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# Socio-Environmental Innovation in The Management of Urban Solid Waste in The Amazon

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## Abstract

Inadequate disposal of urban solid waste (USW) contaminates the soil, groundwater, bodies of surface water and the atmosphere, due to the emission of polluting gases. It causes urban flooding due to the obstruction of storm-water drainage systems caused by accumulated USW. Carried by rainwater, it also, among other environmental events, affects the macro- and micro-climate, raising the local and global temperature. In this scenario the present study asks how innovation in the management of urban solid waste can contribute to social and environmental innovation. The general objective of this work was to study the management of USW in the Amazon sub-region, given the advent of social and environmental innovation. To obtain its results, it took the following as its specific objectives: (1) interpreting the current management of the USW of the sub region of interest; (2) describing the ultimate destination of the USW; and (3) proposing models of socioenvironmental innovation for the management of USW in the local sub-regions. The case study method was applied, using the necessary procedures. It was observed that the management of USW in the studied sub region is restricted to public power facilities, where it employs few processes or technologies. Regarding the final disposal of the USW, the municipalities have not instituted any separation of recyclables from waste products and hence they send all domestic and industrial waste to landfill sites as if nothing was recyclable. In addition, most municipalities continue to dump contaminants in their old sites, pending decisions to close them and ask responsible bodies to supervise them. This paper is an academic contribution to the improvement of waste management. It proposes innovative USW management practices, based on the principle that the Polluter Pays; initiatives that favour socioenvironmental innovation must be substantiated. This research is of interest to scholars working on sustainability and to managers concerned with issues related to socioenvironmental management.

**Keyword:** Socioenvironmental Innovation. Urban Solid Waste, Shared Management. Sanitary landfill.

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# Socio-Environmental Innovation in The Management of Urban Solid Waste in The Amazon

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## Resume

Inadequate disposal of urban solid waste (USW) contaminates the soil, groundwater, bodies of surface water and the atmosphere, due to the emission of polluting gases. It causes urban flooding due to the

obstruction of storm-water drainage systems caused by accumulated USW. Carried by rainwater, it also, among other environmental events, affects the macro- and micro-climate, raising the local and global temperature. In this scenario the present study asks how innovation in the management of urban solid waste can contribute to social and environmental innovation. The general objective of this work was to study the management of USW in the Amazon sub-region, given the advent of social and environmental innovation. To obtain its results, it took the following as its specific objectives: (1) interpreting the current management of the USW of the sub region of interest; (2) describing the ultimate destination of the USW; and (3) proposing models of socioenvironmental innovation for the management of USW in the local sub-regions. The case study method was applied, using the necessary procedures. It was observed that the management of USW in the studied sub region is restricted to public power facilities, where it employs few processes or technologies. Regarding the final disposal of the USW, the municipalities have not instituted any separation of recyclables from waste products and hence they send all domestic and industrial waste to landfill sites as if nothing was recyclable. In addition, most municipalities continue to dump contaminants in their old sites, pending decisions to close them and ask responsible bodies to supervise them. This paper is an academic contribution to the improvement of waste management. It proposes innovative USW management practices, based on the principle that the Polluter Pays; initiatives that favour socioenvironmental innovation must be substantiated. This research is of interest to scholars working on sustainability and to managers concerned with issues related to socioenvironmental management.

**Keywords:** Socioenvironmental Innovation. Urban Solid Waste, Shared Management. Sanitary landfill.

## 1. INTRODUCTION

The generation of Urban Solid Waste (MSW) in the Amazon region is progressively increasing due to the advance of industrialization, the demographic increase and the increase in the per capita generation of waste, which accelerates this process. The excess of waste is aggravated by its incorrect management, a common scenario in underdeveloped countries and regions. Urban growth in the Brazilian Amazon causes urgent concern, imposing the need for MSW management studies and monitoring to avoid the collapse of this fragile environment.

The inadequate management and disposal of MSW result in the contamination of soil, groundwater, surface water bodies and the atmosphere, due to the emission of polluting gases, while the urban sprawl due to the obstruction of rainwater drainage systems caused by the accumulated MSW and carried by the rains also interferes in the macro and microclimate raising the local and global temperature, among other environmental hazards. Therefore, the management and appropriate treatment of MSW have become topics of general interest, because they can generate social and environmental innovation and present an economic alternative besides promoting environmental quality.

The general objective of the present research is to generate knowledge about the management applied to MSW in an area of the Amazon sub-region and to propose social and environmental innovation tat would improve the process. The specific objectives are (1) to learn about the way in which the MSW of the sub region under scrutiny is managed; (2) to describe the way that MSW is ultimately disposed of; and (3) to

present proposals for social and environmental innovation in managing MSW in the Amazonian region as a whole.

The question that this research seeks to answer is as follows: Is it possible to practise social and environmental innovation in the management of MSW so as to maximize the useful life of the landfills in the Amazon region? This study is divided into an introduction, a theoretical framework, methodology, results and discussions and a conclusion.

## 2. CONCEPTUAL THEORETICAL REVIEW

This study is based on Schumpeter's Theory of Economic Development (TDE), which highlights the mechanism of cyclical innovations capable of maintaining competitiveness through consumption patterns. It establishes the relationship between capitalism and the production of consumer goods whose cycle is discontinuous or unstable and also replaces the paradigms linked to market forces. Innovations are inserted to create and then satisfy unplanned desires in consumers. However, manufacturers try to incorporate a need for products into consumers' daily habits; in this way, as Costa (2006).points out, the productive apparatus changes under new pressures for production, focused on evanescent personal desires.

According to Oenning et al. (2012), the above process tends to increase the demand for more complex products to consume, making the generation and variety of solid waste to dispose of notorious. Rezende et al. (2013) report that the consequences of this cycle represent one of the biggest environmental problems of our day, since most Brazilian cities do not have the infrastructure to cope with the consequences of industrial growth signalled by the greater use of disposables and the other habits of hard consumerism.

### 2.1 Management applied to Urban Solid Waste

The National Policy on Solid Waste (PNRS), established by Law 12.305 of 2010, brings together guidelines and goals for the management of MSW, which deals with its complexity by acting on the principles of shared responsibility, the polluter pays, the preserver receives. and development must be sustainable. This law establishes that solid waste is a material that can be reused over and over and defines waste as an unusable input, raw material in a production chain. MSW is conceptualized as discarded materials, substances, objects or goods that result from human activity whose final destination should be technically and economically viable, using the best available technologies. Integrated management, according to PNRS, consists of joint actions carried out directly and indirectly in the stages of collecting, transporting, trans-shipping, treating and properly disposing of MSW in an and environmentally appropriate way, observing municipally integrated management plans which are aligned with legal standards for the environment.

The work of Reis, Freide and Lopes (2017) points out the need for a new attitude to waste with the lightest possible impact on human health and environmental quality from the life cycle of products, in which industry, commerce, public power and the final consumer participate in an attempt to transform ingrained behaviour and replace it with cognitive management in search of a balanced environment.

The National Institute of Engineering and Auditing Expertise (IPEA, 2018) notes a serious problem in waste processing; for example, few processes and technologies are employed and responsibility for it is

restricted. But the importance of shared responsibility for manufacturers, importers, distributors, traders, consumers and service holders, as demanded under the law, cannot be over-stated. In this scenario, according to PNRS, the business sector is responsible for guiding consumers in the correct disposal of the waste generated by their consumption of products. Products and their packaging must be capable of being recycled or properly disposed of. The government must adopt procedures through standards. laws and enforcement for the reuse of MSW, establishing separate collection systems and promoting proper disposal. Consumers, too, should reject environmentally risky products, join organizations or simply segregate waste. This would separate, package, reuse and properly dispose of waste materials. Table 1 below shows the stages of MSW management.

**Table 1-** Steps in the Urban Solid Waste Management Plan.

| Stage | | Features |
|---|---|---|
| **Separation** | | It is the action of separating waste according to its characteristics wherever and when it is generated and placing it where it can be collected separately from other waste. |
| **Packaging** | | It is the step of treating waste separately according to its characteristics for proper collection according to the type and quantity generated. |
| **Collect** | | It is the act of periodically and selectively picking up separated, classified and conditioned waste. |
| **Transport** | | It the act of transporting waste in a proper manner, obeying the rules and legislation in force, to avoid contamination of the environment. |
| **Destination:** | **Recycling** | It is the transformation of waste into inputs or new products. |
| | **Reuse** | It is the process of using solid waste without transforming it, biologically, physically or chemically |
| | **Compost** | It is the act of taking advantage of organic waste in the production of manure. |
| | **Recovery** | It is the act of recovering something for reuse. |
| | **Harnessing** | It is the use of waste for energy or another destination allowed by a competent body. |
| **Treatment** | | This step reduces the amount of pollutants in waste by turning it into inert or biologically stable material. |
| **Disposition** | | It is the orderly distribution of tailings in landfills. |
| **Reverse Logistic** | | In the case of special waste such as batteries or fluorescent lamps, reverse logistics should be encouraged, according to PNRS (2010). |

**Source:** Adapted by the author based on Andreoli et al. (2014) and PNRS (2010).

The Diagnosis of Urban Solid Waste Management (SNIS, 2017) describes the treatment and disposal of MSW produced by the population of 3,556 Brazilian municipalities, representing 80.1% of the country's population. The result of the research indicated the generation of 60,6 million tons of MSW and states that only 3 million tons went through sorting units to reach a rational destination.

A study by the Brazilian Association of Public Cleaning and Special Waste Companies cited in ABRELPE (2016) indicates that between 2014 and 2015 an approximate increase of 12,692 tons of MSW per day was generated in the Amazon and, of 450 municipalities, only 258 in the northern sub-region of Brazil maintained the selective collection programme, revealing a significant risk to the developmental advance in the scenario under review.

Caetano et al (2017) insists that, in the treatment of solid waste, its weight and volume before and after treatment should be measured to gather important information on the efficiency of the procedures applied, the amount of waste that would eventually go to landfill and the average useful life of these units. Gravimetric information would help these units to function better.

### 2.2 Final Disposal of Urban Solid Waste

The PNRS (Brazil, 2010) establishes that MSW should finally be put into landfills to avoid risks to public health and safety and minimize its environmental impact. But the country does not follow this guidance; instead, according to a study in ABRELPE (2017), waste is left in dumps, currently numbering 2,976 units operating in Brazilian territory; these have a negative social and environmental impact on about 76 million individuals. Table 2 below presents the three main ways used for disposing of the country's waste.

**Table 2 -** Characterization of the forms of final disposal given to MSW in Brazil and the percentage allocated to each of them in 2017.

| Final Provision | Operational Concept | Features | Amount MSW allocated % |
|---|---|---|---|
| **Dumping ground** | A place where solid waste is indiscriminately disposed of in the soil, with no or minimal control measures for operations or for protection of the environment. | Affects health through endemic proliferation, basic sanitation and risk to waste pickers. Research indicates its responsibility for approximately 10% of greenhouse gases by 2025. This provision is currently illegal. | 19,2 |
| **Controlled landfill** | It was created to eliminate dumps by applying more developed engineering techniques, which confine the waste by a layer of inert material as each workday ends. | It causes localized pollution due to the inefficient waterproofing in the lower part that favours untreated leaks and untreated gas production due to improper handling. | 10,8 |

| | | | |
|---|---|---|---|
| **Sanitary landfill** | Final disposal site of the tailings after the waste has been segregated, where treatment is more efficient than n the other two. It has an effluent treatment plant (for sludge), produces no bad smell and any gas that is generated an be burnt of. | Controlled periodic coverage and the softening of recyclable materials in the dumping area. The bottom of the cells is waterproofed by a polyethylene blanket that prevents percolates from dispersing. The leachate is collected along channels and directed for treatment. | 36,9 |

**Note:** According to research in SNIS (2017) 33.1% of MSW generated in the country has no recorded information about its final disposal.

**Source:** Adapted from Abrelpe (2017); NBR 8849 (1985); Ronaldo Filho, et al (2017); Souza and Fernandes (2016); SNIS (2017).

The deadline for the disposal of dumps, promoting environmentally appropriate actions for controlled landfills and building sanitary landfills to meet Brazilian municipalities, as established in the PNRS (Brazil, 2010) expired in 2014 and, according to the National Confederation of Municipalities (CNM, 2015), new deadlines, from 2018 to 202,1were set for the municipalities to adapt to the new rules.

A study by the District Plan for Integrated Solid Waste Management (PDGIRS) (2018) reveals the continuous irregular use of incineration by public companies and alternative proposals for using waste are still awaited. Due to legal regulations, some companies use technologies such as the autoclave to sterilize hazardous waste to prevent contaminating liquid or gaseous effluents from being generated.

### 2.3 Concept of social and environmental innovation

According to Figueiredo (2009), innovation implies uniting different types and parts of knowledge and transforming them into new products and services useful to the market. It should be seen as a process and not as a set of isolated events. Figueiredo reports that a successful innovation is one that returns the original investment made to develop it, plus additional returns.

Oliveira (2013) conceives that innovation can take different forms, seeking and taking advantage of new opportunities in both economic and social areas to meet human needs and wishes. The author addresses the two categories of innovation, technological (subdivided into process and product innovation) and non-technological (subdivided into marketing, organizational, inter-organizational, environmental and social). Oliveira (2013) reports in his research that the central feature of social innovation is the improved quality of life and asserts that social innovations should seek improved well-being for individuals and the community, with solutions to individual and collective problems. Environmental innovation is the process of developing new ideas and practices aimed at preserving the environment; it can involve processes, products, business models, decisions and relationships that contribute to the prevention or reduction of effects that harm the environment. Andreoli et al (2014) highlight three relevant aspects for socioenvironmental innovation in MSW management, namely, the environmental, which relates to the practice of environmental education, to train people to separate and store waste at its source and dispose of

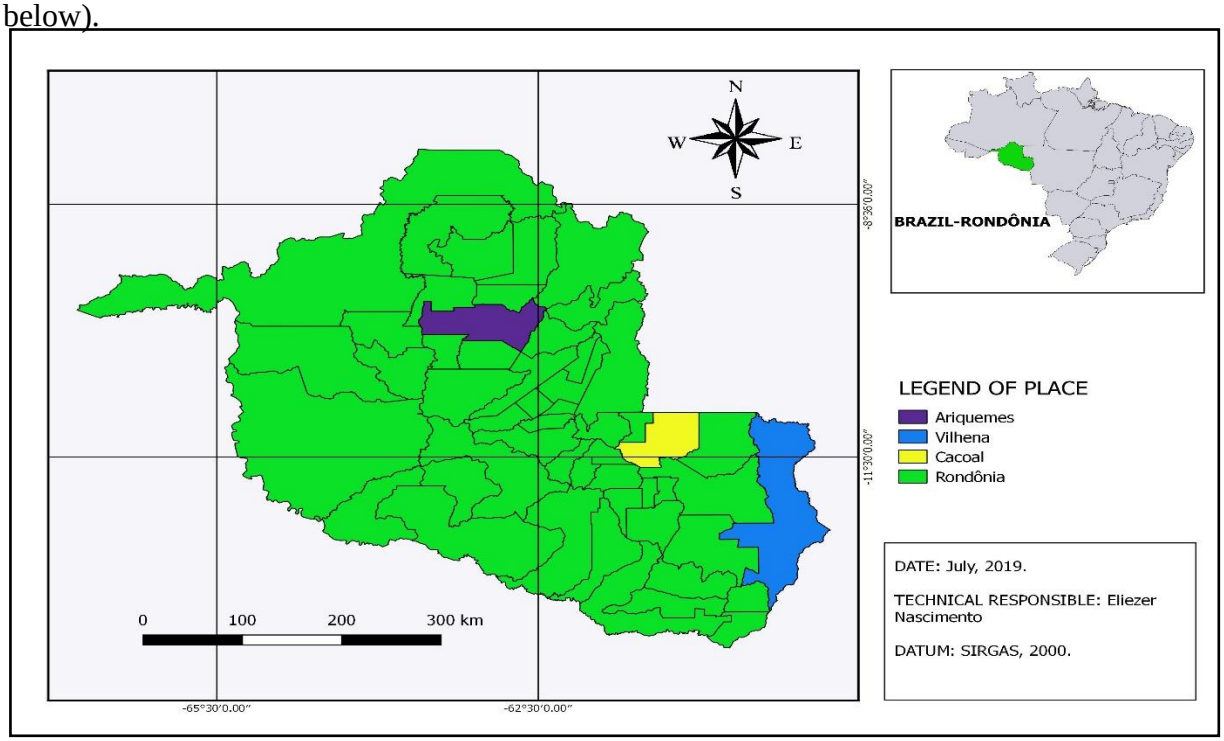
it properly later; the social, which concerns the organization of rag-pickers through cooperatives, removing them from informal work and giving them labour guarantees; and the economic, through the use of income generating technologies that help the waste handling process, sending some to centres where it is treated as raw material.

This provision is foreseen in the PNRS, which specifies that MSW must be managed in cooperation with the pickers or their associations; the Federal Government prioritizes monetary funds for use by the municipalities that do so. According to Besen (2017), this measure seeks to maintain the cooperation between public and private bodies regarding local and regional diversity if it helps eco-efficiency.

But for MSW management to benefit from social innovation and for cooperatives to co-ordinate autonomous waste pickers, the latter must be guaranteed adequate conditions of service. However, the waste picker cooperatives scattered throughout the country at present show no such thing. Ribeiro et al. (2014) base their study on an analysis of 33 cooperatives in which they identified a lack of class incentives, social vulnerability, poor working conditions, exposure to unhealthy agents and dangerous conditions without adequate protective measures.

## 3. RESEARCH METHODOLOGY

The present case study is located in the state of Rondônia, the northern sub-region of the country, which contains has three operating landfills, in the cities of Vilhena, Cacoal and Ariquemes (see Map 1 below).




**Map 1:** Map of the municipalities of the state of Rondônia that have landfills.
**Source:** Prepared by the authors using Qguis software.

It should be noted that this research does not include the landfill located in the city of Ariquemes, because it does not belong to the Intermunicipal Sanitation Consortium that administers the other two landfills and provides the data for this study. Companies operating in landfills located in the municipalities

of Vilhena and Cacoal provide final MSW disposal services to approximately 56% of the state's population, which, according to the estimate of IBGE (2010) has 1,562,409 inhabitants. The people served by the two latter landfills lives in 29 of the state's 52 municipalities, as can be seen in Table 1 below. This description can be taken as an example of the situation in other localities of the Brazilian Amazon.

**Table 1:** Estimated population in 2010 of each consortium municipality.

| **Town that houses the landfill** | **Municipalities earmarking their MSW for the Vilhena landfill** | **Estimated population in 2010 IBGE Census** |
|---|---|---|
| **Vilhena** | Cabixi | 6.313 |
| | Cacoal | 78.574 |
| | Castanheiras | 3.575 |
| | Cerejeiras | 17.029 |
| | Chupinguaia | 8.301 |
| | Corumbiara | 8.783 |
| | Espigão D'Oeste | 28.729 |
| | Pimenta Bueno | 33.822 |
| | Pimenteiras D'Oeste | 2.315 |
| | Presidente Médici | 22.319 |
| | São Felipe D'Oeste | 6.018 |
| | Vila Bela | * |
| | Vilhena | 76.202 |
| | **Total** | 291.980 |
| **Town that houses the landfill** | **Municipalities earmarking their MSW for the Cacoal landfill** | **Estimated population in 2010 IBGE Census** |
| **Cacoal** | Alto Alegre dos Parecis | 12.816 |
| | Alta Floresta D' Oeste | 24.392 |
| | Cacoal | 78.574 |
| | Castanheiras | 3.575 |
| | Espigão D'Oeste | 28.729 |
| | Ministro Andreazza | 10.352 |
| | Nova Brasilândia D' Oeste | 19.874 |
| | Novo horizonte D' Oeste | 10.240 |
| | Parecis | 4.810 |
| | Particulares | * |
| | Pimenta Bueno | 33.822 |
| | Presidente Médici | 22.319 |
| | Rolim de Moura | 50.648 |

| | | |
|---|---|---|
| | Santa Luzia D' Oeste | 8.886 |
| | São Felipe | 6.018 |
| | São Miguel do Guaporé | 21.828 |
| | **Total** | 336.883 |

* Information not available.

**Source:** Prepared from IBGE data (2010).

### 3.1 Regarding the Method

As defined by Creswell (2013), the choice of method depends on the typology of the procedure s specified by the intention of the research. However, Chiavenato (2014) reports that the Case Study Method is the most appropriate for business research, since it can substantiate reality in order to treat it scientifically. However, it must overcome the complexity of validation throughout the investigation process if it is to offer qualified results. This method is recommended when the research object is outside the research centre; for this reason, on-site information is collected to yield data for further processing. The case is a problem or a situation awaiting solution, which requires investigation, treatment and the offer of a solution that has scientific value only when supported by body of theory and concepts to guide the treatment. The decision in this research to use the Case Study Method with the related procedures and techniques is justified be its qualitative and quantitative nature.

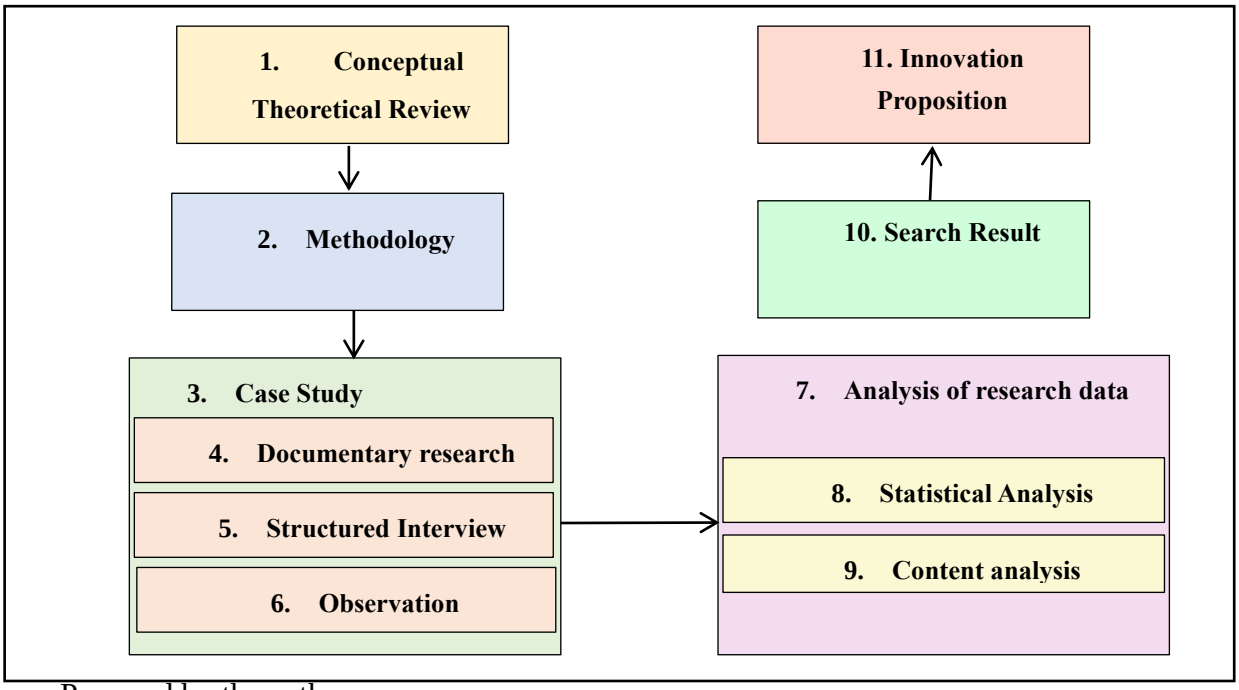
### 3.2 Procedures

Cooper and Schindler (2016) state that a formal study begins when there is something that has been explored, perhaps with a hypothesis or research question. This involves precise procedures and specification of the source of data with a view to testing hypotheses or answering research questions by collecting data relevant to the intended research. Such procedures are necessary for the objectives to be achieved and for the questions which guide the research to be answered. Marconi and Lakatos (2017) believe that this procedure indicates how the research will be carried out and the investigative steps to be taken, all requiring specific techniques depending on the phenomenon to be investigated.

This research is qualitative and quantitative, descriptive and empirical. It seeks to describe and interpret facts or phenomena recorded in a given region so as to answer the research question, and expects a practical application of its findings. Figure 1 and Table 3 below detail the phases of this task.

**Figure 1:** Phases of the study.

↑




**Source:** Prepared by the authors.

**Table 3:** Description of the elements shown in Figure1.

| Item | Procedures Applied | What the Procedures Involve |
|---|---|---|
| 1 | Conceptual Theoretical Review | Search in reputable books and journals on the Internet for the theoretical and conceptual basis of the research to be carried out, regarding the management of MSW, final disposal of MSW and socio-environmental innovation. |
| 2 | Methodology | The collection, analysis, criticism and interpretation of the data that the researchers propose for the study. |
| 3 | Case study | A research approach in simple or applied social science. |
| 4 | Documentary research | Analysis of documents such as public or private data, reports and publications, statistics, etc. |
| 5 | Structured Interviews | Interviews with respondents in which the interviewer previously compiles a script of questions to be asked. |
| 6 | Real-life observation | Data logging as it occurs in real time. |
| 7 | Research Data Analysis | It is the transformation of data into information, meaning, in search of problem-solving. |
| 8 | Descriptive statistical analysis | A branch of statistics that applies various techniques to describe and summarize a dataset. |
| 9 | Content analysis | Analyzing the structure of a text, which may be the transcript of an interview. |
| 10 | Search results | Results achieved through the application of research and analysis of collected data. |
| 11 | Innovation Proposition | Proposed MSW management practices that address the principles and purposes of social innovation and environmental innovation. |

**Source:** Based on survey data.

**3.3 Data collection and processing techniques**

The preparation of this task required several procedures; First, a bibliographic survey was carried out, cataloguing and reading texts in books, technical journals, theses and dissertations. Specialized websites were consulted, especially those of electronic journals. In this phase, it was possible to elaborate on the theoretical-conceptual body and the research methodology. In the operational phase of the research, the research environment was established, since the task demanded field research. Documentary research, which according to Chizzotti (2018) is an integral part of any systematic research that precedes or accompanies fieldwork, was given due weight. It can be a dominant aspect of works that aim to show the current situation of a subject or trace the historical evolution of a problem.

Participating city councils of the Inter-municipal Sanitation Consortium were asked for information on the disposal of their MSW in the Consortium Landfills. Other data were obtained from the municipal governments of Ministro Andreazza, Rolim de Moura, Seringueiras, Nova Brasilândia D´Oeste , Espigão D'Oeste, Parecis and Ji-Paraná, referring to the rate charged for collecting urban solid waste and the criteria adopted for it in the different sectors of the urban perimeter. Interviews complying with the protocol on ethical authorization and informed consent were then held. According to Saunders, Lewis and Thornhill (2012), interviewing may be defined as a purposeful conversation between two or more people, requiring the interviewer to ask concise and unambiguous questions, which the interviewee is willing to listen to and answer carefully. The employees of the executive sector of the Municipality of Rolim de Moura were interviewed to ascertain the amount of MSW generated, details of the local economy and the measures taken by the municipality to reduce the amount of MSW. Some managers of the company MFM Environmental Solutions provided databases regarding the treatment and amount of solid waste received from the consortium of municipalities for environmentally appropriate disposal. Finally, the company Cool Clean, which provides collection services for some municipalities of the state, was asked about the existence of gravity studies, the use of selective collection, the frequency of collection by sector and the revenue obtained from providing services leading to the disposal of MSW in a landfill.

Real-life observations, according to Araújo and Gouveia (2018), refer to the procedure by which researchers use all their senses to gather data on certain facts as they occur *in situ*. Our observation let us interpret that new models of waste management were being used by traditional waste pickers in a cooperative taken as a reference in the municipality of Ministro Andreazza; in light of this we understood the way that this cooperative worked and the income earned by the operators through the structure of an organized system extending from the collection to the sorting and dispatch of the MSW. We observed normal practices previously forgotten by social actors, which contributed greatly to the environmental quality.

The numerical data collected in the research through bibliographic surveys were treated and analyzed by means of descriptive statistics. Using Microsoft Excel software, we selected, categorized, coded, tabulated, analyzed and interpreted these data. The information collected through interviews and observations was analyzed using the interpretive technique of content analysis.

## 4. SEARCH RESULTS

In the sub region under scrutiny, the effects caused by Schumpeter's Theory of Economic Development (TDE) are felt mainly because of the capitalist conception of population consumption patterns. As reported by Costa (2006), in this sub region widespread consumerism of non-durable consumer goods prevails and the media contribute to the emergence and maintenance of unplanned consumer desires, which change as new products are designed and released.

The previously reported result of the above process is the increased generation of MSW, as cited by Oenning et. al. (2012), which in the region under study represents one of today's greatest environmental problems, since they all present some kind of management problem in handling and disposing of their MSW, even though they form a consortium with the Sanitary Landfill of Vilhena and Cacoal. According to Rezende et al. (2013), the problem may worsen as the population and industry increase, because the use of disposables and non-durable consumer goods will also increase.

### 4.1 Interpretation of the current Urban Solid Waste Management in the sub-region studied.

Information collected through semi-structured interviews of MSW collection and disposal agents and landfill representatives showed that management and integrated management contracts disobey the PNRS by having no rules for the priority action of separating waste at its source, at least into dry and wet and collecting it selectively. Hence, the companies that collect, transport and tranship MSW reported operational problems in their work. They state that because the users of the services provided do not separate organic and inorganic residues where they originate and do not package them adequately, it is difficult or impossible to apply proper treatment techniques for reusing, recycling and composting waste. They also report that it contaminates all material to mix organic waste with other waste that might have been recycled.

The lack of gravimetric studies of MSW to help calculate the useful life of waste cells and units as a whole was also observed. This makes management actions difficult and results in poor planning of landfill operations. Importantly, the absence of adequate treatment techniques results in more MSW going to landfills, which reduces their useful life and thus adds to their cost.

An interview with the pickers of the cooperative at the sorting centre in the city of Ministro Andreazza revealed that the MSW there is sorted into categories before being sent to the Cacoal municipal landfill. The pickers reported that, of the weekly volume of 32 $m^3$ of MSW (approximately six trucks), approximately four trucks are recovered, leaving only two full of tailings consigned to the landfill. In this municipality, the government pays a financial incentive to the organized cooperative, which contributes to the costs of the workshops.

The company that manages the landfill in the municipality of Cacoal reported the public practice of improper disposal of MSW along the road leading to the dumps, although there is a sanitary landfill in operation in the locality. This is not identified and punished by the local authority. This practice reveals legal normative regulations being disobeyed and the ignorance of the population, pending environmental education. There is no doubt that environmental education and the punishment of law-breakers would significantly reduce such behaviour in the region under scrutiny. In Colorado do Oeste, whose economic

driving force is the agricultural market, cattle deaths due to the ingestion of plastic bags from the city's dump have already been reported.

The use of few of the processes and technologies cited by the National Institute of Engineering and Auditing Expertise (IPEA, 2018) and the restriction of responsibilities to a few are also observed in the sub-region studied, where the few observable processes and technologies and few responsibilities were restricted to the public authorities. Manufacturers, importers, distributors, traders, consumers and service holders are never involved in the sharing of responsibility – everything is down to the municipalities.

We observed that the need for a new attitude to waste with the participation of industry, commerce, public power and the final consumer in an attempt to transform ingrained or omitted behaviors (Reis, Freide and Lopes (2017) applies also to the studied sub region, where measures should be taken to reduce the harm to human health from the life cycle of products and to provide better environmental quality.

### 4.2 Description of the final disposal of solid urban waste in the sub-region studied

Table 2 below shows recent data from the consortium municipalities on the volume of MSW disposed of as waste in the landfills of the municipalities of Vilhena and Cacoal.

**Table 2:** Graphic volume of MSW that each cooperated municipality consigns to landfills.

| MSW Destination Landfill | County | MSW volume for Vilhena landfill (tonnes) | | | |
|---|---|---|---|---|---|
| | | Year 2014 | Year 2015 | Year 2016 | Year 2017 |
| Vilhena Landfill | Cabixi | * | 436 | 717 | 687 |
| | Cerejeiras | * | * | 1.160 | 3.331 |
| | Chupinguaia | * | 477 | 975 | 1.023 |
| | Corumbiara | 162 | 448 | 492 | 507 |
| | Pimenteiras D'Oeste | 191 | 223 | 213 | 228 |
| | Vilhena | 19.214 | 20.652 | 20.245 | 19.875 |
| | Alto Alegre dos Parecis | * | * | 312 | 925 |
| | Alta Floresta | * | * | 883 | 2.822 |
| ** Cacoal landfill | Presidente Médici | 2.312 | 2.626 | 2.600 | 2.605 |
| | São Felipe D'Oeste | 79 | 219 | 261 | 294 |
| | Cacoal | 19.143 | 19.967 | 16.916 | 21.318 |
| | Castanheiras | 286 | * | 33 | 161 |
| | Espigão D'Oeste | 1.437 | 3.614 | 3.450 | 3.433 |
| | Pimenta Bueno | 1.811 | 3.172 | * | 3.055 |

| | | | | | |
|---|---|---|---|---|---|
| | Ministro Andreazza | * | * | 273 | 524 |
| | Nova Brasilândia D' Oeste | * | * | 366 | 1.228 |
| | Novo Horizonte D' Oeste | * | * | 155 | 512 |
| | Parecis | * | * | 87 | 245 |
| | Primavera de Rondônia | * | * | * | * |
| | São Miguel do Guaporé | * | * | * | 56 |
| | Santa Luzia D' Oeste | * | * | 206 | 599 |
| | Rolim de Moura | * | * | 7.171 | 9.293 |
| | Seringueiras | * | * | * | * |
| | Teixeirópolis | * | * | * | * |

* Absence of data.

** The Cacoal municipal landfill began operations in 2016. Before this date, the MSW of the municipalities already in a consortium were consigned to the Vilhena sanitary landfill, which was already in operation.

**Source:** Data provided by MFM Soluções Ambientais.

The table above shows that some municipalities sometimes have no data on the volume of MSW destined for the landfill, for example, the municipalities of Cerejeiras, Alto Alegre dos Parecis, Alto Floresta, Minister Andreazza, among others, lacking data for 2014 and 2015 and Primavera de Rondônia, Seringueiras and Teixerópolis, lacking data from 2014 to 2017. They lack the needed data due to their late association with the inter-municipal consortium that manages the landfills, This indicates that the final disposal of their MSW before the association occurred improperly in dumps.

According to the collection company, municipalities that dispose of their waste to the Vilhena and Cacoal landfills under study pay approximately $ 38 per tonne of waste. Table 3 represents the consortium municipalities and the volume of municipal solid waste per capita, per unit of total weight in kg, sent to the Vilhena and Cacoal landfills in 2018.

**Table 3 -** Quantity of MSW disposed of in landfills by a municipality in 2018.

| Municipalities adopting landfills | Municipalities that allocate MSW to landfills | Estimated population for 2018 (IBGE, 2010) | Waste disposal in the year 2018 in kg | Disposition per capita in the year 2018 in Kg |
|---|---|---|---|---|
| **Vilhena** | Cabixi | 5.438 | 709.740 | 130,51 |
| | Cerejeiras | 16.444 | 3.240.220 | 197,05 |
| | Chupinguaia | 10.886 | 1.024.240 | 94,09 |
| | Corumbiara | 7.567 | 580.630 | 76,74 |
| | Pimenteiras D'Oeste | 2.191 | 235.120 | 107,32 |
| | Vilhena | 97.448 | 21.130.310 | 216,84 |
| | Alto Alegre dos Parecis | 13.227 | 849.100 | 64,20 |
| | Alta Floresta D' Oeste | 23.167 | 2.863.654 | 123,61 |
| | **Subtotal** | **176.368** | **30.633.014** | **1.010,36** |
| **Cacoal** | Cacoal | 84.813 | 17.395.740 | 205,11 |
| | Castanheiras | 3.119 | 184.050 | 59,01 |
| | Espigão D'Oeste | 32.047 | 3.123.890 | 97,48 |
| | Ministro Andreazza | 9.762 | 442.660 | 45,35 |
| | Nova Brasilândia D' Oeste | 20.459 | 1.250.750 | 61,14 |
| | Novo horizonte D' Oeste | 8.751 | 506.040 | 57,83 |
| | Parecis | 5.947 | 238.210 | 40,06 |
| | Pimenta Bueno | 36.434 | 2.019.020 | 55,42 |
| | Presidente Médici | 19.409 | 84.220 | 4,34 |
| | Primavera de Rondônia | 2.939 | 2.273.960 | 773,72 |
| | Rolim de moura | 54.702 | 9.189.560 | 167,99 |
| | Santa Luzia D' Oeste | 6.781 | 585.820 | 86,40 |
| | São Felipe | 5.280 | 288.460 | 54,63 |
| | São Miguel do Guaporé | 22.931 | 76.020 | 3,32 |
| | Seringueiras | 11.860 | 377.860 | 31,86 |
| | Teixeirópolis | 4.384 | 154.080 | 35,15 |
| | **Subtotal** | **329.618** | **38.190.340** | **1.717,67** |
| | **Total** | **505.986** | **68.823.354** | **2728,03** |

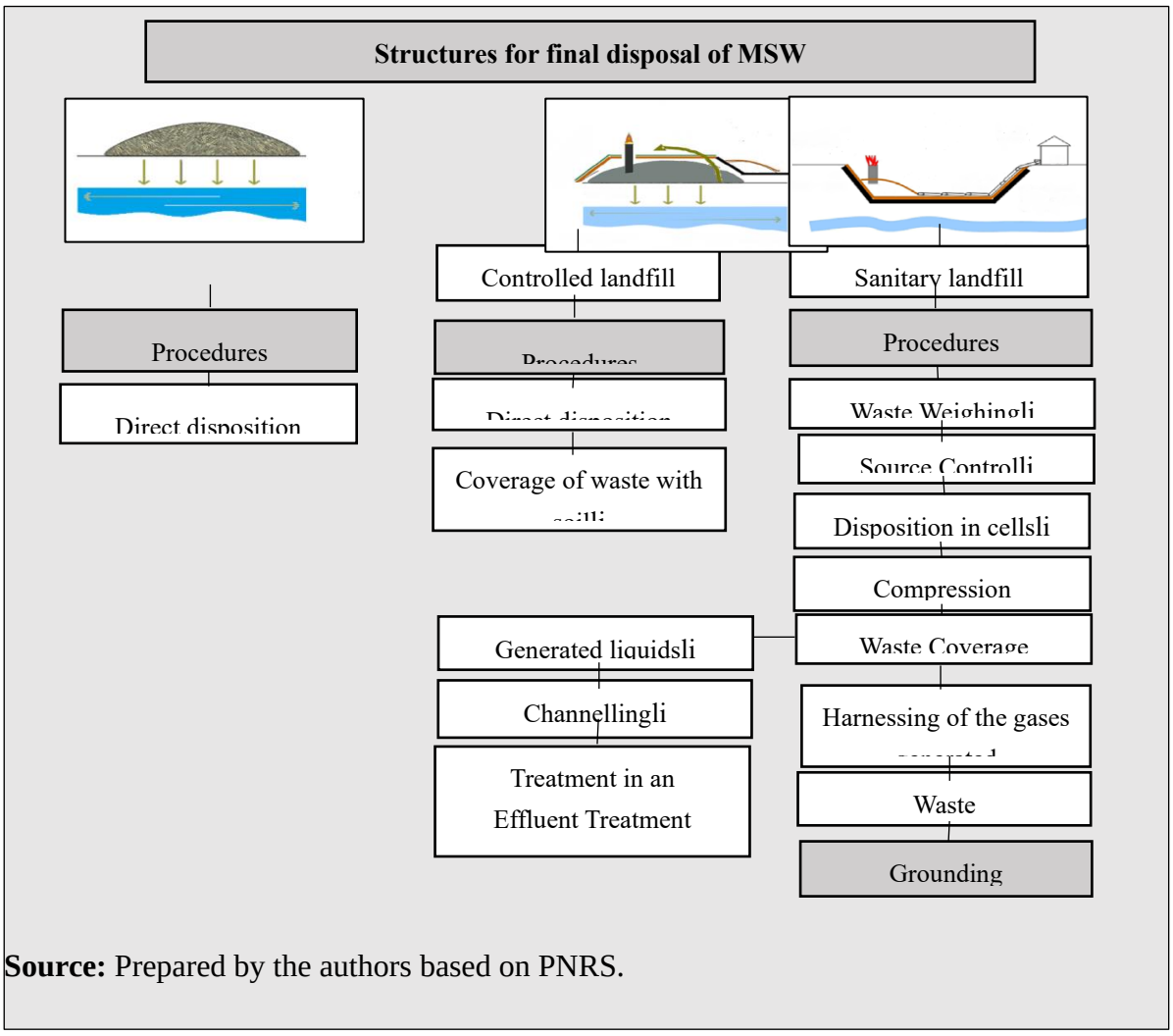
**Source:** MFM Environmental Solutions, 2018 and IBGE (2018).

The average per capita disposal of MSW in 2018 in all municipalities, except for Primavera de Rondônia, is lower than the results presented by the Brazilian Association of Public Cleaning and Special Waste Companies of 0.872 kg/inhabitant/day, that is, 318 kg /inhabitant/year (ABRELPE, 2017). Even so, some localities, despite being associated with the Intermunicipal Consortium for the disposal of their MSW to landfills, have contractual issues with outsourced companies which impact on the collection stage. They

also have serious cultural issues with the population, where the habit of burning MSW or other inappropriate methods of disposal is rooted in habit, consequently reducing the final amount disposed of in landfills.

Table 3 shows that municipalities, especially Primavera in Rondônia, differed greatly in the generation of waste per capita in 2018, suggesting the presence of errors in the weighing of waste destined for landfills. If so, the municipalities where waste is incorrectly measured would cost the Consortium more for the disposal of this waste. This research also involved questioning the Legislative Power in the municipalities located in the scenario under study, in order to clarify the legal regulations regarding the destination and disposal of MSW. The results indicated that the Public Prosecution Service has been notifying those who are responsible for the removal of dumps and the rehabilitation of the land to prevent the encumbrance of these inadequate structures being occupied. It was identified *in loco* that action to dispose of dumps is still awaited and involves measures coordinated by municipal managers, according to the rules provided for in PNRS (Brasil, 2010). Most municipalities continue to get rid of contaminants but have not supervised the actions being taken, making it difficult to resolve the problem. Table 4 shows the MSW disposal sites commonly used in the sub region under study and is based on the elements shown in Figure 2.

**Figure 2 -** Final disposal of municipal solid waste in the sub region studied.




**Source:** Prepared by the authors based on PNRS.

**Table 4 -** Description of the places where municipal solid waste is destined for the sub region under review.

| Local | Description |
|---|---|
| **Open access** | Widely used in the scenario under study, it is a site where the disposal of MSW is prohibited, because it impacts on the chemical, physical and biological properties of the soil since the effluent is untreated and gases are generated by the waste which may contaminate nearby surface water and the water table. |
| **Controlled landfill** | Despite the compaction and periodic coverage of soil-layered residues, the possibility of soil and groundwater contamination makes it an environmentally unviable option. |
| **Sanitary landfill** | Consists of lining a pit with a soil protective blanket, the installation of channels to collect the slurry and gas channelling. This destination is the most appropriate kind, because it allows the generated byproducts such as slurry and gases to be treated. |

**Source:** Prepared by the authors based on PNRS (Brazil, 2010).

The survey results indicate that the Cacoal and Vilhena landfill administrators take the following steps: a) they weigh the waste arriving at the landfill; b) the generating sources are controlled; c) the waste is sent to a cell suitable for the disposal of tailings; d) it is compacted and covered with a layer of clay as sanitary protection; e) the percolating liquids generated are channelled and treated by an anaerobic lagoon system, optional maturation and physical-chemical treatment; f) the gases generated in the waste decomposition process are captured and transformed by a combustion process, i.e. the gases generated are burned.

This research aimed to evaluate the effectiveness of such effluent treatment systems and operating systems in the units that took part in the study. As regards the segregation of the waste received in landfills, the manager of the company that operates the units stated in an interview that, as PNRS had determined (Brazil, 2010), it should be the responsibility of the municipal executive to collect materials chosen and divided for disposal in accordance with legal norms, i.e. it should promote the recycling, reuse and composting of materials, provide social support to waste pickers and waste pickers' cooperatives and direct waste only to landfills. However, because this function is being neglected by the municipalities, a sorting and transshipment station was being installed in the structures of the landfill located in the city of Cacoal.

### 4.3 Proposal for Social and Environmental Innovation in the MSW Management Process

The social and environmental innovation to be proposed in the present case study has already been practised in the city of Antwerp in Belgium and is based on the principle that the polluter pays. This is a system in which the consumer pays for door-to-door collection of. waste according to the amount. Thus, the more a citizen recycles, the less s/he will pay for waste collection.

According to information gathered from the municipal managers, most of the Consortium's member municipalities already charge for the collection of MSW and the population of these municipalities pays this fee either annually, together with the Property Tax (IPTU), or in 12 monthly payments, together with a charge for the supply of treated water. The municipalities of Cabixi, Minister Andreazza, Primavera de

Rondônia, Alto Alegre dos Parecis, São Francisco do Guaporé and São Domingo do Guaporé in the consortium currently do not charge for the service.

In the context under review, a technique proposed in this study for promoting social and environmental welfare, would be to charge the population of all municipalities for the collection of MSW on the same basis of calculation. The charge should be built into the property tax and then residents who choose to split their waste into dry and wet should be offered a discount. As determined in the PNRS, the dry waste should be collected by a specified pickup truck and transported to a cooperative in each municipality that organizes and supports them.

In the cooperatives, this waste would earn income for the waste pickers' families through recycling and composting. The waste would be sent to the landfill in Cacoal or Vilhena, along with the MSW of those residents who did not separate their household waste.

The arrangements would persuade the population to separate their waste, as part of their environmental education, and would ensure that smaller amount of waste needed to be disposed of in the environment, since the greater part would be disposed of correctly. Moreover, the families of the cooperative collectors would benefit and so would the income of the municipality, because sending less to the landfill reduces the amount paid monthly to dispose of it.

Such a proposal, as defined by Oliveira (2013) and Andreoli et al. (2014), is characterized as social innovation because it improves the well-being of individuals and the community and offers solutions to the individual and collective problems of waste pickers. of recycled materials. When disorganized and without state support waste pickers cannot organize the separation of MSW and the commercial exploitation of this material to thus generate individuals' incomes. As an environmental innovation, it is a practice aimed at preserving the environment: since recycling is a way of reusing natural resources then unused natural resources remain untouched. It spreads environmental education and contributes to the prevention or reduction of environmentally harmful human actions.

## 5. CONCLUSION

In the development of this research, we obtained some timely conclusions about the objects investigated. Regarding the management of MSW in the sub region studied, the main observations were as follows: no contractual clauses specifying the need for MSW equipment and means of transport for waste divided into organic and inorganic, in the contracts between the companies providing the service collection centres and the consortium municipalities. This fact causes operational problems, because the population does not separate waste items nor properly package them, alleging the lack of proper transportation. This makes it difficult or impossible to apply the proper treatment techniques that involve reuse, recycling and composting. Moreover, the MSW is not studied gravimetrically, which hinders the action taken to manage it, resulting in a failure to plan landfill operations. The useful life of waste cells and units as a whole cannot then be measured. However, it was observed that a waste picker cooperative supported by the municipal management in the city of Ministro Andreazza is in the process of separating recyclables and marketing them for profit, while the remaining MSW goes to the landfill, demonstrating the importance, both environmentally and socially, of supporting organized cooperatives of waste pickers who practise

recycling. It was noted in the consortium municipalities that the population as a whole is devoid of good environmental habits and ignorant of the need for them, because even those municipalities that host landfills, such as Vilhena and Cacoal, still find their population habitually disposes of MSW by the side of the road and/or in deactivated dumps. Few technical processes and technologies have been observed in the management of MSW, for which the public authorities are entirely responsible.

Regarding the final disposal of MSW, the per capita value in 2018 of all municipalities, except for Primavera de Rondônia, is lower than the results presented by the Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE, 2017), namely, 318 kg/inhabitant/year. Even so, some localities, despite being associated with the Intermunicipal Consortium for the disposal of their MSW to landfills, have contractual issues with outsourced companies which impact on the collection stage. They also have serious cultural issues with the population, where the habit of burning MSW or other inappropriate methods of disposal is rooted in habit, consequently reducing the final amount disposed of in landfills.

There were indications of errors in weighing the waste consigned to landfills by the consortium municipalities; if so, they are bearing the greater charges than their waste disposal costs. It was observed that the Public Prosecution Service has been notifying those in the municipalities who are responsible for getting rid of the dumps and rehabilitating the land, thus preventing these inadequate structures from being occupied. However, it was identified *in loco* that action to dispose of the dumps is still being awaited and most of the municipalities continue to dump contaminants in these units, pending the supervision and definitive solution of the problems that they present. The manager of the company that operates the Cacoal de Vilhena Landfills, reported that a sorting and transshipment station was installed at the landfill located in the city of Cacoal. The municipalities and cooperatives of organized waste pickers could have collected segregated MSW and properly dispose of recyclable materials, while composting organic material, but have failed to do so.

As a social and environmental innovation in the MSW management process in the se study, a practice was proposed based on the principle that the polluter pays and the more citizens recycle, the less they need pay for the collection of their waste. It would be charged with MSW collection services to the population of all the associated municipalities and would have the same basis for calculation, embedded in the IPTU; and residents who separated their waste into organic and inorganic would have their charge discounted. Eventually, as determined by PNRS, a specific truck would collect and transport waste to the cooperatives in each municipality that organized and supported them. The practice would encourage the population to separate their waste, thus environmentally educating them and augmenting the income for families working for recyclable waste pickers' cooperatives. It can be characterized as an initiative in social and environmental innovation and it answers the question that this research set itself; whether it is possible and viable as a social and environmental innovation in the management of MSW that can maximize the useful life of the landfills.

The difficulties encountered in carrying out the study came from the bureaucracy of the public agencies that stored the data required for the research and, in some cases, the servers' lack of knowledge about which sectors hold the requested information, or even the misleading instructions they gave. This resulted in

delays before the agents holding the information could be found. Sometimes requests for information, via email and/or telephone were not returned, even after several repetitions.

We suggest that new research could examine the gravimetric characterization of the urban solid waste that is consigned to the landfills of the State of Rondônia so that corrective measures could be taken, aiming at the energetic use of gravimetrics, thus maximizing the useful life of the units. Researchers in this area could estimate the useful life of the units and the best time for new installations, given the complexity of their environmental impact and the licensing process for their operation; thus solutions to problems such as those in the past could be avoided. To contain the volume of improperly disposed of solid waste, garbage dumps could be installed that were responsible for the invaluable social and environmental impact that is still being felt.

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