for collective basic sanitation system

Nº	Questions	Aid assess severity elements
Question 1	Do the risk factors favor the occurrence of the hazardous events?	Yes: the risk factor does not comply with legal norms, normative and technical-scientific recommendations No: the risk factor complies with legal norms, normative and technical-scientific recommendations
Question 2	Is the concentration of hazardous agents (physical, chemical and microbiological) (or would it be) at odds with the potability standard?	Good quality: the parameters are in accordance with the potability standard. Bad quality: the parameters are above the potability standard.
Question 3 ⁽¹⁾	Are there vulnerable groups (children, elderly, immunosuppressed) exposed to the hazardous agent?	Vulnerable group: children (individuals under the age of 5); pregnant women and the elderly (over 60 years old) (BRASIL, 2010a)
Question 4	Are there records of health problems and/or diseases related to the event and the hazardous agent in question?	Prevalence of diseases related to inadequate basic sanitation ⁽²⁾ .

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Note: (1) question 3 may raise the severity level if vulnerable groups are present; (2) see list of diseases in scientific literature.

To answer Question 1, it is necessary to verify the adequacy situation of all risk factors defined for each evaluated basic sanitation component. The risk factors correspond to both basic sanitation systems constructive and non-constructive aspects, which influence hazardous events, for example, water collection infrastructure, water treatment through filters, disinfection, sanitary landfill, septic tank, rainwater management devices (little dams, containment basin), among others. Checking whether or not these factors are adequate will allow assessing the severity degree of each hazardous event.

For each risk factor evaluated in disagreement with legal norms, normative and technical-scientific recommendations, Question 2 was analyzed, verifying whether the concentration of hazardous agents is or would be in disagreement with the potability standard. The hazard analysis was executed through water laboratory analysis, aiming to verify concentrations above the maximum value allowed (MVA) in legislation. The results allow evaluating the water conditions as good or bad (Table 2).

Question 3 identifies the existence of vulnerable groups (children, elderly, immunosuppressed) exposed to the hazardous agents. These groups are composed by humans likely to acquire a disease or infection and are, therefore, considered vulnerable as defined in Brasil (2010a).

In the last question, the existence of records of health problems and/or diseases related to the event and any hazardous agent in question was evaluated. The answer can be obtained based on diseases notification, or injuries recorded by family health team or self-reported by residents of rural areas. From the answers obtained in questions 1 to 4, the severity is defined (no effect, insignificant, moderate, high and critical).

The risk calculation is obtained for each hazardous events by multiplying the frequency by the severity using Equation 1. Finally, it is possible to prioritize the calculated risks. With this, it will be possible to prioritize the most hazard risks to rural area residents, who need more and urgent control measures, in order to minimize or eliminate the hazardous events. This prioritization can be done in an electronic or physical spreadsheet.

The risk assessment matrix is simple to apply, providing a classification of risks with different significance levels of (ABNT, 2018). However, its construction and application is characterized by its high subjectivity degree (BEZERRA, 2018) and its use will depend on field work team experience according to the area. The risk matrix application without justification or without guidance to interpret the rows and columns is identified as one of transparency failures in its use (COX JUNIOR, 2008). The matrix caption (Table 1) and the guiding questions (Table 2) help the process evaluators to reduce subjectivity, as they direct the interpretation of the matrix items inducing the evaluator to study and justify the estimated risks, providing greater understanding of what each severity level means. Understanding the risk model, severity levels and event occurrence probability, risk classification inversion errors can be avoided (BAYBUTT, 2016).

3.3 Risk assessment process technique application in a rural area

Based on existing basic sanitation infrastructure description and assessment, in the Arraial da Ponte riverside community; risk factors, hazards, the route of contamination, hazardous events and, finally, risk assessment and prioritization of each component with collective solutions in the community.

3.3.1 Water supply system

Table 3 presents the summary of the results of the identification of five risk factors (RF), and five hazardous events (HE) with their respective WSS risk assessment. The community is supplied 100% by WSS, from an intake through a deep tubular well (DTW), approximately 0.2 m in diameter and 58 m deep (SCALIZE et al., 2020b). The water is captured by a vertical axis submersible motor pump located inside the well.

Both HE01 and HE02 were classified as moderate risk. The classification of HE01 occurred due to reserve pump set or generators absence, which could compromise the supply, in case there is any significant damage to the device or lack of energy, as well as the absence of a raw water collection point. It should be noted that the collection point is in good condition, identified and fenced, despite being easily accessible to all residents of the community. In HE02, human occupations were observed, in addition to reports of the lack of periodic maintenance and cleaning (SCALIZE et al., 2020b), which may contribute to water contamination and supply interruption. It is noteworthy that intermittency in the water supply was not reported and, according to Scalize et al. (2021a), there is underground water availability for water supply purposes.

HE03 was classified as a non-tolerable risk, since the WSS did not carry out treatment (disinfection), which is in disagreement with the requirement of Ordinance MS/GM n. 888 (BRASIL, 2021), requiring disinfection for all collectively supplied water. Must be mentioned that disinfection is an important process for inactivating and/or destroying pathogenic microorganisms, resulting in reduction of health risks, and its absence may be related to the incidence of hepatitis A in 100% of people tested in the community (PAGOTTO et al., 2022).

In rural areas, the absence of treatment processes such as disinfection is a reality, impacting the microbiological quality, which can result in the consumption of contaminated water and, consequently, in diseases such as acute diarrhea (SCALIZE et al., 2021b; BARRAGÁN, CUESTA and SUSA, 2021). For Amaral et al. (2003) the risk of outbreaks of waterborne diseases in rural areas is high, mainly due to the possibility of water bacterial contamination, often captured in deep tubular wells without protection or close to sources of pollution, as occurred in the case of the Canudos Settlement, in Brazil (SCALIZE et al., 2014) and in the rural area of Villapinzon, in Colombia (BARRAGÁN, CUESTA and SUSA, 2021).

Table 3 – Result of the identification of risk factors, hazardous events and risk assessment of the Water Supply System in the Riverside Community Arraial da Ponte, Água Limpa-GO

Risk factor (RF)	Hazard	Hazard Event (HE)	Risk measurement		
			Risk (F x S)	Risk level	Risk level description
Infrastructure conditions of the collection point (RF01)	Microbiological, physical and chemical	Possibility of degradation of water quality due to inadequate infrastructure at the catchment point (HE01).	5 x 100 = 500	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce risk to tolerable levels.
Raw water pipeline conditions (RF02)	Microbiological, physical and chemical	Possibility of water contamination and supply interruption due to the conditions of the water main (HE02).	5 x 100 = 500	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce risk to tolerable levels.
Treatment conditions (RF03)	Microbiological, physical and chemical	Possibility of water distributed outside potability standards due to ineffectiveness and inefficiency of treatment (HE03).	5 x 1000 = 5000	Unbearable risk	It is necessary to PRIORITIZE the adoption of control measures to reduce risk to tolerable levels.
Phytosanitary conditions of the collective reservoir (RF04)	Microbiological, physical and chemical	Possibility of degradation of water quality due to inadequate conditions of the reservoir (HE04)	5 x 100 = 500	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce risk to tolerable levels.
Distribution pipe network conditions (RF05)	Microbiological, physical and chemical	Possibility of water degradation and/or supply interruption due to distribution pipe conditions (HE05).	5 x 100 = 500	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce risk to tolerable levels.

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Note: F= Frequency, S = severity.

Untreated water is sent to a bowl-type reservoir, built in metallic material, with a storage capacity of approximately 15 m³. Regarding the phytosanitary conditions of the collective reservoir (RF04), HE04 was classified as moderate risk due to the lack of maintenance and periodic cleaning and flow measurement mechanism. However, its structure was in good

condition, covered, with overflow and access protection mechanism. This whole scenario, associated with the lack of cleaning inside the reservoirs, may favor the growth of the microbial community, which justifies the HE04.

It should be noted that the results of water quality, distributed to the population after the reservoir, were compatible with predominantly use for human consumption, according to CONAMA Resolution n. 396 (BRASIL, 2008) and met potability standards (BRASIL, 2021). It is important to mention that the WSS did not have a qualified professional for systems management and operations, and the sampling plans were not carried out, both for raw and treated water, as recommended by Ordinance GM/MS n. 888 (BRASIL, 2021).

WSS distribution network is underground and operates as a penstock by gravity, with PVC pipes, with a diameter of 25 and 50 mm and approximately 700 m in length. Although it has presented such characteristics, it does not have frequent maintenance, which may compromise water quality and favor supply interruption (SCALIZE et al., 2020b). Therefore, HE05 was classified as moderate risk. The conditions identified in the risk assessment in HE04 and HE05 are conditions that favor the risk of supplying water outside the potability standard, in addition to the use of other unsafe sources (BAZGIR et al., 2020).

The risk scenario identified in the community can harm the health of residents, intensifying diseases related to basic sanitation and, therefore, clear measures must be prioritized to mitigate the hazardous events occurrence. A similar study was observed by Godfrey et al. (2005), when implementing the WSP, from collected water to the final consumer, of Guntur city, India. The authors highlighted the importance of raising awareness on the part of residents in protecting the water source, in the continuous improvement of WSS operation. Bazgir et al. (2020) reported the need to implement adequate sewage solutions, which are viable alternatives that can result in positive points in terms of improving water quality and safety.

However, due the identified factors related to hazardous events, the classified risks represent a threat to water potability, making necessary to propose improvement plans, precisely with socio-educational actions. In addition, the techniques used must be correctly maintained in order to guarantee their efficiency, as in the case of the filter with a ceramic candle or porous ceramic, which is a low-cost and highly efficient technology, but whose maintenance and improper use reduce its efficiency. Increasing the probability of microbiological contamination (COSTA et al., 2013; AZEVEDO, 2014; FERNANDES; MISAEL and CHAVES, 2015).

3.3.2 System for cleaning and handling solid waste

The cleaning and handling of solid waste is defined in Law n. 14,026 (BRASIL, 2020b) as services consisting of collection, transport, treatment and environmentally appropriate final destination of household waste. However, only conventional collection and transport stage were included in the risk assessment of the present study, since the final disposal is located at the municipal headquarters, it means that is not contributing of the basic sanitation infrastructure in the studied rural area. The collection of solid waste was executed by Água Limpa municipality service, in 83.3% of households once a week, and 16.7% said they did not use this service (SCALIZE et al., 2020b). According to these authors, 66.7% of residents have

intra-household segregation and the rest did not segregate their waste and adopted collection by the city hall as their destination.

Table 4 presents the identified RF and HE, as well as the result of the health risk assessment of the population exposed to solid waste management service in the community studied.

HE01 was classified as a non-tolerable risk due to inadequate intradomestic segregation of dry and organic waste, which occurs close to homes, potentially compromising the environment, making it unhealthy and favorable to venomous animals and vectors proliferation. In addition, the friction of rainwater and wind over time, make the waste degrade, and through the leaching process, the toxic inputs that are used in the manufacture of waste can reach the soil and, therefore, the courses underground water sources, offering risks to public health system. In this context, releasing dry residues directly into soil promotes, over the years, biological degradation process, forming leachate, that is, a black liquid generated by residues decomposition containing organic matter, heavy metals, enzymes and microorganisms, which can lead to contamination of groundwater (confined or unconfined) or surface water bodies (BRASIL, 2020c).

Table 4 – Result of the identification of risk factors, hazardous events and risk assessment regarding solid waste in the Riverside Community Arraial da Ponte, Água Limpa-GO

Risk factor (RF)	Hazard	Hazard Event (HE)	Risk measurement		
			Risk (F x S)	Risk level	Risk level description
Segregation of domestic waste within the home (RF01)	Microbiological, physical and chemical	Possibility of compromising the health of the population due to the proliferation of vectors and soil, water and air pollution due to the inadequate segregation of intradomestic waste (HE01).	4 x 100 = 400	Unbearable risk	It is necessary to PRIORITIZE the adoption of control measures to reduce risk to tolerable levels.
Conditions of the packaging infrastructure and situation of door-to-door household waste collection (RF02)	Microbiological, physical and chemical	Possibility of compromising the health of the population due to the accumulation of waste at the municipal collection points with proliferation of vectors, which may cause soil, water and air pollution (HE02).	5 x 10 = 50	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce the risk to tolerable levels.

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Note: F= Frequency, S = severity.

Dry waste improper disposal separated at home occurred in 50.0% of family units, with burning (SCALIZE et al., 2020b). This situation may also emit mutagenic risk particles, as in the case of burning PVC, which emits cadmium (KOVÁTS et al., 2022) which results in a situation of population risk.

Inadequate practices were identified, such as standing water in containers and burning dry waste, such as paper, glass and metal, as well as batteries and infectious waste (SCALIZE et

al., 2020b). Stagnant water provides conditions for the life and reproduction of vectors such as *Aedes aegypti*, which causes dengue, zika, chikungunya and mayaro diseases. According to Pagotto et al. (2022), in this community, the prevalence of dengue markers investigated was 67.6%, and that of Chikungunya, 12.1%. No serological markers for Zika virus infection have been identified.

Batteries contain chemical substances, such as lead and mercury, which can contaminate the soil and/or water, exposing human population and other animals to health risk. According to National Solid Waste Policy (NSWP), these wastes must be returned to their manufacturers, importers, distributors or traders (BRASIL, 2010b), characterizing reverse logistics. Infectious waste, in turn, comes from human or animal health care, so its improper handling can generate environmental contamination, in addition to offering risks to city collectors, as they contain sharp or pointed objects.

Another important risk factor was the inadequate disposal of pesticide packaging residues, which were completely burned (SCALIZE et al., 2020b). This condition leads to environmental and public health concern, as burning can release toxic gases that are harmful to producers and residents. In addition to this, the presence of tires in the backyard, scattered and accumulated waste such as stone and wood, can attract vectors, and as a result, the number of diseases can increase in the community, which justifies its risk classification.

For HE02, a moderate risk was obtained, due to a small portion of the community reporting the absence of the municipal public solid waste collection service. For this situation, it is inferred that this service is available and it is up to the resident to dispose wastes in a specific place for its collection, also being influenced by cultural issues. Hence, a considerable part of the community opted for burn their waste, as a form of disposal.

From the risk assessment here applied, can be highlighted with special attention that proper practice of intradomiciliary segregation of solid waste, as well as the infrastructures for its accommodation, must contemplate the entire community. Uncovered containers and the absence of adequate infrastructure verified in the community (SCALIZE et al., 2020b), can facilitate actions of external agents, such as access by animals, and waste spreading around the backyard due to wind and rain, among others factors, making its collection difficult.

As these are practices to mitigate the effects of inadequate solid waste management, correct dry waste management way, such organic decomposing, are viable alternatives to provide a sustainable environment. Composting can provide substrate to be used in family farming and dry waste, provided that it is separated, can add economic value.

Therefore, after risk assessment, it is evident that this tool can be easily applied by managers and decision makers, in order to seek sustainable alternatives for solid waste management in small communities (LIMA; PAULO, 2018).

3.3.3 Rainwater management system and drainage on access roads and inside the community

The community has access via the State Highway GO 210, valley bottoms, concrete bridge over the Piracanjuba River, Ezequiel and Lambari streams, in addition to being formed by internal roads. Therefore, considering this scenario, was identified: RF01) access road system

infrastructure conditions and situation; RF02) internal roads infrastructure conditions; and RF03) macro drainage system (rivers, canals and streams) infrastructure conditions.

Each risk factor identified presented hazards, hazard events and an associated risk assessment. As for RF01 “road access system infrastructure conditions and situation”, two hazardous events were identified: 1) Possibility of erosion and/or its intensification due to the precariousness and/or inefficiency of devices for managing rainwater and devices for drainage (HE01); and 2) Surface possibility contamination by water sources due to the presence of residues in the access road (HE02). Table 5 presents the RF01, the identified hazardous events and the result of the health risk assessment of the population exposed to the access roads of the community.

Table 5 – Result of the identification of risk factors, hazardous events and risk assessment of the access roads to the Riverside Community Arraial da Ponte, Água Limpa-GO

Risk factor (RF)	Hazard	Hazard Event (HE)	Risk measurement		
			Risk (F x S)	Risk level	Risk level description
Infrastructure conditions and situation of the access road system (RF01)	Microbiological, physical and chemical	Possibility of erosion and/or its intensification due to the precariousness and/or inefficiency of rainwater management devices and drainage devices (HE01a).	2 x 100 = 200	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce the risk to tolerable levels.
	Physical, chemical and biological	Possibility of contamination of surface water sources due to the presence of waste in the access route (HE01b).	5 x 1000 = 5000	Unbearable risk	It is necessary to PRIORITIZE the adoption of control measures to reduce risk to tolerable levels.

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Note: F = Frequency, S = severity.

HE01a, considering the primary data collected, occurs daily since erosion processes already exist and can be naturally intensified in rainy season, justifying the frequency value 2 attributed to such hazardous events. Especially in wet season, there is a potential for removal and transport organic and inorganic particles, when the road is exposed to water flow and existing natural slope (MARINHESKI, 2017). Transporting particles can result in surface water resources contamination that exist in the community, either through chemical contamination (chemical elements being carried), physical (siltation due to the transport of particles) and/or microbiological (living organisms that live in the particles carried). As for the severity, despite the already installed erosion condition, the access roads have a curb, gutter and culvert, so that the conditions are only partially inadequate, which corresponds to moderate severity, whose value is 100. Thus, the risk level reached was moderate (200), referring the need of planning and executing control measures to reduce the tolerable levels risks.

As for HE01b, solid waste dumping on access road and the conditions identified at the community are not allowed by Law n. 12,305 (BRASIL, 2010b), item II of art. 47. This is an inadequate condition for collective basic sanitation system, so the value 1000 was assigned to its risk severity. Irregular discharges have a negative impact on the soil and groundwater and

can result in risks to public health and the environment (MORITA et al., 2021). The disposal of these wastes poses a risk, so the assigned frequency is 5, daily. Finally, the level of risk reached is not tolerable (5000), and it is necessary to prioritize the adoption of control measures to reduce the risk to tolerable levels.

Table 6 shows the two risk factors (RF02 and RF03) and the four hazardous events (HE02 and HE03) identified in the community. As for RF02, infrastructure conditions of internal roads, HE02 was identified referring possibly erosion processes, due to containment structures and control insufficiency and/or non-existence, of excess surface runoff in the peridomicile.

Table 6 – Result of the identification of risk factors, hazardous events and risk assessment in the micro-drainage system of the internal roads and in the macro-drainage system (rivers, canals and streams) of the Ribeirinha Community Arraial da Ponte, Água Limpa-GO

Risk factor (RF)	Hazard	Hazard Event (HE)	Risk measurement		
			Risk (F x S)	Risk level	Risk level description
Conditions of infrastructure on internal roads (RF02)	Microbiological, physical and chemical	Possibility of erosive processes due to the insufficiency and/or non-existence of containment structures and control of excess surface runoff in the peridomicile (HE02).	2 x 100 = 200	Moderate risk	Level of attention, it is necessary to PLAN the adoption of control measures to reduce the risk to tolerable levels.
Infrastructure conditions of the macro drainage system (rivers, canals and streams) (RF03)	Microbiological, physical and chemical	Possibility of silting up of the Piracanjuba River due to the degraded state of the riparian forest (HE03).	2 x 1000 = 2000	Unbearable risk	It is necessary to PRIORITIZE the adoption of control measures to reduce risk to tolerable levels.

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Note: F= Frequency, S = severity.

According to data collected in the present research, no problems were identified in the households as consequence of leaks, runoff or flooding due to river flooding. In front of the lots, there were no devices related to dam/containment basin type and there is no erosion record on internal roads. However, as there is no culvert, manhole or curb and/or gutter, serving 33.3% and 50% of households, is possible that erosion events can occur anytime in the future, as structural measures might help for erosion control (CANHOLI, 2005). Erosion phenomena entails the entrainment of organic and inorganic particles, which could cause physical, chemical and/or microbiological contamination. As the erosive phenomena are intensified during the rainy season, frequency of 2 was assigned. Considering that there are insufficient devices to control the surface runoff, it is considered that conditions are partially inadequate, therefore, a value of 100 was assigned. In the end, an evaluation was made the risk as moderate, with the need to plan control measures adoption to reduce risk of tolerable levels.

As for risk factor RF02, infrastructure conditions of the macro-drainage system (rivers, canals and streams), the possibility of silting up of the Piracanjuba River due to riparian forest degraded stage (HE02) was identified. This event can occur mainly during the rainy season, which is why a value of 2 was assigned. Silting is one of the main consequences of riparian forest degraded or non-existent stage, affecting the environment and populations life quality

(OLIVEIRA; PEREIRA; VIEIRA, 2011). The existing conditions are inadequate, since there is no riparian forest cover, and the impact is high on the environment. Therefore, the severity is classified as high and the risk is not tolerable, where it is necessary to prioritize the adoption of control measures to reduce the risk to tolerable levels.

3.3.4 Sanitary sewage system

For sanitary sewage component, there is no collective system in the community. However, all households are served by individual sewage solutions (rudimentary septic tank), leaving managers to propose technological solutions for individual treatment of greywater and/or fecal water.

4. CONCLUSION

The present work allowed to conclude that:

- The probability/consequence matrix technique enable to assess health risks of populations exposed to basic sanitation conditions, at household level on individual basis (at the household level). However, the matrix application can be applied in collective basic sanitation systems by component and/or stage, and it may be necessary to evaluate individual solutions in collectively way.
- The proposed method allows identifying hazardous events, considering risk group factors and contamination routes;
- The proposed RAP fulfilled its objective and highlighted critical situations in the evaluated community, showing the general situation, revealing basic sanitation conditions and health points to the need for greater attention from managers, as well as effective public policies implementation;
- For the water supply, the most worrying situation was observed in the supply of untreated water, specifically without disinfection, which reached unacceptable risk levels, in addition to low adherence to protection barriers inside houses in the community;
- Regarding the solid waste management component, despite the city hall collects waste at least once a week, 83.3% of households use this service, requiring the adherence of all residents. Thus, 50% of households that separate dry waste, burn their wastes as a way to eliminate it;
- For erosion and silting in the community, moderate and unacceptable risks were identified, despite the precarious existence of compensatory technical solutions and/or drainage devices;
- From the health point of view, the scenario found in the community was one of prevalence of dengue and Chikungunya markers, which may be related to vectors proliferation, due inadequate domestic waste segregation inside the house, as well as waste accumulation on municipal collection points.

Finally, implement RAP in rural areas is a great challenge, since in most of these areas there are singularities in the existing basic sanitation systems and solutions; limitations and lack

of data and information; in addition to the knowledge and experience of the risk assessment team. In this sense, the application of RAP in other rural areas is recommended, aiming to integrate the results found in public policies looking for improve and prioritize economical investments.

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