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SITUATIONAL ANALYSIS OF THE TERESINA SANITARY LANDFILL AND ASSESSMENT OF THE EFFICIENCY OF THE COMPOSTAGE PROCESS

Análise situacional do aterro sanitário de teresina e avaliação da eficiência do processo de compostagem

Análisis de situación del vertedero sanitario de teresina y evaluación de la eficiencia del proceso de compostaje

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ABSTRACT

Landfills are examples of spaces with operational techniques aimed at protecting the environment from potential damage. These landfills receive a large amount of waste daily, including organic waste, which can be transformed into compost for agriculture through composting. The central question is: Is there viability for the composting process under the geospatial conditions of the Teresina landfill? The main objective is to analyze spatial viability for implementing a Composting Unit in the landfill to utilize the deposited organic waste. The research is based on a methodological approach that incorporates literature review, document analysis, and field data collection as essential procedures. These methods were employed to provide a comprehensive and in-depth understanding of the topic under analysis. During the visit to the landfill, it was possible to understand its operation, including the controlled landfill in operation and the sanitary landfill under construction. Additionally, the entry of waste and organic residues into the landfill was observed. Although there is space for the construction of a Composting Unit, as of the visit date, nothing had been implemented. It is concluded that the landfill has spatial viability for a Composting Unit, along with raw material for organic compost production. Therefore, a composting unit in the landfill will optimize space. Up to the time of the visit, the Teresina landfill showed inefficiency in treating organic waste.

Keywords: Organic compost; Final disposition; Composting Unit; Viability.

RESUMO

Os aterros sanitários são exemplos de espaços que possuem técnicas operacionais para proteger o meio ambiente de possíveis danos. Esses aterros recebem, diariamente, uma grande quantidade de resíduos, cujos resíduos orgânicos se encontram entre eles, os quais podem ser transformados em compostos para a agricultura através da compostagem. Como questão problema, tem-se a seguinte pergunta: Existe viabilidade do processo de compostagem nas condições geoespaciais do aterro de Teresina? Como objetivo central, analisar a viabilidade espacial para a implantação de uma Unidade de Compostagem no aterro, a fim de utilizar os resíduos orgânicos lá depositados. A pesquisa em questão fundamentou-se em uma abordagem metodológica que incorporou a revisão bibliográfica, a análise de documentos e a coleta de dados em campo como procedimentos essenciais. Esses métodos foram empregados de forma a proporcionar uma compreensão abrangente e aprofundada do tema em análise. Durante a visita ao aterro, foi possível conhecer o seu funcionamento, onde se encontra o aterro controlado em operação e o aterro sanitário, por sua vez, em construção. Possibilitou-se, ademais, observar a entrada dos resíduos, bem como os resíduos orgânicos no aterro. Estes resíduos orgânicos são soterrados e há um espaço para a construção de uma Unidade de Compostagem, contudo, até a data da visita, nada foi implantado. Conclui-se que o aterro possui viabilidade espacial para ter uma Unidade de Compostagem, além de matéria-prima para a produção de composto orgânico. Dessa forma, uma unidade de compostagem no aterro proporcionará a otimização do espaço. Até o momento da visita, o aterro de Teresina, apresentou ineficiência no tratamento dos resíduos orgânicos.

Palavras-chave: Composto orgânico; Disposição final; Unidade de Compostagem; Viabilidade.

RESUMEN

Los vertederos son ejemplos de espacios con técnicas operativas diseñadas para proteger el medio ambiente de posibles daños. Estos vertederos reciben diariamente una gran cantidad de residuos, incluidos los residuos orgánicos, que pueden transformarse en compost para la agricultura mediante el compostaje. La pregunta central es: ¿Existe viabilidad para el proceso de compostaje en las condiciones geoespaciales del vertedero de Teresina? El objetivo principal es analizar la viabilidad espacial para la implementación de una Unidad de Compostaje en el vertedero para utilizar los residuos orgánicos depositados. La investigación se basa en un enfoque metodológico que incorpora la revisión bibliográfica, el análisis de documentos y la recopilación de datos en campo como procedimientos esenciales. Estos métodos se emplearon para proporcionar una comprensión completa y profunda del tema en análisis. Durante la visita al vertedero, fue posible entender su funcionamiento, incluido el vertedero controlado en operación y el vertedero sanitario en construcción. Además, se observó la entrada de residuos y residuos orgánicos en el vertedero. Aunque hay espacio para la construcción de una Unidad de Compostaje, hasta la fecha de la visita, no se había implementado nada. Se concluye que el vertedero tiene viabilidad espacial para una Unidad de Compostaje, junto con materia prima para la producción de compost orgánico. Por lo tanto, una unidad de compostaje en el vertedero optimizará el espacio. Hasta el momento de la visita, el vertedero de Teresina mostraba ineficiencia en el tratamiento de los residuos orgánicos.

Palabras clave: Abono orgánico; Disposición final; Unidad de compostaje; Viabilidad.

1 INTRODUCTION

In Brazil, concerns about solid waste arose in the mid-19th century. Previously, care with these disposals was carried out during festive periods, as the number of discarded

objects in the space increased (Costa; Nascimento; Ometto, 2020). Regarding the issue of solid waste, inadequate disposal of such waste in space could cause environmental and social problems. In this sense, Geography, a science that contributes to the debate on environmental issues (Mendonça, 2020), helps to understand the problems of spreading untreated waste.

The construction of space through the presence of waste throughout history, and its final disposal, even if it is natural waste or transformed by the industrial process, causes damage to geographic space, while telling the story of some civilizations and their consumer objects (Nascimento; Cruz, 2017). Based on the changes that occurred in society, due to industrial growth, population growth and the development of a capitalist system that aims at production and capital, it became urgent to develop waste management projects (Castro; Santos; Souza, 2022).

Law No. 12,305/2010, which establishes the National Solid Waste Policy (PNRS), guides the management of solid waste in Brazil. Its content brings together a set of principles, instruments, objectives, guidelines, and actions to be adopted with a view to integrated administration and adequate management of solid waste (Brasil, 2010).

One of the measures brought by PNRS is the environmentally appropriate final disposal of waste – waste that has lost the possibility of being integrated into the production chain, as its life span has expired – and the final destination of solid waste, which can be reused, recycled, and composted (Brasil, 2010). With the discussion about the environmentally correct final destination proposed by NSWP, composting emerges as a strategic solution for organic waste.

Composting uses organic matter, which in a physical-chemical and biological process generates a product with bioenergetic potential, which has nutrients for use in plantations and in the recovery of degraded areas. This final product is called organic compound and can be produced on a small, medium, or large scale (Brito; Knox, 2020).

Composting appears as a measure that aims to reduce the amount of waste sent to landfills, where, according to the PNRS, discarded material (waste that can no longer be reused/recycled) should go (Brasil, 2010). Establishing composting environments requires preliminary research to learn about costs, transportation logistics, installation operations and the direction of compost produced, windrow construction, which is a term commonly used to describe a pile or mound of organic material in the composting process (Rodrigues et al, 2022).

This purpose gives the research social and environmental relevance, producing knowledge about Teresina's municipal landfill and the importance and benefits of implementing composting in this space. Given this panorama, the research provides an approach to the environmentally appropriate final disposal site for waste in Teresina.

As a problem issue, we have the following question: Is the composting process viable in the geospatial conditions of the Teresina landfill? The objective is to analyze the spatial feasibility for implementing a Composting Unit at the landfill, in order to use organic waste deposited at the site.

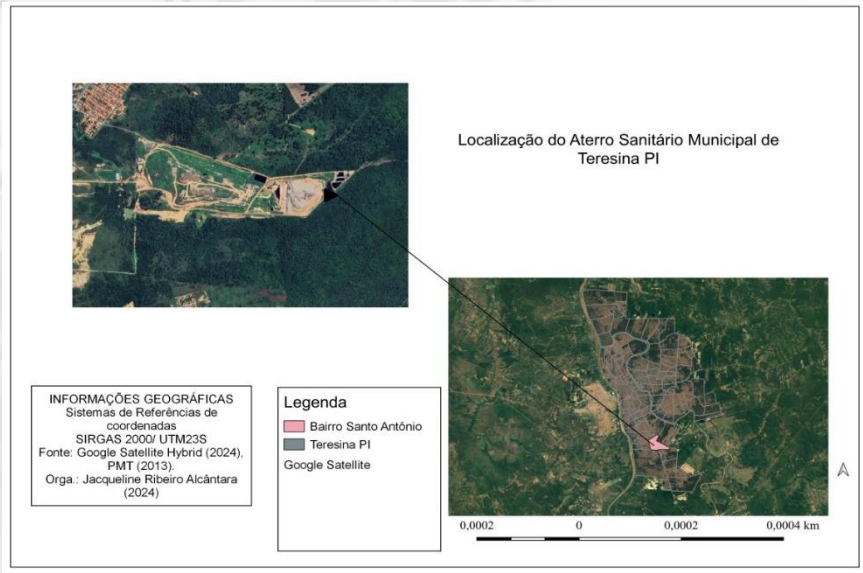
2 MATERIALS AND METHODS

2.1 Characterization of the study object

The study was carried out in Teresina, a municipality located in the Central-North Mesoregion of Piauí, in the Northeast region of Brazil (IBGE, 2023a). The city is part of an Integrated Development Network of Greater Teresina (RIDE). RIDES are regions of development and socioeconomic cooperation between nearby municipalities (Silva, 2020). Regarding the population of Teresina, according to the new demographic census, from 2022, Teresina has 866,300 inhabitants (IBGE, 2024).

The Teresina Municipal Sanitary Landfill (ASMT) is located at Km 7 - BR 316, in the Santo Antônio neighborhood, under the responsibility of the Superintendency of Decentralized Administrative Actions (SAAD) South, of Teresina city hall (Teresina, 2021a). Figure 01 shows the location of Teresina landfill.

Figure 01 – Location of Teresina (PI) Landfill



Source: The authors, 2024.

ASMT is under the coordination of the Municipal Department of Urban Development and Housing (SEMDUH), which is responsible for managing this project. According to information from SEMDUH, which made available the environmental licensing document valid until 2025, the ASMT is located in the scattered area of the lower Parnaíba basin, in the region between the rivers, since the city of Teresina is located between two rivers, the Parnaíba and the Poti (Baptista, 2021).

2.2 Methodological procedures

The investigation used bibliographical research, document analysis and field data collection as methodological procedures. For bibliographical research, articles, dissertations, and theses, that bring together studies on Urban Solid Waste (MSW), final waste disposal, landfill, and composting, were used.

The documentary analysis provides information on Law No. 12,305/2010, which establishes the National Solid Waste Policy (PNRS), on the final disposal of waste and documents from the municipal public body. Through an official letter, Teresina City Council was also asked for data on the quantity and types of waste sent to the landfill. Regarding what was proposed for the research, the municipal Secretariat for Urban Development and Housing (SEMDUH) made available tables with information on the amount of landfill waste from 2010 to 2022.

Regarding field research, a visit was made to the Teresina landfill, which took place in February 2022, with the purpose of learning about its operation and observing the work carried out on site. During the visit, we also sought to learn about the type of landfill the city has, observing whether it is a controlled landfill or a sanitary landfill and the feasibility of implementing a composting unit in its space.

3. RESULTS AND DISCUSSIONS

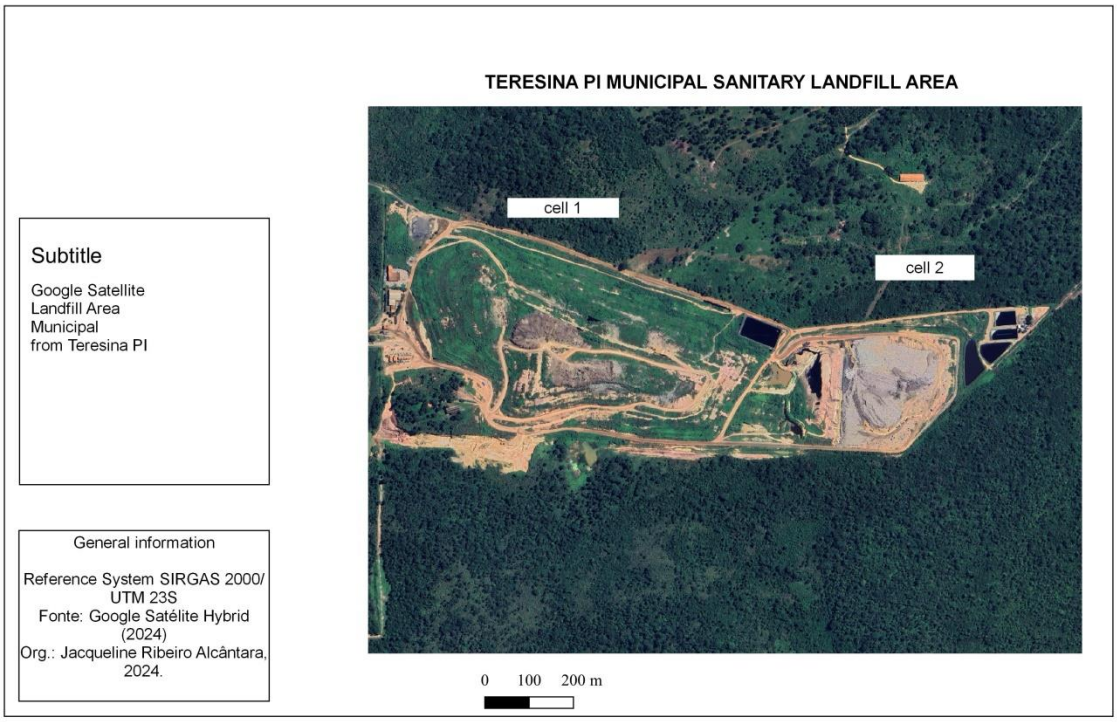
3.1 Landfill structure

The waste disposal site in Teresina was built in 1982 as a dump. In 2013, it became controlled, in a location considered far from the urban center of the city at that time (Alcântara; Iwata; Baptista, 2022). From this perspective, in 2018, municipal management created a project to build the sanitary landfill, as until then, the controlled landfill was in operation. This landfill will put into practice what governs article 54 of the PNRS, which states

that capitals, RIDES, and metropolitan regions would have a deadline of August 2021 to implement an environmentally correct location to receive waste (Brasil, 2010).

The space where the municipal sanitary landfill of Teresina (ASMT) is located, according to the Municipality of Teresina (PMT) – in its Logistics and Related Engineering Studies report, from the year 2021 – has 48.59 hectares, being divided as follows: 33.31 hectares of controlled landfill and 15.28 hectares of sanitary landfill under construction (Teresina, 2021a). Figure 02 shows the location of Teresina Municipal Landfill.

Figure 02 – Teresina (PI) Landfill Area



Source: The authors, 2024.

In the Structuring of the Urban Solid Waste Management System (MSW) in the Municipality of Teresina/PI, as outlined in the Reference Business Plan, it is highlighted that the estimated useful life of the controlled landfill is 3 to 4 years. The start of operations at the new landfill is expected to occur before the controlled landfill ceases operations, with this transition being carried out gradually (Teresina, 2021b).

Currently, the landfill is divided as follows: Cell 1 and Cell 2, as shown in figure 02. Cell 1 refers to the controlled landfill, still in operation and receiving waste daily into its space. This controlled landfill will not be completely deactivated, this deactivation will take place gradually and its area will later be recovered.

In cell 1, there is an accumulation of waste that forms a slope, from 5 to 7 meters high (Teresina, 2021a). In cell 2, the landfill is under construction, but there is already waste disposed of in cell 2. In figure 03, there are images of Cell 1 (controlled landfill) and Cell 2 (sanitary landfill):

Figure 03 – Mosaic of photographs of Teresina PI landfill.

A. Waste pile in Cell 1; B. Machines working in the Cell 1 waste pile; C. landfill under construction (Cell 2); D. Cell 2 area with waste.
Source: Authors' personal archive, 2022.

In cell 1, there is a slurry lagoon, which is waterproofed. In cell 2, there is an Effluent Treatment Station (ETE), with a lagoon where effluents from the cells are directed. This lagoon, it is worth noting, is also waterproofed. There is also a tank in this space that receives the effluent after treatment. The landfill's ETE has an aeration tank, whose functionality consists of a treatment with the presence of oxygen and microorganisms originating from the tank itself, which decomposes the organic matter present there, forming flakes (Rocha, 2020).

Percolated liquid, also known as leachate, is generated during the waste decomposition process. If not managed properly, this liquid can contaminate the soil due to its toxic load, resulting in environmental degradation. In more serious cases, if it reaches the water table, there is a significant risk of pollution. Therefore, it is imperative to treat this liquid

urgently to avoid damage to the environment (Santos et al., 2021). Figure 04 shows the leachate in the landfill and the aeration tank:

Figure 04 – Photograph mosaic of the liquid percolated in Teresina landfill and its treatment.

A. Slurry lagoon in cell 2; B. Cell 1 slurry lagoon; C. Aeration tank in cell 2; D. Effluent treated in cell 2.
Source: Authors' personal archive, 2022.

The landfill's ETE is in regular operation, separating the treated effluent and sludge. The effluent, after treatment, is placed in a tank and made available to the landfill. It is then used to wet the controlled landfill, in addition to washing the trucks that work in public cleaning in the city. The sludge, in turn, is stored in a tank and, upon reaching its maximum capacity, is disposed of in the controlled landfill.

This sludge, which contains organic matter, could be reused in the production of organic compost (Brasil, 2020). However, the product would require a chemical analysis to know its quality and whether it meets the criteria and parameters of CONAMA Resolution No. 498/2020, which deals with the use of sludge in soils (Brasil, 2020).

Based on the documentary analysis of the environmental license – made available by SEMDUH, which contains the category of landfill operating license valid until the last month of 2025 – it is observed that cell 1 will be regularized after the end of its operation as one of its environmental recovery purposes, in addition to the total completion of cell 2.

This document additionally requires the quarterly submission of a consolidated report covering the implementation of monitoring the geotechnical stabilization of the massif, the quality of groundwater and surface waters, as well as leachate management and the adequate functioning of the Effluent Treatment Station (ETE), along with gas emissions. The information mentioned is consistent with the environmental license issuance date, which is December 2021.

3.2 TYPES OF MATERIAL COLLECTED

In Teresina, waste that is sent to the landfill is collected door-to-door by the municipal public service and is taken by trucks specific for this activity. Upon entering the landfill, they are weighed and the arrival time and the area of the city from which the waste was collected are recorded (Alcântara, Iwata, Baptista, 2022).

The logistics and related engineering study report explains how waste is disposed of after the trucks arrive, organized as follows: the most voluminous are separated by types of waste, arranged in their specific area; organics are taken to another sector of the landfill and recyclables are collected by waste picker associations (Teresina, 2021a).

According to the Municipality of Teresina, the waste that is sent to the landfill comes from households (urban and rural), extra-household waste, special waste (feathers and viscera), selective collection, products from Waste Collection Points (PRR), also weeding and overflowing (Teresina, 2021a). According to the document provided by SEMDUH, there is no separation of organic waste, which is found in household waste.

3.3 QUANTITATIVE DATA

From a quantitative point of view, the research, through SEMDUH documents, provides a history of the amount of waste from 2010 to 2022, observing the increase in this waste in the landfill. Table 01 shows the amount of waste disposed of in Teresina landfill from 2010 to 2021:

Table 01 – Amount of waste disposed of in Teresina landfill in tons/year.

Years	Accumulated	Average month
2010	435,776.20	36,314.68
2011	475,957.26	39,663.11
2012	523,958.26	43,663.19

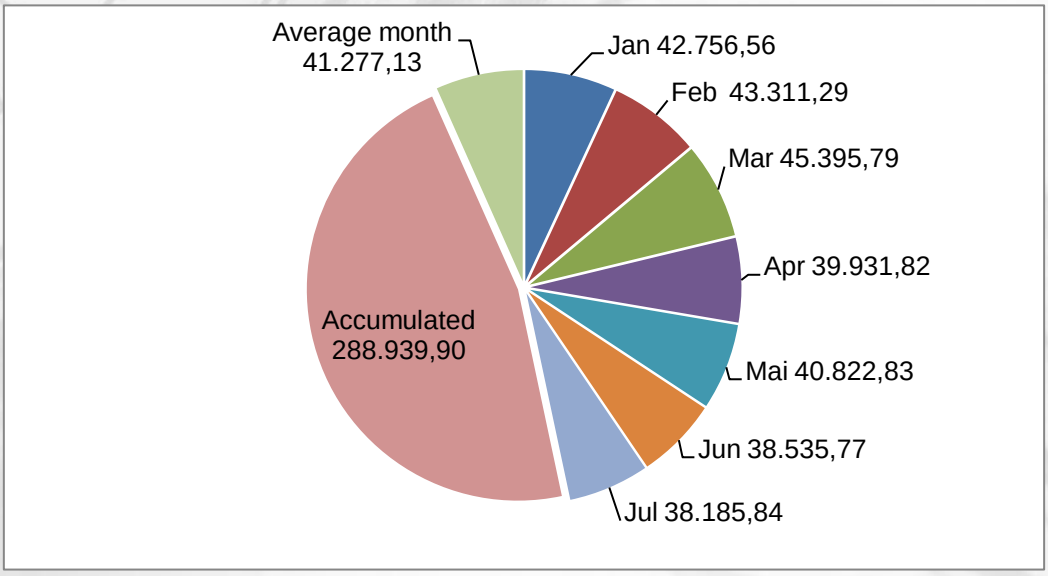
2013	475,782.24	39,648.52
2014	462,461.06	38,538.42
2015	445,624.47	37,135.37
2016	398,422.75	33,201.90
2017	423,615.57	35,301.30
2018	440,206.28	36,683.86
2019	454,730.96	37,894.25
2020	498,183.52	41,515.29
2021	512,799.45	42,733.29

Source: Data made available by SEMDUH (2022).

Analyzing table 01, the accumulated and average/month of waste disposed in the landfill in Teresina is understood. It is observed that in the years 2010 to 2012 there was an increase in waste sent to landfill. In the period from 2013 to 2016 there was a reduction in quantity, returning to growth again in 2017 until 2021.

As it was not possible to conduct interviews, the reason for the decrease in waste sent to landfill in the years 2013 to 2016 was not discovered. All information contained here, it is worth noting, is in documents that were requested from SEMDUH. In 2022, SEMDUH made data available on the amount of waste, both accumulated and the average/month from January to July. In figure 05, there is a graph with 2022 data on the amount of waste disposed of in Teresina landfill.

Figure 05 – Amount of waste disposed of in Teresina landfill in 2022 in tons/month.



Source: Data made available by SEMDUH (2022).

Between the year 2020 and 2021, there was approximately a 2.85% increase in waste sent to landfill. It is speculated, therefore, that organic products also suffered increases. The accumulated, until the middle of 2022, was 288,939.90 and the average/month was 41,277.13, according to data made available by SEMDUH. Making a comparison with the previous year, 2021, only until the middle of the year, 2022 is already approaching the value of waste disposed of in the landfill in the year 2021 in its average/month.

In 2022, only until the middle of the year, there will already be a significant increase in RSU, therefore, it is necessary to reduce the amount of organic waste in Teresina landfill in order to improve the space and, it is understood, given these facts, that the best strategy for this situation is the process called composting.

3.4 COMPOSTING AS A SOLUTION FOR REDUCING ORGANIC WASTE IN THE LANDFILL OF TERESINA, PI

Regarding composting as a strategic solution for organic waste, article 3, item VII, deals with the environmentally appropriate waste final destination. Article 35, in turn, brings the principles of shared responsibility, including, in section V, the articulation between public and private authorities and society to use the compound produced (Brasil, 2010).

Composting is a solution for managing organic waste, which uses the technique of transforming organic matter into fertilizers. Fertilizers are compounds that, through physical, chemical, and biological processes, are rich in nutrients and fertilize the soil, in addition to being used in plantations, gardens, among others (Faria *et al*., 2020).

Teresina City Hall (2021a, p. 30) informs that “Pruning and weeding waste is sent to a specific front, for subsequent landfilling or composting”. It is possible to prove the landfilling of some organic waste in the landfill, as shown in figure 06.

It was not possible to get closer to the place where prunings and tree branches were burying (Figure 06), however, it was possible to verify that tractors were breaking down the organic material and some trucks buried them. Furthermore, it was not found that other types of organic waste besides pruning were going through the landfilling process. Even so, the city hall report mentions composting, although this procedure is not in practice at the site under study.

During the visit to the landfill, it was seen an area that was being reserved for the construction of a composting unit. It was possible to observe that the landfill is viable for composting, also having abundant raw material and labor. The raw material, in this case, is organic waste that is disposed of in the landfill.

Figure 06 – Some organic waste at Teresina landfill

Source: Authors' personal archive, 2022.

As for labor, workers who are dedicated to collecting and using waste for their subsistence, as established in chapter II of the principles and objectives of the National Solid Waste Policy (PNRS), specifically in article 7, item XII, must be included within the scope of the principle of shared responsibility, helping to reintroduce waste that can still be reused and recycled into the economy (Brasil, 2010).

Composting in the landfill could integrate waste pickers into a profitable activity within this space, putting into practice what governs the National Solid Waste Policy (PNRS), when it comes to the environmentally correct final disposal of waste and gives the reintroduction of waste pickers responsibility shared in the waste life cycle. In figure 07, there is the area reserved for composting in the landfill.

The landfill administrators have plans to install a composting unit, whose logistical engineering and related study report indicates that there is an intention to reduce the amount of waste in the landfill and that they are establishing technological routes. In total there will be three routes for organic waste (Teresina, 2021a).

Figure 07 – Area for construction of the Composting Unit

Source: Authors' personal archive, 2022.

According to the report, this method, composting, will be important to improve the useful life of the landfill and, in particular, will contribute to reducing the amount of organic waste in its space. Therefore, the area chosen for composting will receive 60 tons/day, with a forecast of 45 days for stabilization and a production of 40 tons of organic compost per day with the possibility of commercialization. The waste from this process will be sent to the landfill (Teresina, 2021a).

4 CONCLUSION

It was possible to visit Teresina landfill, which is functioning as a controlled landfill. It is appropriate to inform that there is already construction of the sanitary landfill, some spaces in the initial phase of implementation, with one area in the process of waterproofing, and another in operation, receiving waste daily.

Regarding the amount of organic waste, this information was not found, realizing during the visit that there is no separation of Urban Solid Waste (RSU). Organic waste is mixed with RSU, and there is no specific amount of it. Regarding composting in the landfill, it was possible to verify that it is feasible to build a composting unit, with spaces for the implementation and use of machines to crush and mix organic waste and for the production of compounds.

Until the time this research was produced, there was no activity aimed at composting organic waste in Teresina landfill, as the use of this waste in the production of compost would reduce the amount of waste disposed of in the landfill, increasing its lifespan, in

addition to optimize space and reduce the negative impacts on the environment caused by its decomposition.

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REFERENCES

ALCÂNTARA, J. R; IWATA, B. D. F; BAPTISTA, E. M. C. RESÍDUOS SÓLIDOS EM TERESINA – PIAUÍ: Entre a legislação e a destinação. **Edição especial de lançamento Rebrape**. V.1 n.1. 2022. Disponível em: https://revistas.ifpi.edu.br/index.php/rebrape/issue/archive. Acesso: 21 jan. 2023.

BAPTISTA, E.M.C. RIO POTI: CAMINHOS DE SUAS ÁGUAS. **Revista da Academia de Ciências do Piauí**, Volume 1, Número 2, p. 301 – 306, Jan./Jun., 2021.

BRASIL. Ministério do Meio Ambiente (MMA). Conselho Nacional do Meio Ambiente (CONAMA). **Resolução CONAMA Nº 0498, de 19/08/2020**. Define critérios e procedimentos para produção e aplicação de biossólido em solos, e dá outras providências. Disponível em: https://www.in.gov.br/en/web/dou/-/resolucao-n-498-de-19-de-agosto-de-2020-273467970. Acesso em: 31 ago. 2022.

BRASIL. **Lei nº 12.305, de 02 de agosto de 2010**. Institui a Política Nacional de Resíduos Sólidos; altera a Lei no 9.605, de 12 de fevereiro de 1998; e dá outras providências. Disponível em http://www.planalto.gov.br/ccivil_03/_Ato2007-2010/2010/Lei/L12305.htm. Acesso em: 16 mai. 2021.

BRITO, J. P. B. D.; KNOX, W. Gestão de resíduos orgânicos: compostagem e horta no CCHLA / UFRN (2018- 2019). **Cadernos de Agroecologia** – ISSN 2236-7934 - Anais do XI Congresso Brasileiro de Agroecologia, São Cristóvão, Sergipe - v. 15, no 2, 2020.

CASTRO, R. S. D. S; SANTOS, V. C. S; SOUZA, R. L. D. (2022) PROPOSTA DE GERENCIAMENTO DE RESÍDUOS SÓLIDOS: RESÍDUOS DE OFICINA MECÂNICA. **Caderno de Graduação - Ciências Exatas E Tecnológicas - UNIT** - SERGIPE, 7(2), 2022. 101. Recuperado de https://periodicos.set.edu.br/cadernoexatas/article/view/10827.

COSTA, N. R. M. D; NASCIMENTO, F. V; OMETTO, J. P. H. B. A história da coleta de resíduos em Novo Hamburgo, RS e uma proposta de uma nova roteirização utilizando sistema de informações geográficas. **Oficina do historiador**, Porto Alegre, v. 13, n. 2, p. 1-12, jul.-dez. 2020.

FARIA, J. C. T, et. al. A compostagem da casca de café carbonizada favorece a produção de mudas de ingá**. Nativa,** Sinop, v. 8, n. 2, p. 224-230, mar./abr. 2020.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. Censo demográfico 2022. **Prévia da População dos Municípios com base nos dados do Censo Demográfico 2022 coletados até 25/12/2022**. Disponível em: https://www.ibge.gov.br/estatisticas/sociais/saude/22827-censo-demografico-2022.html?=&t=resultados. Acesso: 17 fev. 2023a.

IBGE. INSTITUTO BRASILEIRO DE GEOGRAFIA E ESTATÍSTICA. **Cidades e estados**. Disponível em: https://www.ibge.gov.br/cidades-e-estados/pi/teresina.html. Acesso: 09 mar. 2024.

MENDONÇA, F. **Geografia e meio ambiente**. 9. ed. 1. reimp. 2020.

NASCIMENTO, C. M. T. D; CRUZ, M. L. B. D. Resíduos sólidos: presença e ameaça no espaço geográfico. **GeoTextos**, vol. 13, n. 2, dezembro 2017.

NASCIMENTO, C. M. T. D; CRUZ, M. L. B. D. **Resíduos sólidos:** presença e ameaça no espaço geográfico. GeoTextos, vol. 13, n. 2, dezembro 2017. C. do Nascimento, M. da Cruz. 183-206.

ROCHA, M. C. V. **Microbiologia Ambiental**. 1 ed. Curitiba; Editora Intersaberes, 2020.

RODRIGUES, A. D. S. *et al*. A representatividade da compostagem na destinação dos resíduos orgânicos no Brasil e nordeste brasileiro. **Revista tecnologia e sociedade**. V.18, n. 53 (2022).

SANTOS, J. P. M. *et al.* Tratamento eletroquímico de chorume empregando diferentes eletrodos. **Research, Society and Development**, v. 10, n.15, e447101522102, 2021.

SILVA, L. P. D. **SPILLOVERS ESPACIAIS DE CRIMINALIDADE NA REGIÃO INTEGRADA PARA DESENVOLVIMENTO DO DISTRITO FEDERAL E ENTORNO: UMA ANÁLISE DE CRIMES CONTRA A PESSOA E CONTRA O PATRIMÔNIO**. Tese (Doutorado) – Universidade Federal de Goiás. Instituto de Estudos Socioambientais (IESA). Goiânia, 2020. 304f.

TERESINA. SECRETARIA MUNICIPAL DE PLANEJAMENTO – SEMPLAN. Estruturação do SISTEMA DE GESTÃO DE RESÍDUOS SÓLIDOS URBANOS (RSU) no Município de Teresina/PI. **Relatório de Engenharia, Logística e Afins**, 2021a. Disponível em: https://semplan.pmt.pi.gov.br/concessoes-e-parcerias-ppp/consulta-publica/. Acesso em: 06 abr. 2022.

TERESINA. SECRETARIA MUNICIPAL DE PLANEJAMENTO – SEMPLAN. Estruturação do SISTEMA DE GESTÃO DE RESÍDUOS SÓLIDOS URBANOS (RSU) no Município de Teresina/PI. **Plano de Negócio Referencial**, 2021b. Disponível em: https://semplan.pmt.pi.gov.br/concessoes-e-parcerias-ppp/consulta-publica/. Acesso em: 07 abr. 2022.

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