RISK ANALYSIS FOR DOMESTIC WASTE MANAGEMENT PRACTICES IN RURAL BRAZIL

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ABSTRACT

Solid waste management is one of the issues that has been widely discussed in modern society, since it is an increasing issue. Improvement actions have been taken around the world and in Brazil it could not be different. However, the rural area has been left behind regarding the solutions for this particular problem. The objective of this research was to propose waste management alternatives for the current practices in rural Brazil to subsidize decision-making through the assessment of health risks. In this analysis, based on questionnaires applied to rural quilombola communities and scenarios developed from the interviews and proposed by the researchers, a qualitative risk analysis was carried out to help the decision process. The results showed three different scenarios of waste management that contained a maximum of 07 risks in total (high, moderate and low risks). Besides that, it was proposed three different scenarios and the risk analysis was performed again resulting in moderate and low risks only. Furthermore, the major risk to which residents are vulnerable to are the proliferation of vectors that can cause various types of diseases and the diverse types of accidents. Therefore, it is proposed to all communities to perform source separation, home composting with the organic waste and the sale of recyclable waste in the urban centres.

Key words: Risk Analysis, Preliminary Hazard Analysis, Quilombola, Rural.

INTRODUCTION

According to IBGE (2010) “rural” in Brazil stands for the “area outside the urban perimeter of the district, whose spaces and borders are defined by municipal law”, i.e. it is located away from the city and consequently underprivileged in many aspects, such as housing, health, water supply, waste collection, among others. The Quilombolas (descendants from runaway black slaves) mainly inhabit places away from civilization, being that 77.7% of the Quilombola families in Brazil live in the rural areas (SEPPIR, 2016).

The population growth has increased the generation of solid waste worldwide, consequently, increasing the concern with its management. However, the rural area still lacks in this aspect, being that in Brazil only 26.9% of this population has solid waste collection. In China, waste collection in the rural area is mainly organized by the local village committee and similarly only 24.43% of households disposed of the waste in simple landfill (Han et al., 2015). Furthermore, in Nepal and Iran, even though the Municipality collects the rural waste, they are disposed in open dumps or irregular landfills, which shows that improvement in this area is still needed worldwide (Taghipour et al., 2015; Dangi et al., 2013).

The lack of waste management can cause not only aesthetic problems but mainly impacts on public health, since the waste can attract vectors that can cause many diseases and the burning practice can cause serious accidents. Furthermore, the indiscriminate dumping of waste can contaminate surface and ground water and the risks in long-term exposure to solid waste can be physical, chemical or biological, which causes all types of pollution: air, soil and water (Alam & Ahmade, 2013). All these risks were confirmed by researches throughout the world, such as Porto and Freitas (1997), Goldberg et al. (1999), Haas et al. (1999), Englehardt et al. (2003), Li et al. (2015), among others. The risks could affect, for example, the workers of the collection and transportation services and also the residents living nearby the disposal sites or treatment plants, which demands even more studies in the field especially regarding the most vulnerable population and areas where waste management does not properly exist.

An effective way to avoid and prevent the risks is the use of tools, such as Risk Analysis that provides information to aid in the decision-making process in order to solve or minimize health and environmental problems (PMI, 2008). Therefore, the aim of this paper is to propose sustainable alternatives for waste management in the rural area based on risk analysis to subsidize the decision-making process. Additionally, to identify aiming the later

minimization of the exposure to risks arising from improper solid waste handling through a case study in the rural Quilombola communities of Mato Grosso do Sul,

MATERIAL AND METHODS

Study Area

The study was held in the 12 rural out of the 22 Quilombola communities in the State of Mato Grosso do Sul (MS), Brazil, which are shown in Figure 1. The methodology was based in three steps: problem formulation, qualitative risk analysis and proposal of alternatives.

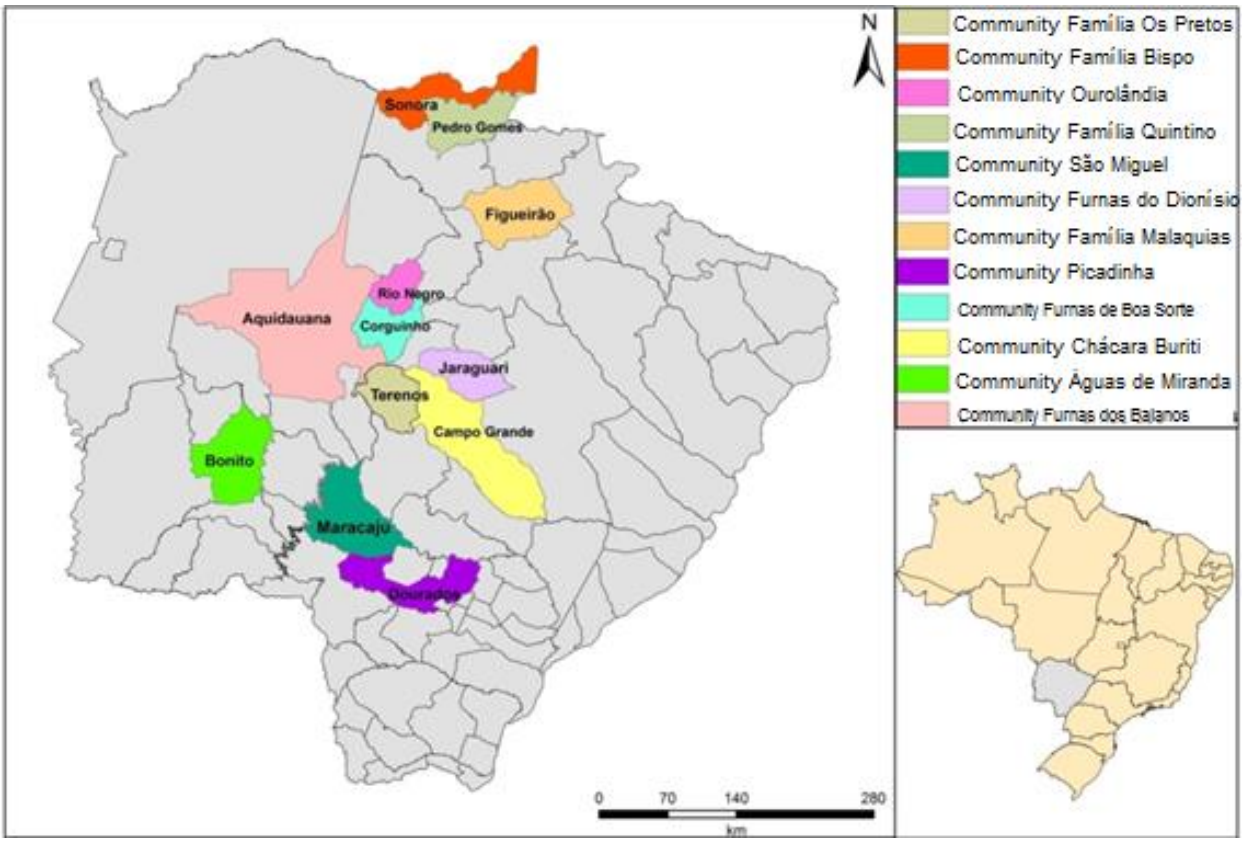

Figure 1. Location of the communities in the State of Mato Grosso do Sul, Brazil. In the left the State of Mato Grosso do Sul with the rural communities highlighted, and in the bottom right the location of MS State in Brazil.

Problem Formulation

The first step was performed through visits and interviews to the households in order to design their current waste management scenario. The sample was determined over the methodology of cluster analysis (Probability Proportional to Size - PPS) in two stages, considering the 12 rural communities. First of all, the communities were gathered into groups according to its geographic region (by Municipality): North (Sonora, Pedro Gomes and Figueirão), Center (Campo Grande, Corguinho, Jaraguari, Aquidauana and Terenos) and South (Maracaju, Nioaque and Dourados). Then, the municipalities were systematically selected using the families as a parameter, organized in decreasing order, with a random start and a constant jump calculated, considering the number of sampling points. The sample was composed by 07 (seven) of the 12 communities and the communities visited are describe in the Table 1.

Table 1. Rural Quilombola communities and their main characteristics.

Community	Municipality	Coordinates	Area	Number of Families
Furnas do Dionísio	Jaraguari/MS	20° 8'11.51"S 54°34'56.23"W	1,018.28 ha	57
Furnas de Boa Sorte	Corguinho/MS	19°54'51.28"S 55° 8'22.21"W	1,413.08 ha	41
Família Os Pretos	Terenos/MS	20°24'46.40"S 54°54'28.39"W	-	22
Furnas dos Baianos	Aquidauana/MS	20°28'1.26"S	730 ha	21

Community	Municipality	Coordinates	Area	Number of Families
		55°47'14.28"W		
Chácara Buriti	Campo Grande/MS	20°44'30.76"S 54°32'9.40"W	43 ha	12
Família Malaquias	Figueirão/MS	18°40'55.16"S 53°35'59.77"W	10 ha	27
São Miguel	Maracaju/MS	21°14'52.31"S 55°38'35.40"W	420.68 ha	19

The interviews were held from 12th to 20th of October, 2015, with previous authorization from the communities' leaders. The households were also systematically selected with a random start and constant jump. The households answered a survey in order to give the researchers the information needed. The questionnaire included questions regarding the waste management practices such as generation, storage, final destination, reuse, recycling, among others, and other questions, such as income, water supply, and sewage system for a socioeconomic profile.

The scenarios were designed based on the survey report, considering the information regarding the current waste management practices and waste handling in the households, i.e. from the answers of the residents regarding waste handling it was possible to identify which ones are the most practiced actions within every step of the handling. It was gathered information on what services are provided (or not) and practices that the majority of the households have been performing regarding the waste they generate.

Qualitative Risk Analysis

From the scenarios obtained in the previous phase, it was performed the Risk Analysis using the Preliminary Hazard Analysis (PHA) methodology which enables to identify and analyse the risks in the considered scenarios (RAUSAND, 2011). The report from this tool is given in a table form completed in Microsoft Excel composed of (in this order): i) causes and consequences, ii) frequency classes (according to Table 2), iii) severity classes (according to Table 3) and iv) risk categorisation (according to Figure 2).

Table 2. Frequency classes for risk analysis.

CATEGORY	DENOMINATION	DESCRIPTION
A	Extremely Remote	Possible but very unlikely to occur during the lifetime of the process.
B	Remote	Not expected to occur during the lifetime of the process.
C	Unlikely	Unlikely to occur during the lifetime of the process.
D	Likely	Expected to occur at least once during the lifetime of the process.
E	Frequent	Expected to occur several times during the lifetime of the process.

Source: Petrobrás, 2005.

Table 3. Severity classes for risk analysis.

CATEGORY	DENOMINATION	DESCRIPTION/CHARACTERISTICS
I	Negligible	- No damage or negligible damage to man and/or the environment; - Injuries and/or deaths do not occur and the maximum that can occur are cases of first aid or minor medical treatment.
II	Marginal	- Slight damage to man and/or the environment; - Light injuries.
III	Critical	- Severe damage to man and/or the environment; - Moderate injuries (remote probability of death).
IV	Catastrophic	- Irreparable damage to man and / or environment; - It causes death or injury to several people.

Source: Petrobrás, 2005.

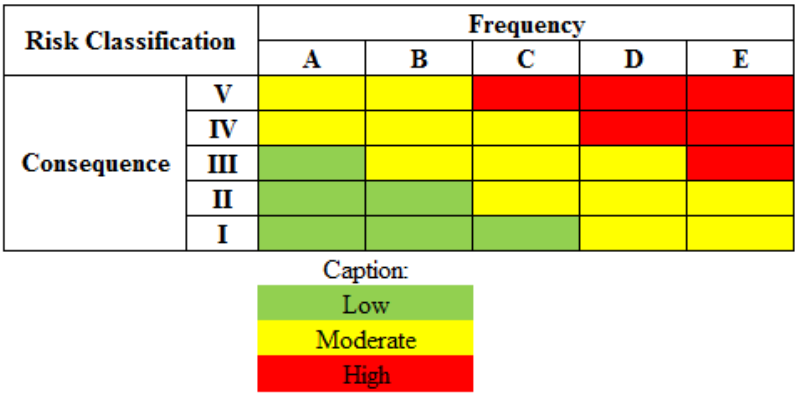

Figure 2. Risk categorization for risk analysis.
Source: Petrobrás, 2005.

After filling out the table, it was possible to classify the obtained risks into the three intensities showed in Figure 2, being low, moderate or high. The analysis performed in this study was qualitative, meaning that calculations were not performed and it was only considered the harmful effects of each hazard on human health. Also, it was only considered the residents of the communities, i.e. all other populations were not taken into account.

Proposal of Alternatives

After performing the risk analysis, it was possible to verify to which risks the residents are most vulnerable to and propose alternatives to minimize them. In that sense, it was designed new scenarios and the risk analysis was performed again to validate one or more of them as ideal to the communities.

RESULTS AND DISCUSSION

Socioeconomic Profile

From the general questions asked in the survey, it was possible to verify that 89.4% of the households inhabit the communities for over 10 years, which indicates that these communities are indeed formed by the descendants of runaway slaves. Furthermore, 74% of the households have shared wells as water supply. None of the communities have wastewater collection and 91.8% of the residents use pits. In Areia Branca (State of Rio Grande do Norte, Brazil) 90% of the households of the rural settlements are supplied by shared wells and in the rural area of Curitiba (State of Paraná, Brazil) 98% of the households use pits for their wastewater disposal (Neto et al., 2014; Larsen, 2010). Furthermore, 24% of the residents asserted that in order to improve their quality of life they need better health services, i.e. any facility that could attend their needs in some cases, followed by waste collection.

Waste Management

The results showed that only 30% of the communities have waste collection, 45.9% of the residents declared to know about selective waste collection and 87.1% know what recycling is. The communities presented three different scenarios for waste management. The community Chácara Buriti which is located in the State capital Campo Grande has waste collection performed by the Municipality. Besides that, the households dispose of the organic fraction (food scraps and leftovers) to the animals. Thereby, the denominated Scenario 01 is composed by the source separation of the waste, being the organics destined to the animals and the dry waste stored in a community container, collected and taken to the municipal landfill, as shown in Figure 3.

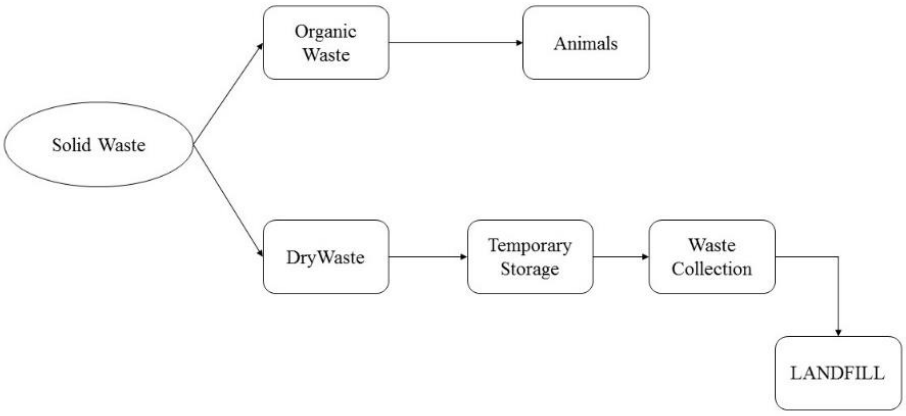

Figure 3. Scenario 01, based on the current practices of Community Chacára Buriti located in Campo Grande/MS.

The Scenario 02 is the one found in the community Familia Malaquias, which consists in the source separation of the waste and the destinations are: organics (food scraps) to the animals and dry waste collected by the Municipality, shown in Figure 4. The differences between the second scenario and the first one are that, for the second, the collection is performed differently since the truck passes through all the houses and the destination of the waste is unknown, since it was not possible to obtain the information with the households or the Municipality.

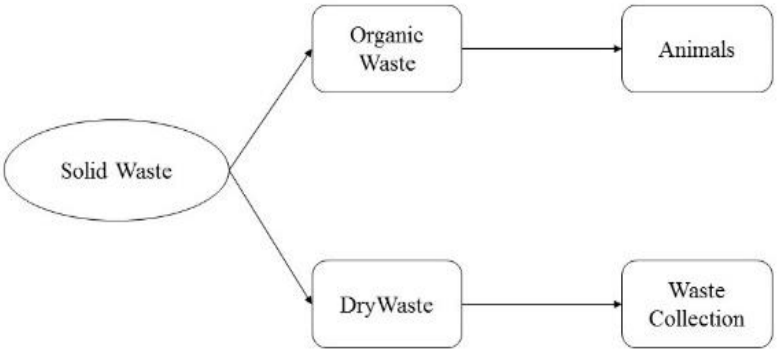

Figure 4. Scenario 02, based on the current practices of Community Família Malaquias located in Figueirão/MS.

The remaining five communities presented the same scenario, denominated Scenario 03, shown in Figure 5. The waste is separated and part of the organics is given to the animals and part goes with the dry waste, i.e. burned. Most of the families have a delimited space in the backyards (like a role) for burning, so they throw the waste directly there until it reaches a certain amount that they consider enough for burning. It was verified that the households that raise animals or pets dispose the organic fraction as for Scenario 01 and 02 and the others burn it with all the dry waste.

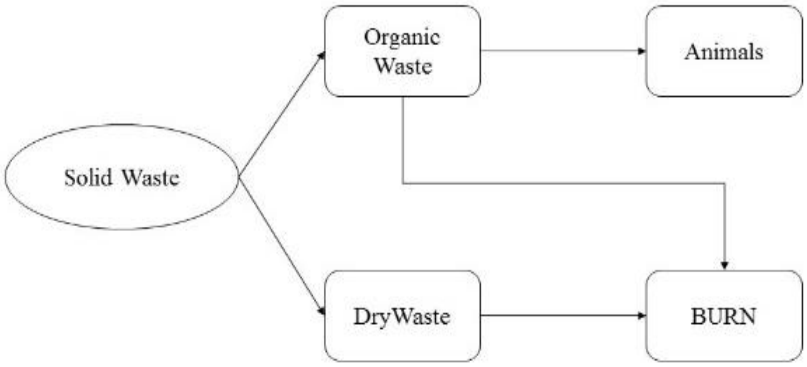

Figure 5. Scenario 03, based on the current practices of Communities Família os Pretos (Terenos/MS), Furnas de Boa Sorte (Corguinho/MS), Furnas do Dionisio (Figueirão/MS), Furnas dos Baianos (Aquidauana/MS) and São Miguel (Maracaju/MS).

Risk Analysis

The risk analysis was then performed in these three scenarios and the summary of the results obtained are presented in the Table 4.

Table 4. Risks presented by scenario and intensity.

Scenario	Risks	Risk Classification	Total Risks
01	Accidents	Moderate	07
	Proliferation of vectors	High	
	Greenhouse gases emission	Moderate	
	Inhalation of atmosferic emissions	High	
	Inhalation of odors	Moderate	
	Exposure to the collecting vehicle	Moderate	
	Accidents	Moderate	
02	Accidents	Moderate	04
	Proliferation of vectors	Moderate	
	Inhalation of atmosferic emissions	High	
	Fire	Moderate	
03	Accidents	Moderate	04
	Proliferation of vectors	Moderate	
	Inhalation of atmosferic emissions	High	
	Fire	Moderate	

The risks identified were: accidents (such as cuts, bruises and burns), proliferation of vectors (such as mosquitoes, cockroaches, rats and flies), exposure to the collecting vehicle (when it goes in the community to collect the waste), greenhouse gases emission, inhalation of atmospheric emissions, inhalation of odours and fire (from burning the waste). From Table 4 it is noticeable that none of the scenarios presented risks with low intensity, which should increase the concern with the management practices of the communities and these risks should be minimized when proposing alternatives.

The main risks verified were the proliferation of vectors and inhalation of atmospheric emissions. Considering that both of these risks have high intensity they should be mitigated to the maximum since both of them may affect the health of the households especially with high exposure.

Proposal of Alternatives

First of all, all the residents from all the communities should perform source separation of the waste in order to enable any treatment. Before the separation though, the residents should minimize the waste generation always considering the waste hierarchy of: no generation, minimization, reuse and recycling, and only then treatments and final disposal of the waste.

Basically, the first step for any decision maker in the communities should be awareness raising of the population regarding the importance of proper waste management. From that, it is possible to consider the implementation of new scenarios in the communities, taking into account the minimization of risks and the practices they currently have.

Proposed Scenarios

From the current scenarios 01, 02 and 03 and the risks found on them, it was designed three new scenarios which were denominated Proposed Scenario 01, 02 and 03. The three proposed scenarios consider the source separation and the possible alternatives taking into account the rural area and what can actually be performed considering their current management situation. In that sense, it was considered home composting and animal feeding for the organics; trading, collection and waste pickers cooperatives for the recyclables; and the rejects should be included in the collection or taken to the urban centres for the Municipalities' handling.

Proposed scenario 01, shown in Figure 6, considers that all the organic fraction should go to home composting and the recyclables sold in the urban centres.

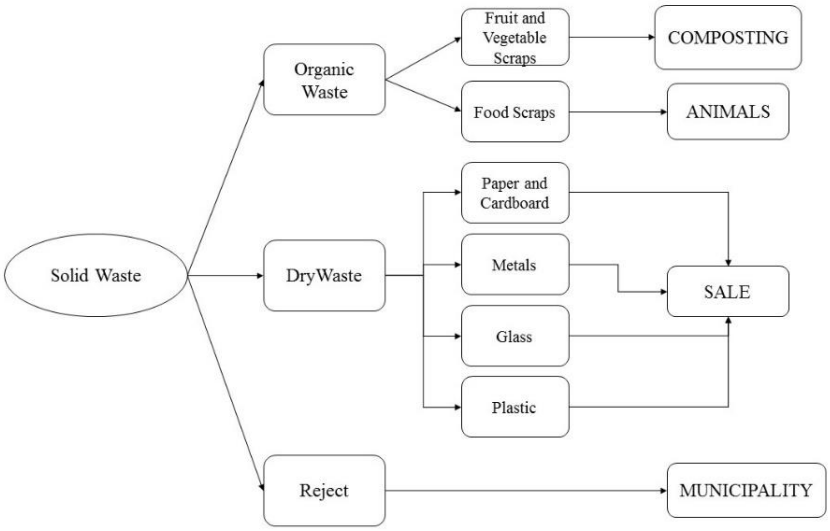

Figure 6. Proposed scenario 01, where home composting and the sale of recyclables are considered.

Proposed scenario 02 also considered home composting but in this case the Municipality would perform waste collection, as shown in Figure 7. In order to make this scenario feasible, the residents would storage the waste in a common container and the truck would pick it all up at one place, instead of door-to-door.

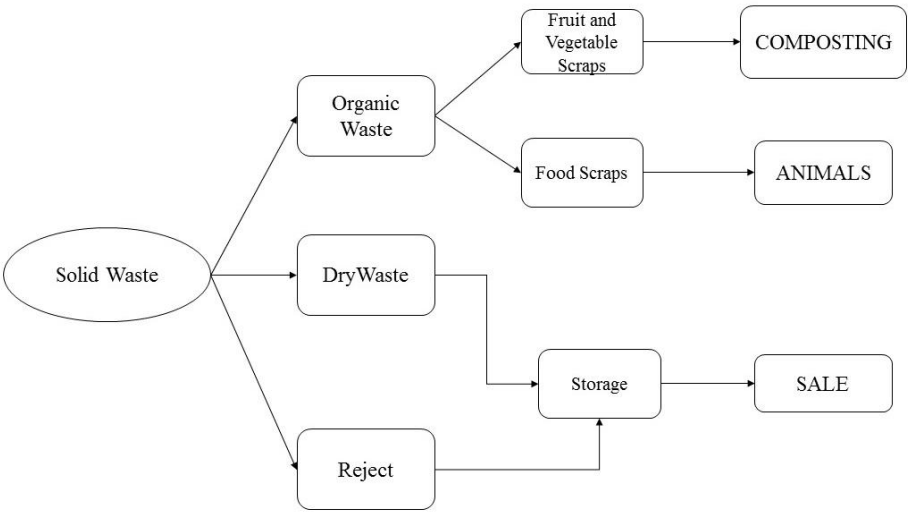

Figure 7. Proposed scenario 02, where home composting and waste collection by the municipality are considered.

For the proposed scenario 03 (Figure 8) it was considered home composting and animal feeding for the organics and the dry waste should go to a waste pickers cooperative, that could be arranged within the communities but it could also work outside of it. This alternative could increase the families' income and also raise awareness regarding the value of the waste.

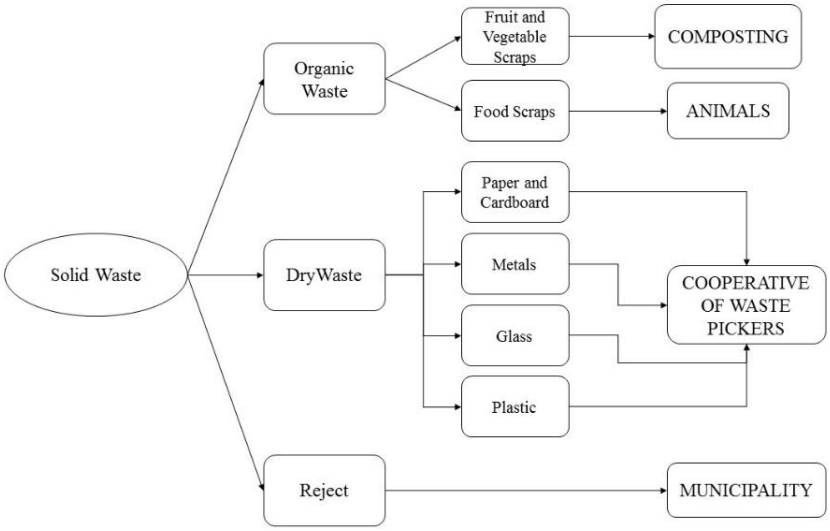

Figure 8. Proposed scenario 03, where home composting and waste pickers' cooperative are considered.

The results of the risk analysis performed for the proposed scenarios are summarized in Table 5. It is important to note that the number of risks was not really reduced but, on the other hand their intensities decreased, remaining only one high risk in the scenarios (Proposed 02), opposed to 04 high risks presented on Table 4.

Table 5. Risks detected in the proposed scenarios with classification and intensity.

Scenario	Risks	Risk Classification	Total Risks
Proposed 01	Accidents from source separation	Moderate	04
	Accidents from glass and metal handling	Moderate	
	Diseases	Moderate	
	Inhalation of odours	Low	
Proposed 02	Accidents from source separation	Moderate	07
	Accidents from container handling	Moderate	

Scenario	Risks	Risk Classification	Total Risks
	Accidents from the collector vehicle	Moderate	
	Diseases	Moderate	
	Inhalation of atmosferic emissions	High	
	Inhalation of odours	Low	
	Continuous exposure to the collection vehicle	Moderate	
Proposed 03	Accidents from source separation	Moderate	05
	Accidents from glass and metal handling	Moderate	
	Accidents from source separation	Moderate	
	Diseases	Moderate	
	Inhalation of odours	Low	

In the proposed scenarios the residents are vulnerable to accidents when i) handling the waste for separation, glass and metals, such as cuts, bruises and falls; ii) moving around the trash can or the container for storage that the residents could bump into it and fall and get bruises; and iii) the presence of collecting vehicle that goes in the community and can cause accidents due to its large size and lack of attention of the driver, for example.

Proposed Alternatives

Comparing the results from the first risk analysis (Table 4) with the results obtained in the second risk analysis performed, shown in Table 5 the best scenario for all the communities is the "proposed scenario 01". That means that, starting from source separation all the households should perform home composting, give the leftovers of food to the animals, and sell the recyclables in the Municipality they are located in. However, it is reasonable to consider that the communities that already have waste collection (Família Malaquias and Chácara Buriti) will not give it up to reduce their exposure to risks and maybe some of the other households are not willing to take their waste to the city either. Therefore, the qualitative risk analysis is not enough to support decision-making in this context, demanding other criteria to complement it and give some real and feasible alternatives for the rural communities, considering their current situation and their willingness to change.

To ensure sustainability to the chosen scenario it is necessary to consider other criteria during the decision-making process. However, even considering only the risks, the information found is important to raise the government's and population's awareness regarding the exposure that this population is subjected in their daily life, especially because there is no application of this tool in these regions in the literature. Furthermore, it is a start point in helping the decision makers to propose alternatives to increase the household's life perspective by minimizing the risks to which they are exposed to.

CONCLUSIONS

- The major risks to which the residents are vulnerable to are the proliferation of vectors and inhalation of atmospheric emissions that can cause several types of diseases, including lung cancer.
- Lower intensities risks were found in the three scenarios proposed that considered home composting for the organics, sale and cooperatives for the recyclables and waste collection.
- Waste handling plays a significant role in the risks and its intensities, i.e. the lack of information and improper handling leads to even more risks.
- The risk analysis was found to be an adequate tool, helping to minimize the risks when proposing alternatives to the communities.
- It was not found other applications of the risk analysis in the literature with the same approach– qualitative and for rural waste.
- Considering only risk analysis all the communities should perform source separation, home composting (due to the high generation of organic waste and the high number of kitchen gardens) and the sale of the recyclables, which correspond to proposed scenario 01.

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