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Diagnosis of solid waste disposal area in Paiçandu (Brazil) and proposal for improvements

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Abstract

Background: The increase in the generation of Urban Solid Waste (RSU) and its inadequate disposal is a major problem to be faced by the public administration, however, the sanitary landfill is one of the solutions for this situation, in order to avoid the bad disposal of this waste and reduce the environmental impacts caused by them. This study sought to diagnose the final disposal system of MSW in the municipality of Paiçandu (Brazil) and propose improvements to the existing infrastructure. Methods: On-site visits were carried out to identify possible irregularities in the system, both in infrastructure and in operation. Thus, an important tool to aid diagnosis and assessment was the Waste Landfill Quality Index (IQR), where, with the follow-up of the technician responsible for the site, the entire questionnaire was filled out. After identifying the conditions at the site, with the support of technical standards, the development of the necessary regularizations for the system was started, along with some proposals for improvements. Results: According to the survey carried out, the score obtained in the IQR was 5.4, which characterizes the system in inadequate conditions. The area does not have rain drainage and the drainage of leachate and gas are compromised, in addition to the existing ditch exceeding its limit, that is, it is saturated. The operation of the system leaves something to be desired, as it outsources the machinery and does not have enough employees. The perimeter of the land does not have adequate fencing and visual isolation, which ends up causing inconvenience to the lots and neighboring residents. Therefore, according to the IQR, the final waste disposal site cannot be considered as a landfill. However, if the regularizations and improvements proposed in this work are carried out, the score and situation of the place can be reconsidered, after a new evaluation.

Keywords
Landfill, Dumping ground, IQR, Degraded area

INTRODUCTION

Currently, one of the problems of urban environments is related to the waste generated by the population. Waste generation is a situation that needs to be avoided; however, until this goal is achieved, the waste must be treated and disposed of correctly so as to cause the least possible damage to the environment and society. The view of a better future needs to be of all. Hence, in 2010, with the purpose of changing the Brazilian scenario in this aspect, the National Solid Waste Policy (PNRS, from the Portuguese Política Nacional de Resíduos Sólidos) was created, constituted by Federal Law No. 12305 (ABNT, 2010). From then, the final disposal of such waste in controlled landfills and dumpsites was prohibited, so the municipalities were obligated to implement appropriate technical measures to solve the problem of treatment and final disposal.

Thus, among the more viable solutions, with the purpose of minimizing the environmental impacts and reducing damages to public health and safety, the disposal of such materials in suitable areas of final environmental disposal, i.e., sanitary landfills, is proposed, according to technical standard NBR 8419 (ABNT, 1992). According to the mentioned standard, unlike dumpsites and controlled landfills, such a disposal system of domestic and commercial solid waste and the sludge resulting from the sewage treatment system is based on engineering principles and inspected by environmental agencies.

This research is of considerable importance to enlighten people about the positive aspects, reduce the prejudice towards this system, and raise awareness of society regarding the consumption of recyclable products that cause less damage to the environment. Although this type of activity devalues the regions closest to the sites, it is something that may facilitate the organization and sanitization of a city's garbage.

A sanitary landfill is defined as a site intended for the appropriate MSW disposal with the lowest possible volume, avoiding damaging the population and the environment. Such a method is backed by engineering studies and technical standards (ABNT, 2010).

There are different ways to build the structure of a landfill; however, this research was based on the trench method, in which ditches are dug with technically-dimensioned superposing cells. Technical standard NBR 13896 (ABNT, 1997) describes the minimal conditions for the design, implementation, and operation of sanitary landfills.

According to that described in technical standard NBR 15849/2010, the impermeabilization of the base and side belonging to the trench is of utmost importance for leachate not to infiltrate the soil, and the base region of the trench must be covered by 60 cm of clay to prevent damages caused by heavy vehicles and pointed waste. Moreover, the standard remarks that the liquid produced by the waste is channeled to the leachate drains, which generally have a minimum inclination of 2% and transport the leachate to the treatment station. It also refers that the gas produced is ejected by the drains that assist in reducing the pressure. It is worth noting that such gases are highly polluting, and, for the situation between the site and

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the other areas external to the surrounding, with the purpose of reducing the impacts, it is recommended that the land perimeter be protected by a fence and vegetation that helps channel the ventilation to prevent foul smells.

The leachate recirculation method, a system that exists on the site, consists of sending back to thecell the liquid that drained from the waste; however, a treatment system that enables releasing such liquid in a watercourse is still necessary (Reichert & Projeto, 2007). Regarding rainwater drainage, one of the recommendations is to open a channel around the entire landfill to provide the necessary trim to the daily cover of the landfill and elude runoff (CREA, 2009).

In Brazil, the scenario referring to MSW disposal is not in a good situation compared to the availability of resources and tools to tackle the situation. According to the Panorama (ABRELP, 2019), in 2018, of the 72.7 million tons of MSW collected, 59.5% were discarded in sanitary landfills. Hence, of the remainder, 23% went to controlled landfills and 17.5% to dumpsites, i.e., 40.5% was disposed of in inappropriate places according to the law. According to the Panorama, one may, thus, conclude that there was a 2.4% increase in correct final disposal relative to 2017.

Paraná has stood out in research on MSW disposal. According to the MSW final disposal situation report in the state of Paraná, only 46.4% of the cities correctly disposed of their waste; however, in the same report, in 2017, this percentage increased to 75.4%, with another 18.5% disposing of their waste in controlled landfills and 6% still in dumpsites (SZIGETHY and ANTENOR, 2020).

Therefore, this study aimed to diagnose the MSW final disposal system of Paiçandu, PR, Brazil, and propose improvements to the existing infrastructure. And to enable this objective, the following specific objectives were used in support: identify the irregular characteristics, situations, and operations of the system; assess the area and the entire current system of MSW final disposal; and design the readjustment together with improvement proposals.

THEORETICAL BACKGROUND

The diversity of MSW in a municipality is enormous. The characteristics relative to quantity andquality vary according to the characteristics of the location, including climatic, demographic, economic, and tourist aspects. Moreover, there are chances to change according to alterations to the population that generates the waste due to the habits and living standards. They may even vary with a modification to the economy of the country, the income level of the population, and so on (Reichert & Projeto, 2007).

The search for sustainability has become more and more important amid the strategic plans of the Brazilian Ministry of Environment. After twenty years of proceedings in the National Congress, Law 12305 (ABNT, 2010) was enacted, which approved the PNRS and came with some priorities, such as ending dumpsites until 2014, implanting selective collection, wet waste composting, and reverse logistics. Such goals are quite challenging for the public power, especially for the municipalities, which are responsible for public cleaning. After 2012, the law made available covenants and priority for the transfer of federal resources related to this purpose to cities and states with consolidated MSW management plans.

In terms of definition, standard NBR 10004 (ABNT, 2004) conceptualized solid or semisolid waste as any material stemming from industrial, hospital, commercial, domestic, agricultural, sweeping, and service activities, as well as sludges resulting from water treatment systems, generated in devices and facilities for managing pollution, and liquids that, due to their composition, cannot be released into the public sewage network or waterbodies or even require economically and technically nonexecutable practices.

However, the theme is more comprehensive than the Standard presents. Its primary focus is on the classification of the waste, considering class I (hazardous) and class II (nonhazardous). Waste may be hazardous when it presents physical, chemical, or infectious characteristics, for having the potential to harm public health, leading to mortality and/or an increase in diseases, or the environment, in situations where the waste was managed incorrectly (ABNT, 2004).

In Brazil, the final disposal of MSW is basically carried out in three ways. In dumpsites, where the waste is deposited over the soil directly, without control or any type of environmental care, harming the soil, the air, and the underground and surface waters of the surrounding region, causing several negative environmental impacts and, therefore, being an irregular method before the law; in controlled landfill, where the disposal site is basically formed by the same system as a sanitary landfill, with the difference being that it has no leachate collection and treatment nor drainage and burning of the biogas generated by the decomposition of the organic matter disposed of there (Monteiro, Zveibil, & Figueiredo, 2001). And, lastly, in sanitary landfills.

Standard NBR 15849 (ABNT, 2010) defines a sanitary landfill as a method of MSW disposal on the surface layer of the Earth crust, without causing damage to public safety and health and minimizing environmental impacts, being a technique based on engineering studies to dispose of such waste in the smallest area possible and synthesize it to the smallest volume possible. The trench method consists of disposal carried out in an excavated site enclosed by three sides, thus enabling a mechanized operation (Figure 3).

According to the Panorama (ABRELPE, 2019), Brazil had an MSW generation of 79 million tons. Of this amount, 92% were collected, i.e., about 6.3 million tons of waste were disposed of in inappropriate locations. It also brought that only approximately 59.5% of such waste was disposed of in sanitary landfills. Hence, it is estimated that 29.5 million tons of MSW ended up in dumpsites and controlled landfills, systems that do not have the correct and necessary structure for waste disposal. However, the reality of the Southern Region is a little different; according to the Abrelpe (2019) data, approximately 87% of the municipalities dispose of their waste in sanitary landfills.

For the success of the design, installation, and operation of this system, certain conditions relative to the location, waste segregation and analysis, monitoring, inspection, personnel training, and closing of the facility are required (ABNT, 1997). As a result of this process, the prohibition of the presence of collectors is guaranteed, the presence of vectors decreases, and the control of the generated pollution increases.

The method covered starts from the principle of localization, such as the existence of little-permeable soil, the proximity of the water table relative to the landfill base, occurrence of floods in the area, declivity of the land from 1% to 30%, having a distance of at least 500 m from the usable area boundaries to population centers and 200 m in case of the existence of water bodies nearby. However, such requirements may be modified if a plausible technical justification is presented by the designer (ABNT, 2010).

As standard NBR 15849 denotes (ABNT, 2010), the impermeabilization is an element that protects the environment, intended to confine the waste from natural soil to minimize the infiltration of leachate and biogas. This element is denominated geosynthetic blanket made of a plastic alloy, elastic and flexible. Moreover, the entire blanket area must be covered with a clay layer of approximately 60 cm to prevent the waste and operation vehicles from damaging the blanket and allowing access to the soil underneath.

Besides being fundamental to a stable operation of the system and mandatory, the drainage system is subdivided into three types. Rainwater drainage consists of a set of structures aimed at appropriately capturing and disposing of rainwater falling on the landfilled areas and their surroundings (ABNT, 1997). Such a system must be conditioned with the rainfall of the site so as not to allow the entry of this drained water in the landfill mass nor the deviation of solid material and percolated liquids outside the landfill perimeter (ABNT, 2010). The rainwater drains must be inspected after storms to guarantee their operation (ABNT, 1997).

The leachate drainage aims to enable the removal and appropriate disposal of the leachate generated within the landfills. Hence, the leachate drains must be installed over the impermeabilization, need to be dimensioned so to avoid a liquid depth over 30 cm, the material used needs to be resistant to the waste and the pressure applied over it during the service life of the landfill, and such channels cannot be obstructed (ABNT, 1997).

The leachate drainage system declivities of the landfill need to reach approximately 2% (ABNT, 2010). Moreover, the drainage of the bottom must be carried out with a material that allows free spaces without landfilling rocky materials, for example (Reichert & Projeto, 2007). To Christensen, Korinek, and Albrechtsen (2001), leachate is a dark fluid with a foul smell generated from the physicochemical and biological decomposition of organic waste.

The gas drainage seeks to enable the appropriate removal of the gases generated amid the landfill and is composed of a perforated concrete shackle with a 50 cm diameter encased with a layer of large-sized crushed stone and a steel mesh. They must be installed 30 m away from each other and at the junctions of the percolate pipes. A burning device is generally used at the drain tip to reduce the impact of these gases on the environment. The drains are installed in stages so as to be 1.0 m above the final height of each ditch (ABNT, 2010). Following the assumptions of Castilhos Junior et al ABNT (2003), the origin of the gas in sanitary landfills is affected by some variables, such as moisture, physical state, pH, temperature, oxygenation rate, and nature.

Waste disposal on the soil must not interfere with the quality of underground waters, inserting undesirable characteristics that escape their classification. Hence, their monitoring through monitoring wells is indispensable, with at least four of such wells being required: one upstream and three downstream of the sanitary landfill area (ABNT, 2010).

The upstream well must assess the original quality of the underground water, while, despite having the same goal, it is recommended that the downstream wells be installed misaligned and transversally to the underground flow, besides them needing to be located near the disposal area, with the purpose of noticing something in disagreement as soon as possible (ABNT, 1997).

Following standard NBR 13896 (ABNT, 1997), a landfill must have a fence surrounding the operation area completely, built to prevent access of outsiders and animals, a living fence surrounding the facility when there are issues related to the neighborhood, dominant winds, with the purpose of retaining dust resulting from the landfill operation and reducing the visual impact and the proliferation of smells to the surrounding areas, an access gate to control entry and exit from the site, signs on the roads and fences with the statement "DANGER - DO NOT ENTER", and a no-build zone at least 10 m in width.

According to Reichert and Projeto (2007), the landfill operation is a very important phase for the success of the system, i.e., for the waste disposal to be executed so as to minimize the environmental impacts. The correct and well-organized disposal differentiates a sanitary landfill from a controlled landfill and/or dumpsites. Even if it is a well-designed and implemented construction work, there is a risk of serious environmental problems if poorly operated. It is indispensable that good operation techniques are adopted to maximize the managerial and engineering skills of the personnel who work at the site. For example, the landfill manager needs to supervise the activities daily, with the support and regular visits of the responsible engineer being necessary to guarantee that the design and the disposal plan are being followed. They must also have the power to make decisions about day-to-day situations and have access to sufficient physical and financial resources.

To guarantee a better operation of the landfill, some auxiliary structures are necessary, such as a balance to measure and assess the amount of waste that comes into the landfill; this is important to diagnose statistical data that may help elaborate future management plans. The offices assist with the virtual accounting of the weighed amounts that arrive, the material used, and personnel control, among other administrative services (Reichert & Projeto, 2007).

MATERIALS AND METHODS

This item aims to present the materials and methods, taking into account the following approaches: research types, study area characterization, and methodological procedure.

RESEARCH TYPE DEFINITION

According to Gil and Como (2012), bibliographic research has, as a basis, material that already exists. The advantage of this type of research is to allow the individual a broad and more considerable coverage relative to the researched phenomenon than direct research, rendering it very important in situations where the problem requires very dispersed data. However, some sources provide wrong information, and a study must ensure the conditions of its content. The way to prevent false or incomplete data is to deeply diagnose each piece of information and use several sources. Hence, the theme addressed in this paper fits this type of research because it requires a vast range of content from books, scientific articles, and others of the kind.

According to Bogdan (2003), qualitative research involves obtaining information collected from the direct contact of the researcher with the studied situation, prioritizing the process more than the product. To A. J. H. Silva (2014), qualitative research involves characteristics such as data qualification, information quality assessment, and perception of social actors, concluding that this method does not concern itself with measures. This is because the priority is in the concern with the general process of this system, both constructive and operational.

Regarding survey-type research, such a method takes place basically through questioning a significant group of individuals relative to the studied situation; hence, after quantitative analyses, results corresponding to the collected information are obtained. In general, not all people are questioned because, when this occurs, it is denominated a census, and this is somewhat a more complex procedure executed only by the government or institutions with significant resources (Gil & Como, 2012).

Among the advantages of this method (Gil & Como, 2012), one may mention the direct knowledge of the reality; savings and quickness, given the data are collected through questionnaires, rendering the costs relatively low; and quantification, since the information may be transferred to tables, yielding a more straightforward analysis. However, there are some limitations, such as collecting data from the thoughts and/or perceptions of individuals, with the risk of resulting in distorted information; it offers a petrified situation of the problem, not indicating possible structural alterations.

According to Mattar (2001), quantitative research seeks to validate hypotheses by using structured information, statistics, with the analysis of a high number of representative cases, recommending a final path of action. A. J. H. Silva (2014) described this type of research as something that requires using measures and seeks quantifiable solutions, besides applying the use of basic and/or advanced statistics. Hence, this research also becomes quantitative since it requires statistical data and numerical and structured information to plan the adaptations and improvements and a basis to prove the guarantee of the results.

According to Gil and Como (2012), a case study is a branch of research types that seeks to study the object in depth so as to detail and amplify the knowledge of it. Moreover, the results of such a study are generally treated in the form of hypotheses and not conclusions. Therefore, some of its purposes are the following: to examine real-life situations, the limits of which are not clearly defined; to present the circumstance of the context in which a given verification is being performed; to formulate hypotheses.

The addressed theme may be considered a case study because it was necessary to collect and analyze data from the location and/or situation of the waste final disposal system to conclude hypotheses relative to the site, besides requiring an in-depth study due to the complexities involved and related to the natural, social, and economic environment. Figure 1 presents a flowchart that exposes the steps involved in the conduction of the research.

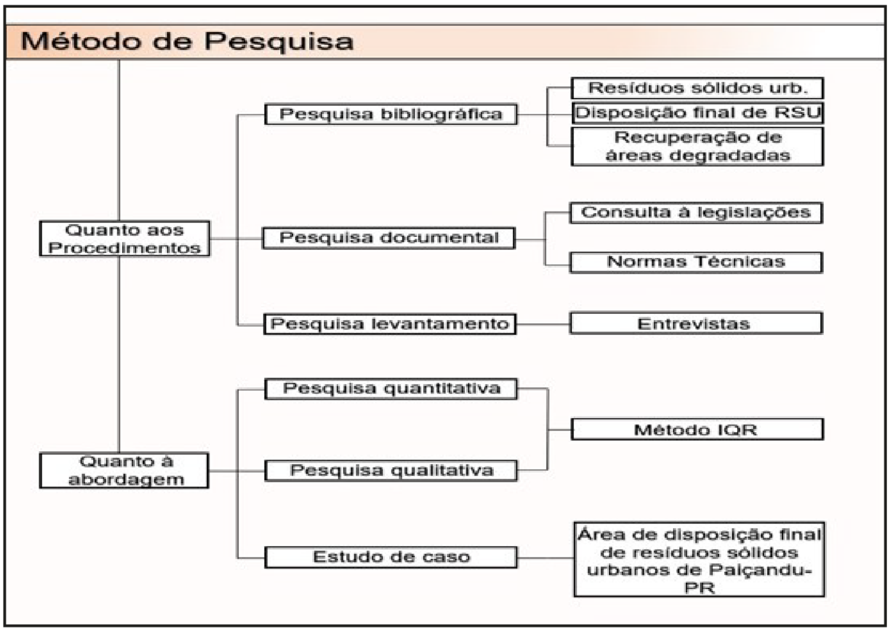

Figure 1. Research Flowchart

Source: Devised by the authors (2021)

STUDY AREA CHARACTERIZATION

The study area will cover the city of Paiçandu (PR), on highway PR 323, on the Maringá-Cianorte axis. It has an estimated population (IBGE, 2019) of 41,281 inhabitants, a territorial area of 171,38 km^2 (IBGE, 2019), including the Água Boa district, and a demographic density of 209.69 inhabitants per square kilometer (ABNT, 2010).

The main economic activities of the municipality are factories, agriculture, and livestock raising. The water supply occurs through the services of SANEPAR, which draws water from artesian wells. The relief may be considered relatively flat, with an average altitude of 438 m above sea level (TOPOGRAPHIC-MAP, 2020). Figure 2 demonstrates the localization of the solid waste final disposal site relative to the city's urban center.

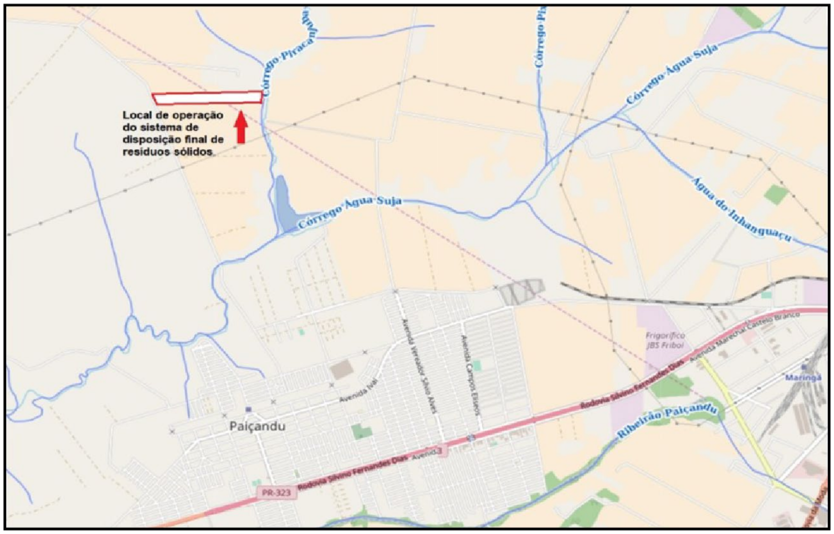

Figure 2. Location of the solid waste final disposal area of the municipality of Paiçandu, PR, Brazil

Source: Google Maps (2020)

According to Rosado (2018), 40,156 inhabitants are contemplated with garbage collection, which is the responsibility of a contracted company, with an average of 21,730 kg/day. There is also an outsourced selective collection system in the municipality. It is important to stress that collective selection is of great importance to a solid waste final disposal system because, by reducing the waste disposed of in a sanitary landfill, its service life increases (Figure 3).

Source: Municipal Environmental Department of Paiçandu, PR (Rosado, 2018).

The site where the solid waste final disposal system operates has an area of approximately ten hectares (Figure 4) and, according to Rosado (2018), receives around 652 tons per month. According to Ordinance No. 259 (PARANÁ, 2014), it is classified in category "A" (waste receiving capacity less than 200 tons per day).

Figure 3. Existing ditch in the solid waste final disposal system

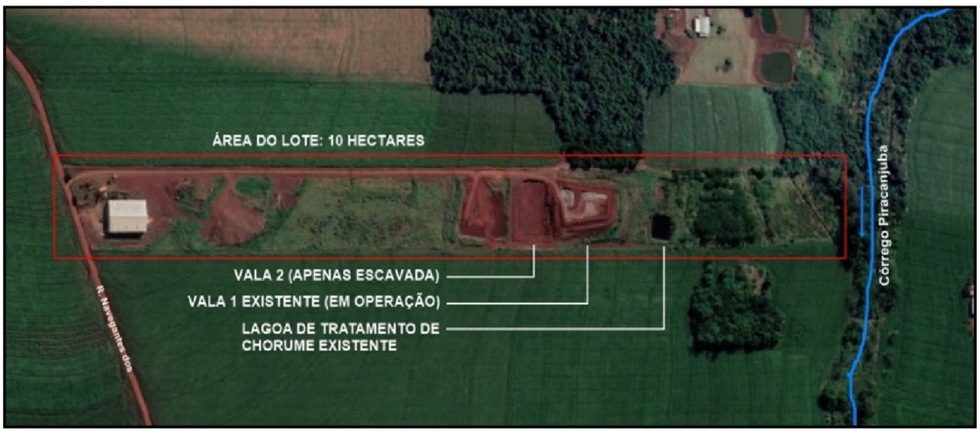

Figure 4. Aerial image of the waste final disposal ofPaiçandu, PR, Brazil

According to Embrapa (2007), the predominant soil of the site is dystroferric red latosol (Oxisol). This soil type presents marked red colors caused by the higher contents and nature of the iron oxides belonging to the material of origin in well-drained sites and homogeneous attributes of texture, color, and structure in depth. Moreover, it is a soil type that predominates in locations with flat and soft wavy reliefs, contributing to agricultural mechanization. Because it is deep and porous, it demonstrates good conditions for root development in depth. Because it is dystroferric, the soil has low fertility and high iron contents. These are deep, old, and evolved soil types.

METHODOLOGICAL PROCEDURES

The study was developed in two steps, namely: diagnosis, with the purpose of understanding the dynamics of the physical environment of the site and assessing the solid waste final disposal area; planning, development, and organization of the proposals for regularization and improvement of the existing system.

More specifically, in the physical environment, we diagnosed the soil type, geology, relief (declivity), and watercourses (superficial and underground), with such data obtained by secondary sources such as the Land, Cartography, and Geology Institute of Paraná and the Underground Water Information System. In the biological environment, we verified with the responsible technician the existence of Permanent Preservation and Legal Reserve areas. Lastly, the structure and operation of the final disposal area were assessed using the Waste Landfill Quality Index (IQR, from the Portuguese Índice de Qualidade de Aterro de Resíduos).

Regarding the first step, before initiating the work, technical research was carried out to verify the current situation of the solid waste final disposal area of the municipality.

Hence, seeking to resolve the doubts concerning the functioning and operation of the solid waste disposal system, an on-site technical visit was carried out accompanied by the responsible technician in September 2020, when the IQR was applied, which, according to CETESB (2019), refers to a questionnaire in which the locational, structural, and operational characteristics of the composting and waste final disposal facilities are assessed and, from such information, it is possible to indicate the environmental conditions of the site.

In turn, relative to the second step, the idea was to use the IQR method to identify and verify possible infrastructure and operational errors and, based on this, it was possible to propose some regularizations and improvements.

RESULTS AND DISCUSSIONS

The final disposal area, the object of this study, receives constant complaints from the inhabitants, especially those residing near the site. According to the contestations by the population, the system presented irregularities considering equipment, operation, and structure, causing damages to the environment and society.

Relative to the locality (ABNT, 1997), it must also be in accordance with that allowed in the zoning of the region, be accepted by most of the population, be at a site where the environmental impact is mitigated, have space to be used for a long time, and the internal and external access to the site needs to be accessible under any climate conditions. Therefore, since the system exists, it is understood that the site met all specifications at the time it was implemented as a sanitary landfill, considering that approval by government agencies was required for the execution.

Currently, the land has an existing ditch that has undergone the implementation of the entire impermeabilization system and drainages, among other procedures necessary for waste disposal, and is in use. Moreover, there is also a ditch that so far has only been excavated, awaiting the implementation of the system and the start of its use for waste disposal.

Therefore, for better understanding, the ditches will be denominated Ditch 1, the one currently operational, receiving waste (it has the necessary system for waste disposal), and Ditch 2, the one that has only been excavated, awaiting the implementation of the system required to initiate its use for solid waste disposal.

DIAGNOSIS AND ASSESSMENT OF THE FINAL DISPOSAL AREA

The applied IQR resulted in a score of 5.4, i.e., the solid waste final disposal system of Paiçandu, PR, is in inadequate conditions, with a score of at least 7.0 being necessary to conform to the appropriate conditions.

At the entrance to the site, there is a structure intended for the security cabin and another for locker rooms and restrooms (Figure 5). However, there are no reception employees at the security cabin. There is a housekeeper who takes care of the site and lives there.

The existing balance has a structure on the side for operating its machinery (Figure 6); however, it is not operational due to the theft of parts. The municipality outsources a large portion of the necessary machinery to operate the site, and there are not enough employees for all the functions required for a good operation. Right at the entrance to the lot, there is a water tank and an artesian well that has allocation according to the responsible technician.

Figure 5. Balance

Figure 6. Lot entrance

There is a shack beside the entrance to the site where the triage and separation of recyclables from the garbage that arrives at the site on the trucks is carried out nowadays. A company that won the bid manages this procedure.

According to standard NBR 13896 (ABNT, 1997), the site does not have appropriate fencing for the type of work operated. Moreover, there is no green curtain (Figures 7 and 8). Another factor to be analyzed is how close the electrical wiring passes to the lot border and, for this reason, may be an obstacle for the implementation of the green curtain. The number of plastic bags dispersed outside the ditch is high. With this, there is a concern with the neighboring lot, which carries out seasonal plantations.

In an interview with the technician, the information regarding the current situation of the site is that Ditch 1 (Figure 9) had already become saturated for one year and a half. The requests for constructing a new ditch, among other necessary adaptations for the site, were filed in advance; however, the procedure to execute the orientations was/is quite bureaucratic.

Figure 8. View of the neighboring lot

Figure 7. Existing fencing

Figure 9. Ditch 1

Therefore, over time, it was necessary to execute some urgent readjustments and, unfortunately, some irregularities emerged, such as superposed cells of the existing ditch even after its service life ended, and the excavation and covering with large-sized crushed stone at the leachate drainage intersection point, which took place because the leachate drain intersection point was compromised and blocked, so a procedure was executed where there was an excavation, the location/pipe was repaired, and a layer of crushed stone was put in so not to block the leachate drainage completely.

Ditch 1 does not have gas drainage because it was buried in the process of covering with garbage and soil; it is not known for sure when this occurred. At some points on the edge of the ditch, near the end of the geomembrane yet still within its domain, there is an accumulation of rainwater in a trench excavated sometime at the end of 2019 when there was a considerable rainfall, so it was executed to drain the rainwater to prevent water with leachate from going beyond the geomembrane. There is still the upwelling of gases on one of the sides of the slope on the ditch lateral.

The leachate drainage of Ditch 1 is not fully effective; when observing the leachate inspection well, the flow that goes by and is destined for the pond is small compared to the size of the existing ditch, so one may conclude that the piping is partially blocked somewhere. The geomembrane of the leachate treatment pond (Figure 10) is damaged at some points (Figures 11 and 12). Therefore, there is a risk of damage to the soil if its level rises to the damaged sites. The rainwater drainage is carried out through level curves of the land. Therefore, there is no rainwater channeling structure to a predetermined container.

The site has several collectors allocated on the neighboring land. The large number of vultures that fly over the site is also notable. There are also dogs loose around the site.

Because the land is located on the edge of a watercourse, it must have a Permanent Preservation area with a strip at least 30 m wide counting from the edge of the bed trough, as per Law No. 12651 (BRAZIL, 2012). For being a rural property, the land must also have a Legal Reserve area with native vegetation. Both areas are located at the end of the lot, on the banks of the Piracanjuba River. Moreover, the road to access the site has no asphalt paving, which hampers access on rainy days.

Figure 10. Leachate treatment pond

Figure 11. Leachate treatment pond

IMPROVEMENTS TO THE FINAL DISPOSAL AREA

Based on the diagnosis and assessment through the IQR, proposals of readjustments and improvements for the appropriate management of the solid waste final disposal site were devised (Table 1).

The table 2 demonstrates the proposals developed to improve the operation of the solid waste final disposal system.

To avoid the entrance of unauthorized people to the landfill area, the installation of fencing around the entire perimeter of the lot is advised. It is recommended that this fence has approximately 2 m in height, with concrete fence posts through which galvanized or barbed wire passes with homogeneous spacing.

Figure 12. Damages to the geomembrane of the leachate treatment pond

Table 1. Structural improvements proposed for the solid waste final disposal area of the municipality of Paiçandu, PR, Brazil

ITEM	IMPROVEMENT PROPOSALS
- Balance	- Acquire the missing parts for the garbage weighing operation
- Fencing	- Install fencing around the entire perimeter of the lot
- Green curtain	- Install a living fence of shrubs or trees around the perimeter
- Rainwater drainage	- Install a rainwater drainage system
- Rainwater containment	- Implement a rainwater accumulation pond
- Damaged geomembrane at the leachate treatment pond	- Execute repairs to the geomembrane
- Leachate treatment	- Hire a specialized company to remove the leachate accumulated on the treatment pond and dispose of it correctly.- Due to the fact there is only the recirculation of the liquid
- Existing ditch (Ditch 1)	- Urgently shut down the existing ditch correctly and with proper care
- New ditch (Ditch 2)	- Implement the entire system necessary to dispose of waste in the existing excavated ditch (Ditch 2), following the dimensioning and execution criteria provided in ABNT standards NBR 15849 (2010), NBR 8419 (1992), and NBR 13896 (1997).

Source: Adapted from ABNT (ABNT, 2010).

Table 2. Operational improvements proposed for the solid waste final disposal area of the municipality of Paiçandu, PR, Brazil

ITEM	IMPROVEMENT PROPOSALS
- Entrance	- Hire/assign an employee to the proper role of a gatekeeper
- Surveillance	- Hire/assign employees to the surveillance and security of the site
- Balance	- Hire/assign an employee with mastery of the equipment for handling and operation
- Machinery	- Acquire machinery with the purpose of minimizing expenses with outsourced equipment

Moreover, there must also be a green belt with the purpose of blocking the view of the operational area, dispersing the foul smell of the garbage, and preventing plastic bags and other objects from flying outside the site limits, as per Monteiro et al. (2001), Figures 13 and 14.

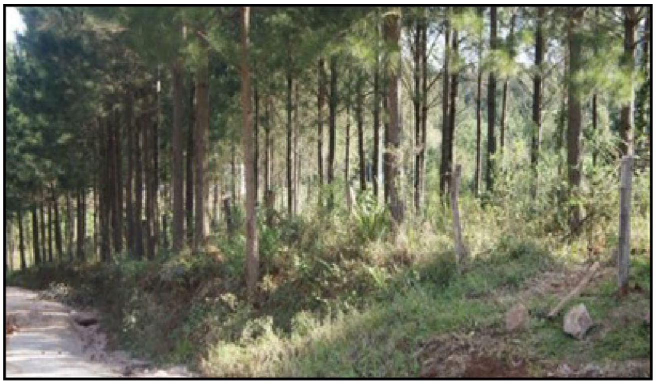

Figure 13. Perimeter vegetation

Reichert and Projeto (2007) reported that, in a sanitary landfill of Porto Alegre, the barbed wire fence was not enough to prevent the entrance of collectors and animals; hence, it was necessary to dig a channel with over 10 m in width around the entire area. Hence, a weekly inspection of the isolation system is recommended with the purpose of repairing possible fencing problems such as damaged wires or even pests on the plant barrier seedlings.

The drainage system needs to be able to support drainage so as to prevent water from accessing the landfill mass and solid and percolated liquid materials from being carried outside the area belonging to the landfill (ABNT, 2010), with the purpose of an appropriate direction for soil infiltration. One of the effective methods for rainwater drainage is the installation of concrete channels (Figures 15 and 16), known as half-round channels.

Standard NBR 8419 (ABNT, 1992) provides guidance about the importance of the existence of a site for discharging the water collected by the surface drainage channels, known as a "rainwater accumulation pond"; it needs to be dimensioned according to the rainfall of the region, landfill area (cell), and the amount of water predicted to be drained through the concrete channels.

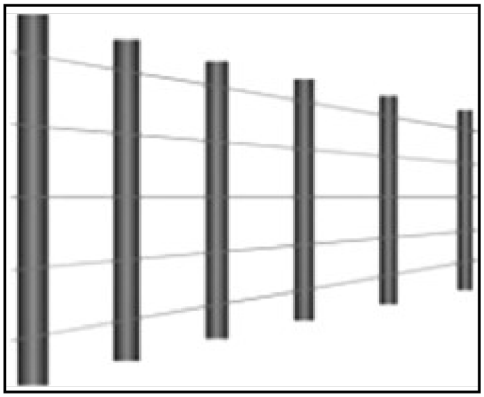

Figure 14. Fence model

Figure 15. Drainage system that exists in the sanitary landfill of Cianorte by Albertin et alalbert Albertin et al. (2011) , PR,

Relative to the geomembrane damage, it may generally be repaired in several ways depending on the material. However, thermofusion welding is generally used for HDPE geomembranes, which consists of heating the faces to be joined through heat transfer via metallic wedge or air blowing, hence welding the two faces (COLMANETTI, 2006).

Based on the existing system for leachate treatment, which occurs through leachate recirculation, hiring a specialized company to remove the leachate from the treatment pond is recommended, executing the geomembrane repairs after.

Considering the urgency in shutting down Ditch 1, it is important to stress that the procedure must be executed with caution since the cell is beyond the limit of its capacity to receive solid waste. Hence, the final covering of the cell with about 60 cm of soil and, over this clay layer, the planting of grass

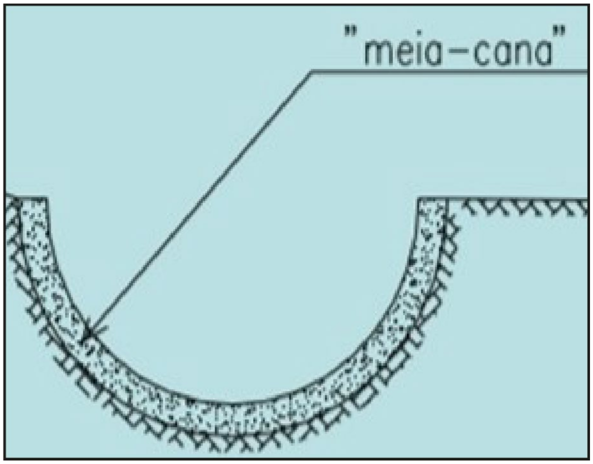

Figure 16. Half-round" channel model

vegetation is recommended. The purpose of this final cover layer is to isolate the waste from the site and reduce rainwater infiltration into the cell. This layer needs to be flexible so to accommodate the displacements that will occur in the future (Reichert & Projeto, 2007).

Regarding implementing a new ditch, considering the existing excavation (Ditch 2), as per Figure 17, the urgent implementation of the entire system required to receive waste is advised.

Figure 17. Ditch 2

Concerning employees qualified for the assigned functions, it is important for each employee assigned to a role to receive training to become qualified. The functions that require employees immediately are the entrance, surveillance/security, and the balance (considering the operation of the balance after it is repaired). Moreover, the necessary personal protection equipment (PPE) must be provided to the employees, as per standard NR 6 (ABNT, 2006).

Relative to the machinery necessary for operating the system, some of extreme importance stand out, such as the crawler bulldozer, used to spread and compact the waste and the soil cover; the wheel loader, for the operation of loading soil onto the dump truck and necessary excavation services; and the dump truck for transporting the soil (ODA, 2009). As Reichert and Projeto (2007) addressed, in situations where a crawler bulldozer is not continuously available, cheaper machinery such as backhoes may be used, which can execute excavation and compaction work yet with less efficiency.

CONCLUSION

This study allowed concluding that, through on-site visits and with the aid of the IQR method, it was possible to diagnose the situation of the solid waste final disposal site of the municipality of Paiçandu, PR, Brazil. Moreover, regularizations and improvements to such a system were proposed.

With the on-site visits, characteristics of irregularities at the site were identified. The existing ditch has superposed cells beyond that allowed, given that the ditch is already saturated. The existing infrastructure does not contemplate gas drainage and has an ineffective leachate drainage system. The site has no rainwater drainage.

A solid waste final disposal site generally emits a foul smell; therefore, fencing it with vegetation is necessary to prevent this smell from traveling to the surrounding areas, besides helping in the visual isolation and preventing plastic bags from flying the neighboring lots; however, the current system does not have appropriate isolation.

The impermeabilization system used to protect the soil is through the installation of an HDPE blanket, generally with 2 mm thickness. The leachate treatment pond is also impermeabilized this way; however, the existing pond is damaged, allowing the risk for soil contamination.

Regarding the operation, most of the machinery used is outsourced, which generates a considerable cost for the city hall. In addition, the site does not have enough employees for an appropriate operation, leaving something to be desired in this aspect. It is worth noting the importance of employee qualification to exercise their respective roles, given that a poor operation may lead the system to decadence.

The IQR was an extremely important tool to assess the area and the entire solid waste final disposal system since it lists several points that need to be considered in a waste final disposal system, from aspects pertaining to the site area to infrastructure, soil characteristics, water resources, and operation. Through the IQR, it was concluded that the site presents inadequate conditions since the score was 5.4, lower than 7.0, which would be the minimum score to fit the "appropriate conditions" aspect.

Given the information obtained, it was possible to develop proposals of readjustments and improvements that could be performed and of the correct way to run the system, with the purpose of transforming the existing waste final disposal system into a proper sanitary landfill with the characteristics and operations of such.

Lastly, the study and analysis of solid waste final disposal systems in municipalities is recommended for future work. Also, to dimension future ditches and maintenances, it is recommended to deeply assess the engineering design of the sanitary landfill, as well as evaluate the compatibility between the design and the implementation, besides obtaining the per capita generation of the municipality through a gravimetric characterization study.

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