REVISTA CAMINHOS DE GEOGRAFIA ISSN 1678-6343
http://www.seer.ufu.br/index.php/caminhosdegeografia/ DOI: https://doi.org/10.14393/RCG2510070751

GRAVIMETRIC COMPOSITION OF SOLID WASTE COLLECTED FROM OPEN-AIR DUMP IN ÁGUAS LINDAS (GOIÁS, BRAZIL)

Magaly del Carmen Fonseca-Medrano
Universidade de Brasília, Departamento de Ciências Ambientais, Brasília, DF, Brasil
fonsecatolke@gmail.com

Larissa Rezende Assis Ribeiro
Universidade Federal de Minas Gerais, Instituto de Engenharia Elétrica, MG, Brasil
larissa.ribeiro@ifg.edu.br

Alexandre Pereira Chahad
Universidade de São Paulo, Instituto de Química, SP, Brasil
alexchahad@gmail.com

Geraldo Andrade de Oliveira
Universidade Federal de Pernambuco, Instituto de Engenharia Elétrica, PE, Brasil
geraldo.oliveira@ifg.edu.br

Leonardo Ramos da Silveira
Universidade de Brasília, Departamento de Geotecnia, Brasília, DF, Brasil
leonardo.silveira@ifg.edu.br

Renato Welmer Veloso
Universidade Federal de Viçosa, Instituto de Agronomia, Viçosa, MG, Brasil
renato.veloso@ifg.edu.br

ABSTRACT

This paper presents the Gravimetric Composition Analysis conducted at *Águas Lindas*' Open-Air Dump to accurately characterize local waste, identify hazardous materials, strategize waste management, assess current practices, and set targets. Utilizing quantitative research, the quartering technique was employed, involving: 1) Sample Collection; 2) Waste Discharge; 3) Waste Homogenization; 4) Waste Division; 5) Half of Waste Removal; 6) Removal of the Other Half; 7) Total Sample Weighing; 8) Waste Sorting; 9) Individual Weighing; and 10) Material Percentages. Results indicated the following composition: miscellaneous (42.8%), biological contaminants (13.7%), organic materials (11.3%), plastic (10.7%), paper/cardboard (9.2%), cloth, rags, leather (3.8%), stone, earth, ceramic (2.9%), glass (2.3%), ferrous metal (1.3%), chemical contaminants (1.2%), non-ferrous metal (0.7%), and wood (0.2%). Conclusions encompassed: 1) Dumpsite Waste Composition; 2) Percentage of Waste Types; 3) Measures to Prevent New Dumpsite Creation; 4) Urgent Need for Regional Recycling Infrastructure; 5) Absence of Municipal Waste Management; and 6) Scarcity of Gravimetric Composition Research. This study underscores the significance of sustainable waste management in regions like *Águas Lindas* and underscores the imperative for tangible actions to address solid waste challenges.

Keywords: Gravimetric composition. Open dump. Quartering analysis. Physical gravimetric analysis. Waste management.

COMPOSIÇÃO GRAVIMÉTRICA DOS RESÍDUOS SÓLIDOS COLETADOS NO LIXÃO A CÉU ABERTO DE ÁGUAS LINDAS (GOIÁS, BRASIL)

RESUMO

Este artigo visa apresentar a Análise de Composição Gravimétrica realizada no Lixão a Céu Aberto de Águas Lindas, com o intuito de caracterizar os resíduos na microrregião, identificar materiais perigosos e definir estratégias de gestão de resíduos. Utilizando pesquisa quantitativa e a técnica de quarteamento, as etapas envolveram coleta, descarte, homogeneização, divisão, remoção, pesagem, triagem e cálculo de porcentagens de materiais. Os resultados revelaram a seguinte composição: diversos (42,8%), contaminantes biológicos (13,7%), materiais orgânicos (11,3%), plástico (10,7%), papel/cartão (9,2%), tecidos, trapos, couro (3,8%), pedra, terra, cerâmica (2,9%), vidro (2,3%), metais ferrosos (1,3%), contaminantes químicos (1,2%), metais não ferrosos (0,7%) e madeira (0,2%). As conclusões destacam a composição dos resíduos do lixão, a necessidade de infraestrutura de reciclagem na região, a falta de gestão de resíduos municipais e a escassez de pesquisas sobre Composição Gravimétrica. São fornecidas recomendações para evitar a formação de novos lixões e melhorar a gestão de resíduos. Esse estudo ressalta a importância da gestão sustentável de resíduos em áreas como Águas Lindas e a necessidade de ações concretas para enfrentar desafios relacionados aos resíduos sólidos.

Palavras-chave: Análise física gravimétrica. Análise de quarteamento. Despejo aberto. Composição gravimétrica. Gestão de resíduos.

INTRODUCTION

Open-Air Dumps Impacts

Open-Air Dumps are a common method of disposing of solid waste. However, they present a number of environmental and social problems. From the environmental perspective, solid waste buried in Open-Air Dumps can release harmful chemicals and gases into the environment, including methane, a potent greenhouse gas that contributes to climate change (AL-WABEL et al., 2022). In addition to contributing to climate change, these open waste locations can also contaminate groundwater and soil, posing a threat to human health and the environment (LUO, 2019; NADAKAVUKAREN; CARAVANOS, 2020, p. 215). When solid waste decomposes, it produces leachate, a toxic liquid that can seep into the ground and contaminate nearby water sources. This can lead to a variety of health problems, including cancer, birth defects, and neurological disorders (MATIAS; PIMENTEL; BORGES, 2021, p.17).

In order to mitigate the negative impacts of Open-Air Dumps, primarily it's important to reduce the amount of waste the community produces and increase recycling and composting efforts. This can help reduce the amount of waste that ends up in Open-Air Dumps and decrease the amount of greenhouse gases released during decomposition (NADAKAVUKAREN; CARAVANOS, 2020, p. 352). Secondly, the creation and improvement of public policies for waste management is essential for operating Open-Air Dumps in a way that minimizes their environmental impact since this situation requires a multi-faceted approach that involves reducing waste production, increasing recycling and composting efforts and operational designing.

This type of study can be extremely important to assess the effectiveness of measures adopted to reduce waste generation and increase the recycling rate. In the case of garbage collectors, who work in the collection and separation of recyclable materials in dumps and sanitary Open-Air Dumps, these studies can be especially useful, as they allow identifying the most common types of waste and their quantity in a given region (SHARMA, 2023). In this way, they can adjust their work methods, directing their efforts to the most abundant and most valued materials in the recycling market. In addition, this type of study can help organize collectors' associations, enabling the creation of networks for the collection and sale of recyclable materials, which can increase the income of these workers and improve their living conditions (RATCLIFF, 2014).

Garbage collectors

Open-Air Dump garbage collectors face a number of challenges in their work. Some of the common problems (PARIATAMBY; SHAHUL; BHATTI, 2019, p.37) they may encounter include:

- Health and safety risks: Garbage collectors are exposed to hazardous materials and substances on a daily basis, which can pose significant health and safety risks. They may be at risk of contracting diseases, experiencing respiratory problems, or suffering from injuries while working (YAW-LISSAH et al., 2022).
- Heavy physical demands: Collecting waste involves a lot of physical labor, including heavy lifting, pushing and pulling, and operating machinery. This can lead to fatigue, strain, and other physical injuries (WIEGO, 2023).

- Poor working conditions: Many Open-Air Dump garbage collectors work in difficult conditions, including extreme temperatures, harsh weather, and dirty or unpleasant environments (MAGALHÃES et al., 2021; WIEGO, 2023).
- Lack of protective equipment: In some cases, garbage collectors may not have access to adequate protective equipment, such as gloves, masks, or boots, which can increase their risk of injury or illness (MAGALHÃES et al., 2021).
- Low pay and limited job security: Waste collection is often a low-paying job with limited job security and benefits, which can make it difficult for workers to make ends meet and plan for the future (MORAIS et al., 2022).

To address these challenges, it's important to provide garbage collectors with adequate training, protective equipment, and working conditions that prioritize their health and safety. It's also important to ensure that garbage collectors are fairly compensated for their work and have access to job security and benefits. By addressing these issues, we can help ensure that garbage collectors are able to do their jobs safely and effectively while contributing to a more sustainable waste management system (SATTERTHWAITE, 2021, p.132).

Solid Waste Management

Solid waste management is a set of practices that involve collection, transport, treatment and final disposal of materials discarded by society. Proper management of solid waste is essential to ensure public health, environmental protection and the population's quality of life (MUTHURAMAN; RAMASWAMY, 2019, p.85).

Solid Waste Management is closely linked to several of the 17 sustainable development goals (SDG). To fulfill these goals by 2030, it will be necessary for governments at the national, regional and local levels, as well as civil society and the private sector, to address those which are closely related with the environment and socio-economical themes (DE LA TORRE et al., 2020, p.191-215).

One of the main benefits of solid waste management is the reduction of air, soil and water pollution. With efficient waste collection and treatment system, it is possible to prevent toxic substances from being released into the environment, which can cause irreversible damage to flora, fauna and human health (EPA, 2016a).

Another important benefit is the reduction of disease risks caused by exposure to contaminated waste. When waste is left exposed, in inappropriate places or without proper treatment, it can become breeding grounds for disease vectors, such as rats, flies and mosquitoes (UFRRJ, 2023).

Sustainable Practices

Sustainable practices in waste management aim to reduce, reuse, and recycle waste, while minimizing environmental impact and promoting resource conservation. Among the strategies for sustainable waste management focused on Open-Air Dumps we have: Open-Air Dump Gas Recovery; Leachate Management; Recycling; Composting and Open-Air Dump Closure and Rehabilitation (RATHOURE, 2019, p.6-10).

In order to do that it’s necessary to integrate different Institutions and Organizations from public and private sectors and in this way implement a circular economy model that maximizes the recovery of valuable resources (GUILLAUME; APPELS; KOČÍ, 2023). In this case, Garbage collectors play a critical role in managing waste and can also play a role in implementing the model. There are several activities included in the strategies for sustainable waste management that could be performed by these collectors such as Recycling and Composting, but, beyond the Open-Air Dump, they can work on Source Separation; Product Reuse and Education and Outreach (MASON; OBERENDER; BROOKING, 2004).

Until the moment of carrying out this study, they were working in Source Separation, Recycling and Product Reuse. Members of the academy have been working to get closer to the local government and other Third Sector institutions that can contribute with various resources and thus be used by garbage collectors.

Brazilian Legislation

Law nº 12.305/10 (BRASIL, 2010), also known as PNRS (*Programa Nacional de Resíduos Sólidos*) (National Solid Waste Policy), was created with the aim of promoting the integrated and sustainable management of solid waste in Brazil. The PNRS establishes guidelines for waste management at all stages, from generation to final disposal, and seeks to encourage the reduction of the amount of waste generated, reuse, recycling and proper disposal of waste.

According to *Norma Brasileira (NBR)* – Technical Norm 10.004/2004 (UFSC, 2004), solid waste is:

> “[...] all those in solid and semi-solid state, which result from industrial, domestic, hospital, commercial, agricultural, services and sweeping activities. Included in this definition is sludge from water treatment systems, generated in pollution control equipment and installations, as well as certain liquids whose particularities make it unfeasible to release them into the public sewage system or bodies of water, which require technical and economical solutions in order to be released.”

On the other hand, this standard establishes the procedures for classifying solid waste in terms of their potential risks to the environment and public health. This standard is essential to ensure the proper management of solid waste, as it allows identifying the types of waste generated and determining the most appropriate form of treatment and final disposal (WANG et al., 2021, p.27-29). Through the study of gravimetry it is possible to quantitatively analyze the various compounds present in a sample by measuring its mass. Carrying out a gravimetric study in a given region can provide valuable information on the composition and quantity of waste generated, in addition to assisting in planning strategies to reduce waste generation and increase efficiency in collection and final disposal (PIRES et al., 2018, p.123-137).

Gravimetric Composition and Gravimetric Analysis

Gravimetric composition and gravimetric analysis are related concepts, but they have different meanings:

- Gravimetric composition refers to the quantitative distribution of different types of materials in a sample or mixture, usually expressed as a percentage of the total mass of the sample. This term is often used in the context of waste management, where the gravimetric composition of solid waste is determined to guide the selection of appropriate disposal and treatment strategies (KENKEL, 2020, p.69-75).
- Gravimetric analysis, on the other hand, is a technique used in analytical chemistry to determine the amount of a substance in a sample by weighing the sample before and after a chemical reaction or physical process that isolates or converts the substance. Gravimetric analysis relies on the principle of conservation of mass, which states that mass cannot be created or destroyed during a chemical reaction or physical process. In this sense there are several types of gravimetric analysis, among the fundamental ones, we can mention: Precipitation; Volatilization; Electrogravimetry and Adsorption gravimetry (WEST; HOLLER; CROUCH, 2014). The classical gravimetric analysis is now almost obsolete, especially when it refers to “chemical” separation (KENKEL, 2020, p.76-83).

METHODOLOGY

Area of Study

The city of *Águas Lindas* is located in the state of *Goiás*, next to the Federal District region and close to *Chácaras Quedas do Descoberto*. In coordinates 15°47'06.0"S 48°15'20.4"W.

It's a city whose demographic growth has increased exponentially, currently accounting for 223 thousand inhabitants (IBGE, 2023). As a result of this growth, several socioeconomic and environmental issues have arisen. The city has an economy based on civil construction, commerce and agriculture, but still faces significant challenges, mainly in relation to unemployment, urban infrastructure, education, health and solid waste management (CODEPLAN, 2018). As consequence of this exponential and unplanned urban growth, an Open-Air Dump was created to dispose unwanted waste and materials.

Disorganized urban growth can exacerbate the problem by creating informal settlements where there is limited access to basic services, including waste management. Residents of these areas may resort to burning or burying their waste, which can lead to air and water pollution and other health hazards (SEELIGER; TUROK, 2014). Furthermore, in areas where waste management is centralized, the lack of infrastructure to transport waste to treatment facilities can lead to the accumulation of waste in unauthorized locations, including Open-Air Dumps. These Open-Air Dumps may not be properly designed or managed, leading to environmental contamination and health risks for nearby communities (THAMMINIDI, 2021, p.403).

There is a real need to find solutions not only in Latin America, but in many developing countries (SAND, 2019). The urgency to take actions is based on the following reasons:

- Cities are running out of space
- Open Open-Air Dumps
- Tourism
- Price of Energy
- Environmental awareness

The author continued highlighting that:

“Many of these challenges are related to poor waste management and can be solved by cleaning the waste in the cities and municipalities. Cleaning the city does not mean transporting the waste from one city to another or to rural areas. We need more permanent solutions”

Technique Implemented

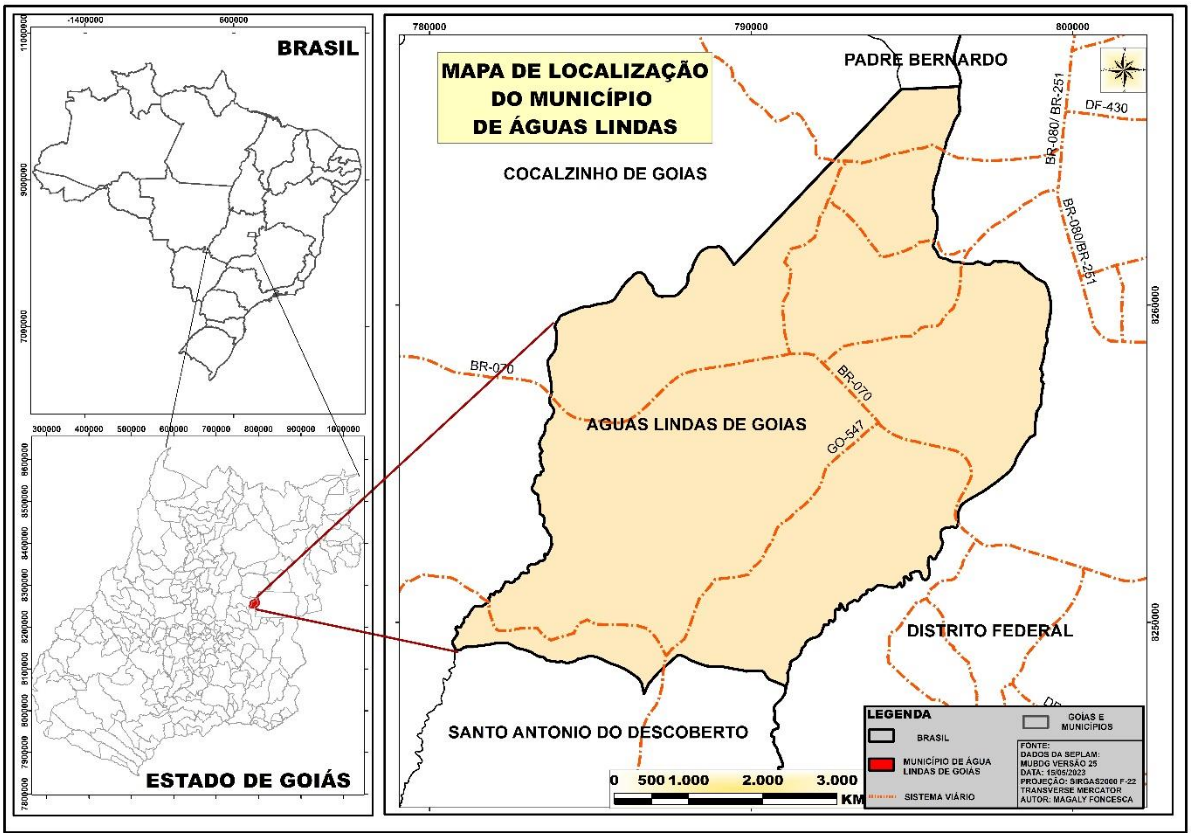
The methodology used to carry out the gravimetry composition study at *Águas Lindas*' Open-Air Dump was the quartering technique (FEMA, 2019), which aims to obtain a representative sample, that is, the collection of a portion of the waste to be studied that, when analyzed, presents the same characteristics and properties of its total mass. According to NBR 10.007/2004 (ABNT, 2004):

> Quartering is the process of dividing a pre-homogenized sample into four equal parts, taking two opposite parts to build a new sample and discarding the remaining parts. The parts not discarded are thoroughly mixed and the quartering process is repeated until the desired volume is obtained. This method will be explained step by step.

To implement the quartering technique, the following steps were followed:

- Samples Collection: The samples were collected in a representative manner at Águas Lindas Garbage Dump in Goiás (Figure 1).

Figure 1 - Location Map of *Águas Lindas* City in *Goiás* State



Source: Google Maps, 2023

The collection schedule occurred as follows:

The weight of samples ranging from 100 kg to 200 kg, which were packed in appropriate containers and correctly identified. The activity took place in the morning, starting at approximately 10 am, when the trucks began to arrive at the two collection points.

- Waste Discharge: It was necessary to unload the waste collected on canvas in an open space. preferably paved.
- Waste Homogenization: This step was carried out with the aid of shovels/sticks and hoes
- Waste Division: From the homogenized residues, two imaginary lines were drawn dividing the residues into four apparently equal parts.

Figure 2 - Quartering performed with the initial sample

Source: Authors

- Half of Waste Removal: Two opposite parts of these residues were removed for disposal.
- Homogenization of the Remaining Parts of the Waste: The two remaining parts were homogenized and divided into four parts again, and the process was repeated until obtaining a sample weighing approximately 200 kg.
- Total Sample Weighing: The mass was determined using a high-precision analytical balance (MENDES; FINETE, 2010).
- Waste Sorting: After weighing the total sample, the waste was sorted on a table or bench. During the sorting process, waste was stored by typology in identified plastic bags.
- Individual Weighing: After separation, each material was weighed separately, to obtain the weight representativeness of each material in the sample.
- Percentage of Materials: To verify the percentage of each material in the sample, the following formula was used:

$$\text{Percentage of each category (\%)} = \left(\frac{\text{Weight of each fraction (Kg)}}{\text{Total Sample Weight}}\right)*100 \quad (1)$$

RESULTS

On the first day of work (Jul/02/2023), the research team visited *Jardim Pérola* 1 and 2, where employees from CAENGE (Construction, Administration and Engineering) led the team to the place intended for work. The initial sample was approximately 100 kg, collected in bags from the content dumped on the ground by the truck. After dividing the content, the final sample was 35.515 kg, distributed as follow: Miscellaneous (35.5%), Organic Matter (27%), and Plastic (14.2%).

On the second day of work (Aug/02/2023), the team visited sectors 9, 10, 11, and 12, where only a portion of the truck's load was dumped at another location.

The initial sample and final sample weighed 2042 kg and 68.29kg respectively. The categories with the highest percentage were Miscellaneous (38%), Biological contaminants (20.5%) and Paper and cardboard (13.8%).

On the third day of work (Sep/02/2023), the team visited the sectors *Gela Goela, Água Bonita 2*, *Royal Parque, Pesque e Pague and Toca de Torto*.

The initial and final sample weighed 205.51 kg and 53.77 kg accordingly. The categories with the highest percentage were Miscellaneous (53.7%), Plastic (11.6%) and Biological Contaminant (8.6%).

According to the gravimetric composition analysis made with the solid waste from *Águas Lindas*' Open-Air Dump, for three days of sampling, the following data were obtained, as shown in Table 1.

Table 1 - Weight and gravimetric composition of the totality of solid waste sampled in Águas Lindas – GO

#	CATEGORIES	WEIGHT (kg)	COMPOSITION (%)
1	Miscellaneous	67.5	42.8
2	Biological Contaminant	21.5	13.7
3	Organic Material	17.8	11.3
4	Plastic	16.9	10.7
5	Paper and Cardboard	14.4	9.2
6	Cloth, Rags, Leather and Rubber	6.0	3.8
7	Stone, Earth and Ceramic	4.5	2.9
8	Glass	3.6	2.3

9	Ferrous Metal	2.1	1.3
10	Chemical Contaminant	1.9	1.2
11	Non Ferrous Metal	1.2	0.7
12	Wood	0.3	0.2
	Total	**157.6**	**100**

Source: Authors, 2023

The waste was primarily composed by Miscellaneous (67.5%), comprising materials with more than one composition, long-life and metallic packaging, residues that are indistinguishable from organic matter, or those that are difficult to identify and separate (very damaged, dirty, small and/or fragmented) (Table 1). The second element of the list is Biological Contaminant (21.5%). These contaminants can include bacteria, viruses, fungi, and other microorganisms that can cause diseases in humans and animals (SZULC; NIZIOŁ; RUMAN, 2023). In third place, we have Organic Materials (17.8%), which can release methane and produce leachate, a toxic liquid that can contaminate groundwater and surface water when not properly managed (AGRAWAL et al., 2019).

In fourth place, we have Plastic (16.9%). This material is widely used in various industries due to its durability, versatility, and low cost; however, plastic waste is a major environmental problem (SMITH; BRISMAN, 2021) and it takes hundreds of years to decompose (CHARIOT, 2021). When it's not properly sorted and cleaned, it can contaminate the entire batch, making it unsuitable for recycling. Another issue is that not all types of plastic are recyclable, and even among the ones that are, not all recycling facilities can process them (SEDAGHAT, 2018; RAVENHALL, 2023). Additionally, the low price of virgin plastic and the lack of incentives to use recycled plastic make it difficult to create a profitable market for recycled plastics (LÊ, 2023).

The next in the list is Paper and Cardboard (14.4%). They are used in many industries, including packaging, printing, and publishing. While they are biodegradable and recyclable, their production and disposal have environmental impacts. Similar to plastic, contamination can affect the quality of the material and reduce its recyclability. Contaminants can include food residue, liquids, and other materials that can compromise the fibers' integrity and make them unsuitable for recycling. Another challenge is that not all paper and cardboard are created equal, and some types are more difficult to recycle than others. For instance, paper products containing a lot of ink or that are heavily coated with wax or plastic may not be easily recyclable. Moreover, recycling paper and cardboard requires significant amounts of water, energy, and chemicals, which can have environmental impacts if not managed properly (CBS; EPA, 2023).

Cloth, Rags, Leather and Rubber (6%) materials can take a long time to decompose, often taking years or even centuries to break down (BEALL, 2020). As they decompose, they can release toxic fumes into the air, including dioxins and furans, especially when they are burned. These gases are highly harmful to human health and the environment (THE PLANET…, 2023).

Materials 4, 5 and 6 can have several negative repercussions. Firstly, they can take up a significant amount of space in Open-Air Dumps, limiting the amount of available space for other waste materials. Second, together with Material 1, 2 and 3, they release methane gas. It's important to mention that Open-Air Dumps are designed to hold a finite amount of waste, and this type of material can quickly fill up that space (DEER, 2023).

Stone, Earth and Ceramic (4.5%) can create problems for the management of the Open-Air Dump itself, such as damaging Open-Air Dump infrastructure and equipment, which can result in costly repairs (EPA, 2016b).

Glass (3.6%) can take up to a million years to decompose, contributing to the waste disposal problem. When not recycled, glass contributes to the depletion of natural resources. The production of new glass requires large amounts of raw materials, including sand, soda ash, and limestone. By not recycling glass, we are wasting these resources, which are becoming increasingly scarce. The production of glass requires a lot of energy, and the burning of fossil fuels during the manufacturing process contributes to the release of carbon dioxide and other greenhouse gases (WWF, 2023). Furthermore, glass represents a latent danger to the environment and public health. Broken glass can cause injuries to people and animals, and glass waste can also contaminate the soil and water if not properly disposed (TTU, 2023).

Ferrous metal (2.1%) is a type of metal that contains iron as its primary component. It is highly valued for its strength, durability, and magnetic properties. These metals are used in a wide variety of applications, including construction, transportation, and manufacturing. Steel, for example, is widely used in the construction of buildings, bridges, and other infrastructure projects, while cast iron is used in the production of pipes, engines, and machine tools (RANI-SAHA; ABU-RAYHAN; KUNDU, 2022; TWI, 2023).

They can release toxic chemicals over time, such as lead, mercury, and cadmium, into the soil and groundwater. These chemicals can contaminate nearby water sources, making them unsafe for human consumption and posing a threat to aquatic life. Another issue is the risk of fire. When ferrous metals come into contact with other materials, such as organic matter, they can cause fires that are difficult to extinguish (THOMAS, 2023).

Chemical contaminants (1.9%) are substances that have the potential to cause harm to human health and the environment, they include, among others, heavy metals, pesticides, and industrial chemicals. When chemical contaminants come into contact with water, they can dissolve and enter the groundwater, potentially contaminating nearby drinking water sources (HUSSAIN; PAULRAJ; NUZHAT, 2022). Another risk associated with chemical contaminants is the potential for fires or explosions. Some chemicals, such as batteries, can react with other materials in the Open-Air Dump, leading to fires or explosions (IRAVANIAN; RAVARI, 2020).

Non-ferrous metals (1.2%), such as aluminum, copper, and brass, can pose environmental and health hazards when they are disposed of in Open-Air Dumps. These metals have properties that make them resistant to corrosion, and they can persist in the environment for a long time (TWI, 2023). As a result, non-ferrous metals can cause a range of issues, including contamination of soil and water, greenhouse gas emissions, and depletion of natural resources (IPCC, 2023). One of the primary environmental concerns associated with non-ferrous metals in Open-Air Dumps is the potential for contamination. They can release toxic substances such as lead, cadmium, and mercury. Recycling non-ferrous metals reduces the need for mining and extraction, which can be environmentally damaging and contribute to habitat loss (LI et al.,2022).

Wood waste (0.3%), such as lumber, plywood, and pallets, is commonly found in Open-Air Dumps. They produce methane and form leachate as well (CHAVAN; LAKSHMIKANTHA; MONDAL, 2022). Trees are harvested to produce wood products, and when they are disposed of in Open-Air Dumps, it the demand for new trees increases. This can lead to deforestation, which is a significant threat to biodiversity and the Earth's climate (SUPNICK, 2023).

Materials 1, 2, 3, 9, 10, 11 and 12 can leach their components into the soil and groundwater. Once this happens, they can spread and contaminate larger areas, affecting ecosystems, water quality, and human populations.

DISCUSSION

Gravimetric composition analysis is a powerful tool used to determine the number of different components present in a sample. This technique involves measuring the mass of each component in a mixture and calculating its percentage by weight. It is commonly used in environmental studies, materials science, and in the analysis of industrial processes (KENKEL, 2020, p.69-75). This article discusses the results of a gravimetric composition analysis of a waste sample, which revealed interesting insights into the different components present in it.

The sample analyzed in this study, as could be observed in Table 1, was composed of various waste materials, including miscellaneous waste, biological contaminants, organic materials, plastic, paper and cardboard, cloth, rags, leather and rubber, stone, earth and ceramic, glass, ferrous metal, chemical contaminants, non-ferrous metal, and wood. The gravimetric composition revealed that miscellaneous waste was the most abundant component, with a percentage of 42.8%, this underscores the importance of employing thorough waste management strategies tailored to address the unique attributes and obstacles linked to individual types of waste (KWAKYE et al, 2024). The second elements found were biological contaminants, with 13.7%, and organic materials, with 11.3%. These elements need special attention due to the fact that their reservoirs represent breeding sites and virus carriers, such as activated sludge (HUANG et al., 2022), animal manures ARGs[1] (CHEN et al., 2021; TIAN et al., 2022) and food wastes (LI et al., 2021; ZHAO et al., 2022), which cause a series of diseases.

Treatments for converting organic wastes into fertilizers or soil modifiers are biological processes involving aerobic and/or anaerobic bacteria (e.g., anaerobic digestion, aerobic composting, and vermicomposting), which can become a new spot for ARGs proliferation (HUANG; BHAT & CUI, 2022, p.2). Moreover, according to Li et al. (2021) the antibiotics present in the processed organic wastes have the potential to infiltrate the soil or nearby water environments when utilized as fertilizers or soil amendments. This has implications for the overall environment, encompassing water resources and the food chain.

Regarding organic waste, Gaudino and Martins (2015), mention that:

> “…the absence of an organic matter composting system justifies the large quantity of this material found in the composition of waste and the need to implement a Solid Waste Sorting and Composting Center in the municipality. The compost, when processed properly, free from contaminants, can be used as fertilizer”.

Plastic and paper/cardboard were also found in significant amounts, with percentages of 10.7% and 9.2%, respectively. This is not surprising given that these materials are commonly used in packaging and are major contributors to landfills. In this matter and especially focusing on plastic waste, according to Parker (2024), this material lies among us for just over a hundred years.

> “The post-World War II era witnessed a surge in the creation and enhancement of numerous innovative plastic items, fundamentally altering contemporary society to the extent that life devoid of plastics would be unrecognizable today. Plastics have played a pivotal role in revolutionizing healthcare through life-saving apparatus, enabling space exploration, reducing the weight of vehicles and aircraft—thus conserving fuel and minimizing pollution—and enhancing safety through the production of helmets, incubators, and devices for purifying potable water.”

Finally, the analysis also showed that cloth, rags, leather, and rubber accounted for 3.8% of the sample, while stone, earth, and ceramic accounted for 2.9%. Glass, ferrous metal, chemical contaminants, non-ferrous metal, and wood were found in smaller amounts, with percentages of 2.3%, 1.3%, 1.2%, 0.7%, and 0.2%, respectively.

The results of this analysis highlight the need for proper waste management practices to reduce the amount of waste that ends up in landfills. It's noteworthy to highlight that the enactment of Law No. 12.305 in 2010 (BRASIL, 2010), establishing the Brazilian National Solid Waste Plan (*Plano Nacional de Resíduos Sólidos*) (PNRS), eliminated the timeframe for eradicating landfill sites. One of the key goals of this legislation was to address challenges related to solid waste management, ensuring secure treatment and proper final disposal. The stipulated deadline for achieving this objective concluded in 2022, yet over 50% of municipalities failed to meet their obligations as outlined by the PNRS, as a consequence, they formulated local public policies for effective solid waste treatment and management (LINO et al., 2023).

In developing countries, the effectiveness of Solid Waste Management (SWM) systems faces numerous challenges. Primarily, there is a shortage of technical expertise, a general lack of awareness among administrators and citizens regarding environmental impacts, and insufficient financial resources. Additionally, international collaborations and funding, intended to provide long-term assistance, can inadvertently worsen the existing challenges. This occurs when solutions are implemented without considering local nuances, leading to the introduction of overly intricate approaches that either quickly prove ineffective or contribute to social inequalities (LAVAGNOLO et al., 2023). The challenge is to implement sustainable solutions to prevent the worsening of an already critical situation and, when possible, turn the necessity into an opportunity. For Brazil, the conversion of energy from organic waste sources holds significant potential. However, politically, this has undergone various stages, starting with

[1] Antibiotic Resistant Gene

the implementation of the Biodiesel B2 blend in 2005, progressing to the B15 blend in 2023 (BRASIL, 2005; 2014; 2016). This journey continued with the emergence of photovoltaic energy in 2011, with its market coverage steadily increasing (ORIGO; SOLBRASIL, 2024). The most recent innovation involves the production of green hydrogen using alternative sources such as vinasse, a byproduct of ethanol production (RAIZEN, 2024). Despite these advancements, the interest in converting organic waste into energy has not been as compelling as anticipated. The key is to explore ways to make this conversion more appealing and capitalize on the potential benefits for sustainable development.

Regarding the methodology, it was possible to identify several strengths. Among them the following can be mentioned:

- Quantitative analysis: the Gravimetric composition analysis provided a quantitative analysis of the components present in the waste sample. This helped in understanding the relative abundance of different materials in the dumpsite.
- Non-destructive: This method is non-destructive, which means that the waste sample could be collected and analyzed without altering its original state. This was particularly useful due to the dumpsite characteristics.
- Reproducibility: This analysis is highly reproducible, and the results obtained can be used to compare different dumpsites.
- Cost-effective: This method was cost-effective and can be used to analyze a large number of waste samples.
- On the other hand, this Gravimetric Composition Analyses also presented the following weaknesses:
-
- Bias: It was not possible to collect large amounts of samples in order to avoid a bias.
- Limited information: Because this method is not a chemical technique, it provides limited information on the chemical and physical properties of the waste components.

A bibliographic review was carried out in three scientific databases, including: SCOPUS, WEB OF SCIENCE and CONNECTED PAPERS. The research was composed of three elements: 1-Key: Gravimetric Composition; 2-Location: Brazil and Time Interval: from 2018 to 2023. The two first databases showed results only in English and the last one in Portuguese.

In the case of SCOPUS, 16 articles (15%) were found from a total of 105. In the WEB OF SCIENCE database, it was possible to find 19 articles (20%) from a total of 94 articles and finally in the CONNECTED PAPERS database 4 papers were found (20%) from a total of 20 articles.

The results of the bibliographic research in the databases previously mentioned, indicate a limited number of studies on gravimetric composition. This technique is used to determine the composition of a sample by measuring its mass, and it has significant applications in various fields such as materials science and environmental monitoring. Therefore, the scarcity of research in this area is surprising and suggests that there is a need for more research in this field.

It's important to mention that Gravimetric composition analysis has numerous advantages, which makes of it a valuable analytical tool for a wide range of applications. One of the main advantages of gravimetric composition is its high degree of accuracy and precision, another advantage is its simplicity and ease of use. The technique is relatively simple to perform and does not require complex equipment or specialized training (ZHENG, 2021).

With regard to theoretical implications, the study provides valuable insights to primarily understand waste generation patterns, where practically 80%[2] of the waste generated in this region comes from recyclable materials. In the case of category #1, a more in-depth study is needed in order to determine in detail its components, secondly, get information about the characterization of waste components which can be used to develop strategies to manage different types of waste, such as recyclable or hazardous waste.

[2] See Table 1 the percentage of the first 4 categories: Miscellaneous (42.8%); Biological Contaminant (13.7%); Organic Material (11.3%) and Plastic (10.7%), their total is: 78.5%.

In terms of practical implications, the study can help identify the potential for resource recovery from waste. Just as the analysis revealed, there is a high percentage of recyclable materials, which indicate the need to implement recycling programs to recover these resources. It was also possible to identify hazardous waste components in the dumpsite, specifically biological and chemical contaminants (#2 and #10 of Table 1) such as: Bacteria and viruses, Parasites, Fungi and molds, Insects and rodents, Odorous compounds (Biological) (HUANG; BHAT; CUI, 2022); Heavy metals, Organic chemical, Polychlorinated biphenyls (PCBs), Pesticides, Asbestos and Chlorofluorocarbons (CFCs) (Chemicals) (CONNELL, MILLER, 2022).

Both Biological and chemical contaminants can have significant impacts on human health, depending on the type and extent of exposure. In the case of biological contaminants, some of the health effects are: Gastrointestinal illness, Respiratory illness, Skin and eye infections and Allergic reactions (SALAMI et al., 2022). Related to the chemical contaminants, they can provoke: Cancer; Skin and eye irritation, Neurological, Respiratory and Reproductive effects, among others (EEA, 2023a).

Finally, as regards the limitations of this study, it was found that the research activities were time-consuming, especially when analyzing complex samples. It also required a high level of precision in the weighing of the sample and the analytical balance used, which was challenging in some settings.

FINAL CONSIDERATIONS

The study sheds light on the pressing need for sustainable waste management practices (ABUBAKAR et al., 2022) in *Águas Lindas*, emphasizing the severe environmental impacts stemming from Open-Air Dumps (ABDEL-SHAFY; MANSOUR, 2018). These sites, while commonly used for non-hazardous waste disposal, carry substantial consequences like greenhouse gas emissions, leaching pollutants, and space limitations, underscoring the urgency for strategic interventions (LUMEN, 2023).

Understanding waste composition reveals the substantial potential for recycling, urging the adoption of technology and infrastructure (OECD, 2021). Establishing recycling systems demands assessing waste patterns, engaging stakeholders, and implementing comprehensive collection and processing methods. However, the analysis also enlighten some aspects, such as leachable components, space-consuming materials, and methane-releasing waste (ECUC, 2021), urging prompt action to manage and mitigate these detrimental elements (UNFCCC, 2016).

Waste is no longer to be dismissed as valueless; instead, it should be viewed as material possessing substantial economic, energy, environmental, and social potential. Strategic handling of investments in infrastructure, alignment with public policy priorities, and the implementation of educational campaigns are imperative. These measures should be meticulously coordinated by local authorities to unite and reinforce collective efforts aimed at achieving sustainability.

Based on the literature review, it is possible to observe the insufficiency of comprehensive studies on gravimetric composition, urging further exploration. Enhancing our knowledge in this realm can catalyze advancements across various scientific disciplines and industries, including materials science, engineering, and energy.

The findings reinforce the imperative to refrain from initiating or expanding dumpsites due to their detrimental health and environmental impacts, especially for the most vulnerable classes (EEA, 2023b), especially in Brazil after the elimination of the deadline for creating landfills contained in Law 12.305 (BRASIL, 2010). Instead, focusing on waste reduction, recycling, and robust waste management practices can significantly mitigate risks (CRISTÓBAL et al., 2022). Building adequate recycling infrastructure is pivotal for a sustainable future, necessitating investments and collaborations among governments, businesses, and individuals.

Promoting sustainable waste management practices remains critical, encompassing source separation, recycling, gas recovery, leachate management, composting, and the closure and rehabilitation of Open-Air Dumps. These strategies demand technological innovations, community involvement, and stringent policies to ensure a healthier environment and improved living conditions for all stakeholders involved in waste management.

Ultimately, this article appeals to the Municipality of *Águas Lindas*, regional stakeholders, and communities to institute sustainable policies. Additionally, it underscores the transformative potential of gravimetric composition studies, advocating for their expanded scope to enhance recycling infrastructure, energy efficiency, and environmental impact mitigation strategies.

ACKNOWLEDGEMENTS

The research presented in this article was made possible through the generous support and funding provided by “Fundação de Desenvolvimento de Tecnópolis – FUNTEC”.

REFERENCES

ABNT - Associação Brasileira de Normas Técnicas. **Documento:** Amostragem de resíduos sólidos (NBR 10007). Universidade Federal de Pelotas. 2004.

ABDEL-SHAFY, H.I.; MANSOUR, MSM. Solid waste issue: Sources, composition, disposal, recycling, and valorization. **Egyptian Journal of Petroleum**, v. 27, p. 1275–1290, 2018. https://doi.org/10.1016/j.ejpe.2018.07.003

ABUBAKAR, I.R.; MANIRUZZAMAN, K.M.; DANO UL, et al. Environmental Sustainability Impacts of Solid Waste Management Practices in the Global South. **International Journal of Environmental Research and Public Health**, v. 19, p. 12717, 2022. https://doi.org/10.3390/ijerph191912717

AGRAWAL, K.; BHARDWAJ, N.; KUMAR, B. et al. Chapter 9 - **Microbial Fuel Cell:** A Boon in Bioremediation of Wastes. In: SHAH, M.; RODRIGUEZ-COUTO, S. (eds) Microbial Wastewater Treatment. **Elsevier**, p. 175–194, 2019. https://doi.org/10.1016/j.egyr.2023.05.255

AL-WABEL, M.; AHMAD, M.; RASHEED, H. et al. Environmental Issues Due to the Open Dumping and Landfilling. In: **Circular Economy in Municipal Solid Waste Landfilling: Biomining & Leachate Treatment**: Sustainable Solid Waste Management: Waste to Wealth. Springer International Publishing, Suiça, p 65–94. 2022. https://doi.org/10.1007/978-3-031-07785-2_4

BEALL, A. **Why clothes are so hard to recycle**. Available in: https://www.bbc.com/future/article/20200710-why-clothes-are-so-hard-to-recycle 2020. Accessed 11 May 2023.

BRASIL. **Lei nº 11.097, de 13 de Janeiro de 2005**, Dispõe sobre a introdução do biodiesel na matriz energética brasileira; altera as Leis nºs 9.478, de 6 de agosto de 1997, 9.847, de 26 de outubro de 1999 e 10.636, de 30 de dezembro de 2002; e dá outras providências. Recuperado 2 de fevereiro de 2024, de https://www.planalto.gov.br/ccivil_03/_ato2004-2006/2005/lei/l11097.htm. 2005.

BRASIL. **Lei 12.305, 2 de Agosto de 2010**. Available in: https://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/l12305.htm Accessed 15 May 2023. 2010.

BRASIL. **Lei Nº 13.033, de 24 de Setembro de 2014**. Dispõe sobre a adição obrigatória de biodiesel ao óleo diesel comercializado com o consumidor final; altera as Leis nºs 9.478, de 6 de agosto de 1997, e 8.723, de 28 de outubro de 1993; revoga dispositivos da Lei nº 11.097, de 13 de janeiro de 2005; e dá outras providências. Recuperado 2 de fevereiro de 2024, de https://www.planalto.gov.br/ccivil_03/_ato2011-2014/2014/lei/l13033.htm. 2014.

BRASIL.. **Lei Nº 13.263, de 23 DE Março de 2016**. Altera a Lei nº 13.033, de 24 de setembro de 2014, para dispor sobre os percentuais de adição de biodiesel ao óleo diesel comercializado no território nacional. Recuperado 2 de fevereiro de 2024, de https://www.planalto.gov.br/ccivil_03/_ato2015-2018/2016/lei/l13263.htm. 2016.

CBS NEWS. **The environmental cost of fast fashion**. Available in: https://www.cbsnews.com/video/the-environmental-cost-of-fast-fashion/ Accessed 10 Jul 2023.

CHARIOT. **How Long Does It Take for Plastic to Decompose?**. Available in: https://chariotenergy.com/blog/how-long-until-plastic-decomposes/ 2021. Accessed 11 May 2023.

CHAVAN, D.; LAKSHMIKANTHA, P.; MONDAL, S. et al. Estimation of spontaneous waste ignition time for prevention and control of landfill fire. **Waste Management**, v. 139, p. 258–268, 2022. https://doi.org/10.1016/j.wasman.2021.11.044

CHEN, Y.; TIAN, H.; ZHU, W.; ZHANG, X.; LI, R.; CHEN, C.; HUANG, Y. l-Cysteine directing synthesis of BiOBr nanosheets. **Journal of Hazardous Materials**, v. 414, p. 17, 2021. https://doi.org/10.1016/j.jhazmat.2021.125544

CRISTÓBAL, J.; VÁZQUEZ-ROWE, I.; MARGALLO, M. et al. Climate change mitigation potential of transitioning from open dumpsters in Peru: Evaluation of mitigation strategies in critical dumpsites. **Science of The Total Environment**, v. 846, p. 157295, 2022. https://doi.org/10.1016/j.scitotenv.2022.157295

CODEPLAN - Companhia de Planejamento do Distrito Federal. **Pesquisa Metropolitana por Amostra de Domicílios** - PMAD 2017/2018 - Águas Lindas de Goiás. 2018.

CONNELL, D.W., MILLER, G.J. Chemistry and Toxicology of Pollution: Ecological and Human Health. **Wiley.** Second Edition**.** 560 p. ISBN: 9781119377603. 2022.

DEER, R. **Landfills: We're Running Out of Space**. Available in: https://www.roadrunnerwm.com/blog/landfills-were-running-out-of-space Accessed 11 May 2023.

DE LA TORRE, E.; ALVAREZ-RISCO, A.; DEL-AGUILA-ARCENTALES, S.; HARRAS, A. Urban Waste Management. In: **Building Sustainable Cities**: Social, Economic and Environmental Factors. Springer International Publishing. 349 p. https://doi.org/10.1007/978-3-030-45533-0

ECUC - Environmental Center University of Colorado. **The Hidden Damage of Landfills**. In: Environmental Center. Available in: https://www.colorado.edu/ecenter/2021/04/15/hidden-damage-landfills. 2021. Accessed 15 May 2023

EEA - European Environment Agency. **Chemicals and health**. Available in: https://www.eea.europa.eu/publications/zero-pollution/health/chemicals. Accessed 17 May 2023. 2023a.

EEA - European Environment Agency. **Municipal solid waste generation and Management**. Available in: https://www.eea.europa.eu/soer/2015/countries-comparison/waste. Accessed 15 May 2023. 2023b.

EPA - Environmental Protection Agency. **Managing and Reducing Wastes: A Guide for Commercial Buildings.** Available in: https://www.epa.gov/smm/managing-and-reducing-wastes-guide-commercial-buildings. 2016a. Accessed 15 May 2023.

EPA - Environmental Protection Agency. **Industrial and Construction and Demolition (C&D) Landfills**. Available in: https://www.epa.gov/landfills/industrial-and-construction-and-demolition-cd-landfills. 2016b. Accessed 11 May 2023.

EPA - Environmental Protection Agency. **Basic Information Details: Paper Recycling**. Available in: https://archive.epa.gov/wastes/conserve/materials/paper/web/html/index-2.html. Accessed 11 May 2023.

FEMA - Fundação Estadual de Meio Ambiente. **Cartilha de orientações: estudo Gravimétrico de Resíduos Sólidos Urbanos**. 27p. Belo Horizonte, 2019.

GAUDINO, S. J.; MARTINS, C. H. Composição gravimétrica dos resíduos sólidos urbanos da coleta convencional de um município de pequeno porte. **Tecno-Lógica**, v. 20, n. 1, p. 01-08, 2015. https://doi.org/10.17058/tecnolog.v20i1.6060

GOOGLE MAPS. **Mapa de Goiás.** Available in: https://www.google.com/maps/place/Goi%C3%A1s/@-15.9000631,-54.0747706,6z/data=!3m1!4b1!4m6!3m5!1s0x935db96386b920f5:0x8c6d8f8cd8cf0d3!8m2!3d-15.7050424!4d-49.3653149!16zL20vMDEyeXpf Accessed 15 May 2023

GUILLAUME, A.; APPELS. L.; KOČÍ, V. Life cycle assessment of municipal biowaste management - a Czech case study. **Journal of Environmental Management**, v. 339, p. 117894, 2023. https://doi.org/10.1016/j.jenvman.2023.117894

HUANG, K.; BHAT, S.A.; CUI, G. **Fate of Biological Contaminants During Recycling of Organic Wastes**. Elsevier Science. First Edition. ISBN: 9780323959971. 2022.

HUSSAIN, C.H.; PAULRAJ, M.; NUZHAT, S. Chapter 6 - Source reduction and waste minimization in chemical industry. In: HUSSAIN CH, PAULRAJ M, NUZHAT S (eds). **Source Reduction and Waste Minimization**. Elsevier, pp 127–135. https://doi.org/10.1016/B978-0-12-824320-6.00006-X

IBGE - Instituto Brasileiro de Geografia e Estatística. **População Águas Lindas de Goiás**. Available in: https://cidades.ibge.gov.br/brasil/go/aguas-lindas-de-goias/panorama Accessed 7 Apr 2023.

IPCC - Intergovernmental Panel on Climate Change. **Non-ferrous metals in the Industry**. Available in: D:\Maggie\Desktop\Produção Acadêmica\Publicações\Em_andamento\2023_ProjetoAPL1\3.CaminhosdaGeografia Accessed 12 May 2023

IRAVANIAN, A.; RAVARI, S.H. Types of Contamination in Landfills and Effects on The Environment: A Review Study. IOP Conf Series: **Earth and Environmental Science**. 2020. https://doi.org/10.1088/1755-1315/614/1/012083

KENKEL, J. Wet Methods and Applications. In: A**nalytical Chemistry Refresher Manual.** CRC Press, p 380. ISBN: 9780367450373. 2020. https://doi.org/10.1201/9781003069966

KWAKYE, S.; AMUAH, E.; ANKOMA, K.; AGYEMANO, E.; Owusu, B.-G. Understanding the performance and challenges of solid waste management in an emerging megacity: Insights from the developing world. **Environmental Challenges**, v. 14, p. 100805, 2024. https://doi.org/10.1016/j.envc.2023.100805

LAVAGNOLO, M. C.; GROSSULE, V.; COSSU, R. **Landfill Disposal in Developing Countries**. Ed. Huang, K., Ahmad, S., Cui, G. In Waste Management in Developing Countries. Springer Nature. 2023. https://doi.org/10.1007/978-3-031-28001-6_2

LÊ, B. **Virgin Plastic vs Recycled Plastic - Which to choose?** Available in: https://www.linkedin.com/pulse/virgin-plastic-vs-recycled-which-choose-billy-l%C3%AA/ Accessed 11 May 2023.

LI, H.; YAO, J.; MIN, N.; DURAN, R. Comprehensive assessment of environmental and health risks of metal(loid)s pollution from non-ferrous metal mining and smelting activities. **Journal of Cleaner Production**, v. 375, p. 134049, 2022. https://doi.org/10.1016/j.jclepro.2022.134049

LUMEN - Environmental Biology. **Chapter 13: Solid and Hazardous Waste**. Available in: https://courses.lumenlearning.com/suny-monroe-environmentalbiology/chapter/15-2-waste-management-strategies/. Accessed 15 May 2023.

LI, X.; Wang, P.; Chu, S.; Su, Y.; Wu, D., Xie, B. The variation of antibiotic resistance genes and their links with microbial communities during full-scale food waste leachate biotreatment processes. **Journal of Hazardous Materials**, v. 416, p. 125744, 2021. https://doi.org/10.1016/j.jhazmat.2021.125744

LINO, F. A. M.; Ismail, K. A. R.; Castañeda-Ayarza, J. A. Municipal solid waste treatment in Brazil: A comprehensive review. **Energy Nexus**, v. 11, p. 100232, 2023. https://doi.org/10.1016/j.nexus.2023.100232

LUO, J. Protecting the City from Climate Changes. In: **Cities around the World: Struggles and Solutions to Urban Life** [2 volumes]. ABC-CLIO Editor. ISBN: 9798216061052. 2019.

MAGALHÃES, E.; FERNANDES, M.; VIANA, M. et al. Health and Work Conditions of Garbage Collectors: A Cross-Sectional Study. **The Open Nursing Journal.** 2021. **DOI.** 10.2174/1874434602115010319.

MASON, I.G.; OBERENDER, A.; BROOKING, A.K. Source separation and potential re-use of resource residuals at a university campus. Resources, **Conservation and Recycling**, v. 40, p.155–172, 2004. https://doi.org/10.1016/S0921-3449(03)00068-5

MATIAS, M.; PIMENTEL, I.; BORGES, A. Waste Management Policies and Practices in Brazil. In: **Waste Management Policies and Practices in BRICS Nations**. CRC Press. ISBN: 9780367440992. 2021.

MENDES, M.; FINETE, Virginia de L.M. Fundamentos de Química Experimental. In: MOLINARO, Etelcia Moraes; CAPUTO, Luzia Fátima Gonçalves; AMENDOEIRA, Maria Regina Reis (Org.). **Conceitos e métodos para a formação de profissionais em laboratórios de saúde**. v.1. Rio de Janeiro: EPSJV. p. 223-286. 2010.

MORAIS, J.; CORDER, G.; GOLEV, A. et al. Global review of human waste-picking and its contribution to poverty alleviation and a circular economy. **Environmental Research Letters**, v. 17, n. 6, 2022. https://doi.org/10.1088/1748-9326/ac6b49

MUTHURAMAN, L.; RAMASWAMY, S. **SOLID WASTE MANAGEMENT.** E-book. 360 p. MJP Publisher. 2019.

NADAKAVUKAREN, A.; CARAVANOS, J. **Our Global Environment: A Health Perspective.** Eighth Edition. Waveland Press. 506 p. ISBN: 1478637714. 2020.

OECD - Organization for Economic Cooperation and Development. Document PDF - **Towards a more resource-efficient and circular economy: The role of the G20**. 2021. Available in: https://www.oecd.org/. Accessed 24 Jun 2023.

ORIGO. **A história da energia solar no Brasil** Available in: https://origoenergia.com.br/blog/energia/a-historia-da-energia-solar-no-brasil/ Accessed 2 Feb 2024

PARIATAMBY, A.; SHAHUL, F., BHATTI, M.S. Sustainable Waste Management Challenges in Developing Countries. **IGI Global**. 586 p. ISBN: 9781799801986. 2019. https://doi.org/10.4018/978-1-7998-0198-6

PARKER, L. **Plastic pollution facts and information**. Available in: . https://www.nationalgeographic.com/environment/article/plastic-pollution Accessed 2 Feb 2024

PIRES, A.; MARTINHO, G.; RODRIGUES, S.; GOMES, M.I. **Sustainable Solid Waste Collection and Management**. Springer International Publishing. 728 p. https://doi.org/10.1007/978-3-319-93200-2

RAIZEN, B. **Redefinindo o futuro da energia**. Available in: https://www.raizen.com.br Accessed 2 Feb 2024.

RANI-SAHA, T.; ABU-RAYHAN, M.; KUNDU, R. et al. Heavy metal contaminations of soil in waste dumping and non-dumping sites in Khulna: Human health risk assessment. **Results in Chemistry**, v. 4, p. 100434, 2022. https://doi.org/10.1016/j.rechem.2022.100434

RATCLIFF, J. **Weighing the advantages of gravimetric analysis**. 51:30–31. Available in: https://www.researchgate.net/publication/291897516_Weighing_the_advantages_of_gravimetric_analysis. 2014.

RATHOURE, A. **Zero Waste: Management Practices for Environmental Sustainability**. Estados Unidos: CRC Press 355p. ISBN: 9780429607868. 2019. https://doi.org/10.1201/9780429059247

RAVENHALL, L. **Why can't all plastic be recycled?** – The Waste Management & Recycling Blog. Available in: https://www.forgerecycling.co.uk/blog/why-cant-all-plastic-be-recycled/ Accessed 11 May 2023.

SALAMI, R.; KORDI, M.; DELANGIZ, N. et al. **C**hapter 2 - Biological contamination and the control of biological contaminants in the environment**.** In: Naeem M, Aftab T, Ali Ansari A, et al (eds) **Hazardous and Trace Materials in Soil and Plants**. Academic Press, pp 9–14. ISBN: 9780323914109. 2022. https://doi.org/10.1016/B978-0-323-91632-5.00010-0

SAND, R. **Why waste disposal is very important in Latin America**. Available in: https://crosswrap.com/why-waste-disposal-is-very-important-in-latin-america/ Accessed 13 Apr 2023. 2019.

SATTERTHWAITE, D. Environmental Justice and the Sustainable City. In: **The Earthscan Reader in Sustainable Cities**. Taylor & Francis. 288 p. ISBN: 9781317762614. 2021. https://doi.org/10.4324/9781315800462

SEDAGHAT, L. **Things You Didn't Know About Plastic (and Recycling)**. Available in: https://blog.nationalgeographic.org/2018/04/04/7-things-you-didnt-know-about-plastic-and-recycling/. 2018. Accessed 11 May 2023.

SEELIGER, L.; TUROK, I. Averting a downward spiral: building resilience in informal urban settlements through adaptive governance. **Environment and Urbanization**, v. 26, p. 184–199, 2014. https://doi.org/10.1177/0956247813516240

SHARMA, K. **Gravimetric analysis: Steps, Types, Advantages, Disadvantages.** Available in: https://thechemistrynotes.com/gravimetric-analysis/ Accessed 7 Apr 2023.

SMITH, O.; BRISMAN, A. Plastic Waste and the Environmental Crisis Industry. **Crit Crim**, v. 29, p. 289–309, 2021. https://doi.org/10.1007/s10612-021-09562-4

SUPNICK, A. **The impact of climate change on deforestation and food security**: Amazon deforestation: a case study. Lulu Press, Inc. ISBN: 9781447781479. 2023.

SOLBRASIL. **Evolução da Energia Solar no Brasil**. Available in: https://solbrasilenergia.com.br/evolucao-da-energia-solar-no-brasil/ Accessed 2 Feb 2024.

SZULC, J.; NIZIOŁ, J.; RUMAN, T. et al. Biological and chemical contamination of illegal, uncontrolled refuse storage areas in Poland. **Environmental Research**, v. 228, p. 115825, 2023. https://doi.org/10.1016/j.envres.2023.115825

THAMMINIDI, M. **PMF IAS Environment for UPSC 2022-23: Environment, Ecology and Biodiversity**. PMF IAS.500 p. ISBN: 9789355263315. 2021.

THE PLANET VOICE. **Fast Fashion Environmental Impact: How Fast Fashion is Destroying The World.** Available in: https://www.youtube.com/watch?v=6AEr0tpTAMs#:~:text=did%20you%20know%20fast%20fashion,referred%20to%20as%20throwaway%20fashion . Accessed 17 May 2023.

THOMAS, G.P. **Ferrous Metals Recycling**. Available in: D:\Maggie\Desktop\Produção Acadêmica\Publicações\Em_andamento\2023_ProjetoAPL1\3.CaminhosdaGeografia. Accessed 11 May 2023

TIAN, T.; Dai, S.; Liu, D.; Wang, Y.; Qiao, W.; Yang, M.; Zhang, Y. Occurrence and transfer characteristics of blaCTX-M genes among Escherichia coli in anaerobic digestion systems treating swine waste. **Science of The Total Environment**, v. 834, p. 155321, 2022. https://doi.org/10.1016/j.scitotenv.2022.155321

TTU - Texas Tech University. **Glass Waste Management**. Available in: https://www.depts.ttu.edu/ehs/environmental/hazardous-waste/glass.php. Accessed 11 May 2023

TWI. **Ferrous vs Non-Ferrous Metals (What is the Difference?)**. Available in: https://www.twi-global.com/technical-knowledge/faqs/ferrous-vs-non-ferrous-metals.aspx. Accessed 11 May 2023

UFSC - Universidade Federal de São Carlos. **Documento:** ABNT NBR 10004-Resíduos sólidos – Classificação. 2004.

UFRRJ - Universidade Federal Rural do Rio de Janeiro. **Doenças relacionadas ao lixo**. Available in: http://www.ufrrj.br/institutos/it/de/acidentes/lixo1.htm. Accessed 8 Apr 2023.

UNFCCC - United Nations Framework Convention on Climate Change. Landfill composting. In: **UN Climate Technology Centre & Network** (CTCN). 2016. Available in: D:\Maggie\Desktop\Produção Acadêmica\Publicações\Em_andamento\2023_ProjetoAPL1\3.CaminhosdaGeografia. Accessed 15 May 2023.

WANG, L.K.; WANG, M.H.S.; HUNG, Y.T.; SHAMMAS, N.K. **Integrated Natural Resources Management**. 447 p. ISBN: 9783030551728. Springer International Publishing. 2021. https://doi.org/10.1007/978-3-030-55172-8

WEST, D.; HOLLER, J.; CROUCH, S. Métodos Gravimétricos de Análise. In: **Fundamentos de Química Analítica**, 9th ed. Cengage Learning, São Paulo, pp 279–300. ISBN: 978-0-495-55828-6. 2014.

WIEGO - Waste Pickers. In: **Workers in informal employment: Globalizing and Organizing**. Available in: https://www.wiego.org/waste-pickers. Accessed 11 May 2023.

WWF - World Wide Fund for Nature. **Recycling Glass - How it helps environment**. Available in: https://wwf.panda.org/discover/knowledge_hub/teacher_resources/project_ideas/recycling_glass. Accessed 11 May 2023

YAW-LISSAH, S.; AMOGRE, M.; KRUGU. J. et al. Our Work, Our Health, No One's Concern: Domestic Waste Collectors' Perceptions of Occupational Safety and Self-Reported Health Issues in an Urban Town in Ghana. International **Journal of Environmental Research and Public Health**. 2022. https://doi.org/10.3390/ijerph19116539

ZHAO, C.; Xin, L.; Xu, X.; Qin, Y.; Wu, W. Dynamics of antibiotics and antibiotic resistance genes in four types of kitchen waste composting processes. J**ournal of Hazardous Materials**, v. 424, p. 127526, 2022. https://doi.org/10.1016/j.jhazmat.2021.127526

ZHENG, CH. Method, Advantages and Disadvantages of Gravimetric analysis: A Brief Introduction. **Research & Reviews: Journal of Pharmaceutical (RRJPA)**, v. 10, n. 5, 2021.

Recebido em: 11/09/2023
Aceito para publicação em: 14/02/2024