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Bibliometric research to determine characterization tests for solid waste disposal areas: case study of a controlled landfill in Brazil

Recherche bibliométrique pour déterminer les essais de caractérisation des sites de décharge: étude de cas d'une décharge contrôlée au Brésil

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ABSTRACT: Inadequate landfills and dumpsites are usually areas of solid waste disposal with no previous characterization. The Controlled Landfill of Brasilia Jockey Club (Landfill BJC) lies in Brazil's capital. It is the second largest inadequate landfill in the world. This work aims to develop a proposal for a testing campaign to characterize a waste disposal area. It is expected to provide tools to guide the survey of geotechnical and environmental experiments in landfills for remediation or energy recovery. Bibliometric research was performed on 43 papers from Brazil and 12 countries to catalog the literature data. The data from experiments analyzed were divided into geotechnical, geophysical, and solid waste. A site diagnosis was made to define the most relevant tests for landfill characterization. As a result, the chosen tests were the electromagnetic and seismic (geophysics); particle size; permeability; pH; metal concentration; nutrient concentration; Atterberg limits (geotechnical tests); gravimetry; volatile solids; compressibility; COD -Chemical Oxygen Demand- of the leachate; metal concentration; calorific potential (solid waste) for the characterization of BJC. The proposed methodology can be applied to establish geotechnical investigations in landfills.

RÉSUMÉ : Les décharges inadéquates sont généralement des zones d'élimination des déchets solides sans caractérisation antérieure. La décharge contrôlée du Brasilia Jockey Club (BJC décharge) est située dans la capitale du Brésil et c'est la deuxième plus grande décharge inadéquate au monde. Ce travail consiste à proposer une campagne d'essais pour caractériser une décharge de déchets urbains et guider l'étude des tests géotechniques et environnementaux en vue de leur remédiation ou de la production d'énergie. Une recherche bibliométrique a été effectuée sur 43 articles du Brésil et de 12 pays pour cataloguer les data de la littérature. Les résultats ont été divisés en trois catégories : géotechnique, géophysique et déchets solides. Un diagnostic du site a été réalisé afin de définir les tests les plus pertinents pour la caractérisation. Les tests suivants ont été choisis : électromagnétique et sismique (géophysique) ; granulométrie ; perméabilité ; pH ; concentration de métaux ; concentration de nutriments ; limites d'Atterberg (tests géotechniques) ; gravimétrie ; solides volatils ; compressibilité ; DCO - Demande Chimique en Oxygène- du lixiviat ; concentration en métaux ; potentiel calorifique (déchets solides). La méthodologie proposée peut être appliquée pour des études géotechniques dans les décharges.

KEYWORDS: Landfills, solid waste, proposal of testing campaign, bibliometry, controlled landfill of Brasilia Jockey Club.

1 INTRODUCTION

Especially when built without engineering planning, landfill sites are great potential polluters of soil, air, and water. According to a Brazilian Association of Public Cleaning Companies and Special Waste report, around 40% of the waste generated in Brazil is still disposed of in irregular places (Santos, 2019). Landfills need impermeabilization, drainage, and structural components established based on field and laboratory tests to avoid contamination issues. Therefore, the geotechnical characterization of the soil and solid waste is essential for the proper planning of landfills.

The Controlled Landfill of Brasilia Jockey Club (Landfill BJC) is an open dumpsite considered the second-largest globally. It is located in Brasília, Brazil's capital. It has received urban waste since the 1960s, totaling over 30 million tons of waste (Cruvinel et al., 2017). In 2018 the site was decommissioned and studied for environmental remediation and energy recovery of waste and biogas. Over the years of operation, several researchers conducted studies to characterize the area, of which we can mention: Franco (1996), Feitosa et al. (1999), Santos (2004), Cardim (2008), Cavalcanti (2014), and Guedes (2020).

Despite the large number of works carried out in this field, there is still a lack of current data. Some regions are not adequately sampled for characterization.

This work aims to perform a proposal for a test campaign to characterize BJC Landfill for remediation and energy recovery based on bibliometric research. In total, 26 works from Brazil and 17 works from 12 other countries were cataloged. The data from experiments analyzed were divided into geotechnical, geophysical, and solid waste. Statistics were performed to define the most relevant tests for landfill characterization. A diagnosis of the study area was carried out to identify the most relevant complementary tests. The results can contribute to the decision-making about the tests to be executed. The methodology can be applied to different tropical landfills around the world.

This work is part of a research and development project for environmental remediation and energy recovery of the BJC landfill in Brazil (RAEESA–Remediation Action for Energy, Environmental and Sustainability in Landfills). Therefore, the tests' definition needs to be conducted on-site to establish the material's properties, the planning of waste mining and energy use of waste and biogas to assess the economic viability of the implementation of the power station.

2 STUDY AREA

The object of study is the Landfill BJC, located in Brazil, at point 15°46'20.7372" S, 47°59'45.0204" W. The site in question, as mentioned previously, is considered the second-largest dumpsite in the world, with about 200 hectares of area, receiving for more than 50 years from domestic to hospital waste. In 2018, the site was deactivated and started to receive only construction waste. Figure 1 shows the JCB Landfill area's location map in relation to its host city and Brazil.

The region's climate is characteristic of the tropical Brazilian Central Plateau, with two well-defined seasons, the dry and cold winter and the humid and hot summer. The stratigraphic unit of the landfill is slate, the geological unit being the Paranoá Group.

The topsoil has high porosity and high variation of texture and mineralogical composition. The predominant soil classes in the area are red latosol and red-yellow latosol (Santos, 2019).

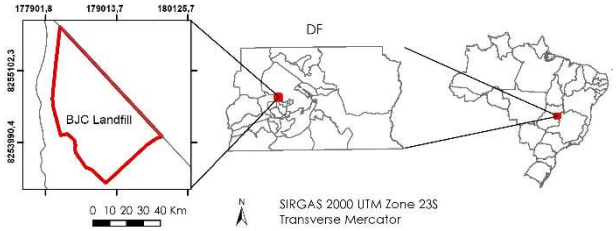

Figure 1. The location map of the JCB Landfill area.

3 MATERIALS AND METHODS

The research methodology employed is classified as exploratory based on a bibliometric survey applied to a case study, whose main steps are:

(1) Bibliometric survey: First, bibliometric research covered topics related to the characterization of areas contaminated by the incorrect disposal of solid waste. Using the platforms "Google Academic" and "Web of Science", it was cataloged 43 technical papers (theses, dissertations, articles, and reports) developed in 13 countries: Austria (Wolfsberger et al., 2014), Brazil (Porciúncula and Leal, 2019 and works in Table 1), Belgium (Quaghebeur et al., 2018; Parrodi et al., 2019), China (Zhou et al., 2014), Colombia (Porras et al., 2013), Cuba (Hernández-Nazario et al., 2018), England (Gutiérrez-Gutiérrez et al., 2015), Finland (Kaartinen et al., 2013), India (Lakshmikanthan et al., 2017; Ramaiah et al., 2017; Sharma et al., 2019), Italy (Pecorini and Iannelli, 2020), Nigeria (Lawal et al., 2019; Fabota et al., 2020), Pakistan (Azam et al., 2020) and The United States of America (Yargicoglu et al., 2014; Zhao et al., 2020). Emphasis was given to the works about the area of the study Landfill BJC.

(2) Data mining: The 43 papers were divided into three main categories, as follows:

(a) Geotechnics;
(b) Geophysics;
(c) Solid Waste.

The most statistically significant tests for a waste disposal area's characterization were selected according to these results.

(3) Diagnosis of the study area: The existing data for the characterization of the Landfill BJC was used to diagnose the area, raise the deficiencies, and suggest strategic sampling points for carrying out additional tests. The data were spatialized using geoprocessing tools – ArcGIS.

Finally, the test campaign for the BJC Landfill was developed based on the most important characterization tests.

4 RESULTS AND DISCUSSIONS

4.1 *Analysis of data obtained from the literature*

For the three categories defined in section 3, the characterization tests found in the set of references consulted were:

(a) Geotechnics (Specific mass; pH; Soil classification; Casagrande classification; Atterberg limits; Particle size; Permeability; Metal concentration; Nutrient concentration; Water retention capacity; Compressibility; Metal concentration; Contaminant concentration; Shear strength; Electrical conductivity; Physical indices; Pesticides; Volatile, Dissolved and Total solids; Standard penetration test).

(b) Geophysics (Electrical resistivity; Ground-penetrating radar (GPR); Eletromagnetics and Seismic).

(c) Solid Waste (Gravimetry; Humidity; Density; pH; Specific mass of the waste; Volatile solids; Calorific potential; Particle size; Compressibility; Organic matter; Biogas; Carbon; Nitrogen; Hydrogen; Chloride; Metal concentration; Contaminant concentration; Chemical Oxygen Demand (COD) of the leachate; Electrical conductivity; Physical indices; Shear strength; Water retention capacity; Compressibility, Ash, Sulphur, Oxygen).

From these categories, it was selected the most recurring ones. Figure 2 presents the results of the tests most found in the works belonging to the database. The database created contains 23 papers for the category of Solid waste, 19 for Geotechnics, and 13 for Geophysics for landfill characterization. Some studies were able to be considered in more than one category.

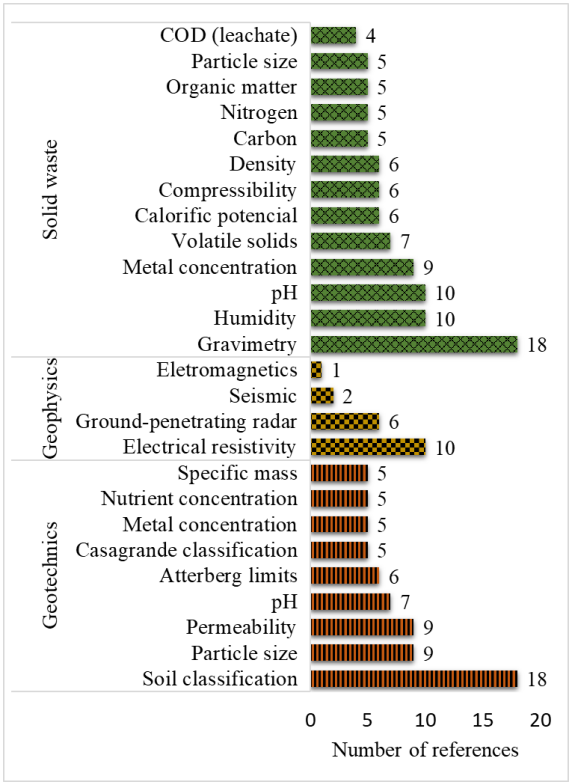

Figure 2. Statistical results of the most recurrent properties in literature for each category.

By analyzing the data, the results indicate that the tests most performed in landfills were: determination of gravimetry, humidity, and pH for the characterization of solid waste; electrical resistivity, GPR and seismic for the geophysical characterization of the area; and in Geotechnics, soil classification, granulometry, and permeability of soil used in the construction of the landfill and its foundation.

4.2 *Diagnosis of the study area*

A diagnosis of the tests already performed at BJC Landfill was made. The points already tested were marked using geoprocessing (ArcGIS) to visualize what has been previously done and develop the new campaign proposal for complementary tests.

It was looked for studies carried out from 1978 to 2020. In total, 37 papers about the BJC Landfill were found, 25 technical works were selected, discarding those related to other themes, such as water contamination at BJC Landfill. Table 1 shows the list of papers used in this research.

Table 1. List of the work on the BJC landfill and the category of tests performed.

Reference	Test category*	Reference	Test category*
1. Amorim & Aguiar (1978)	(c)	14. Água & Terra (2006)	(a)(c)
2. Boaventura et al. (1995)	(a)	15. Santana (2007)	(a)(c)
3. Franco (1996)	(b)	16. Cardim (2008)	(c)
4. Santos (1996)	(c)	17. Santana & Imanã-Encinas (2009)	(a)
5. Pastore (1997)	(a)(b)	18. Tapahuasco (2009)	(a)(c)
6. Pastore (1998)	(a)(b)	19. Stollberg & Weiss (2011)	(b)
7. LM (1998)	(a)(c)	20. Greentec (2012)	(a)(c)
8. Bernardes et al. (1999)	(a)(b)	21. Greentec (2012)	(a)
9. Farias et al. (1999)	(a)	22. Greentec (2012)	(a)
10. Abreu (2001)	(a)	23. Cavalcanti (2013)	(b)
11. Santos (2004)	(a)(c)	24. Cavalcanti (2014)	(b)
12. Santana & Imanã-Encinas (2004)	(a)	25. Guedes et al. (2020)	(b)
13. PROGEA (2005)	(a)(b)		

*(a) Geotechnics; (b) Geophysics; (c) Solid Waste.

The field tests previously conducted at the BJC landfill were mapped from the information provided in the works. In some works, the sampling points were undescribed, or it was unable to georeference the coordinates. The results for the cataloged studies' sampling points are shown in Figure 3 (geotechnical characterization) and Figure 4 (geophysical characterization).

As for the solid waste essays, most of the authors tested the non-landed waste; therefore, no specific map was generated for this category. The sampling points were coincident with the works that made solid waste in conjunction with geotechnical characterization, and they are in Figure 3.

For the definition of future geotechnical sampling points, priority was given to places where there was no previous characterization. For this, the areas of influence of the tests previously performed were defined. In this way, 200 m buffers were generated in ArcGIS around the landmarks shown in Figure 3. Figure 5 presents this contour. These areas were discarded from the new proposal since they have already been characterized.

The areas delimited with the buffers in Figure 5 were removed from this base map to generate a map with the unserved geotechnical test areas, shown in Figure 6. This map shows the results of priority areas for future geotechnical sampling at BJC Landfill, as unserved areas, totaling 1.498.700 m². This analysis has been considered the disposal areas over the years, ranging from 1975 to the present day. Santos (2019) analyzed the waste disposal area over the years, which evaluated different temporal image records to define how solid waste disposal occurred over the years of its operation. This work used a 200 m buffer to compensate for the uncertainties of the georeferencing instruments.

The definition of priority sampling areas for geophysical tests and residue characterization tests was not done because the researchers considered that the entire landfill area lacks in tests of these types.

4.3 *Suggestion for future trials*

After defining the areas of interest for future testing, the priority tests were determined. The results were achieved by crossing the data already obtained at the BJC landfill and the most recurrent data in the literature of Figure 2. The purpose of this selection was to prioritize tests that were not previously performed at the landfill based on the bibliometric research.

Thus, the testing campaign for characterization of the BJC landfill for environmental remediation and energy recovery purposes is described in Table 2.

Table 2. The testing campaign for characterization of the BJC landfill for environmental remediation and energy recovery purposes.

Solid waste	**Geotechnics**	**Geophysics**
Gravimetry of the landfilled waste	Particle size	Electromagnetic
Volatile Solids	Permeability	
Compressibility	pH	
COD of the leachate	Metal concentration	Seismic Reflection and Refraction
Metal concentration	Nutrient concentration	
Calorific potential	Atterberg limits	

The results of the solid waste tests indicated the measurement of key properties in the monitoring of settlements (compressibility), in the energy use (calorific potential and concentration of metals), in the treatment and pollutant potential of the waste (gravimetry, volatile solids, and COD). This stage is crucial in the analysis of the energetic properties of waste for exploitation purposes. It also serves to evaluate the contamination, biodegradation and to plan treatment methods.

Regarding geotechnical characterization, classical soil tests and tests on contamination (metal concentration) were proposed. We also obtained tests on contaminants and water percolation (permeability), which are essential mainly in unsaturated soils typical of Brazil's studied region. Nutrient testing refers to the viability of bioremediation at the BJC landfill. The comprehensive soil characterization of the BJC landfill is fundamental in modeling the transport of contaminants, defining the risk to human health, and analyzing the chemistry and physics of the porous medium. Thus, it is possible to define techniques of environmental remediation and minimization of risks to the environment.

The proposed geophysical tests are complementary to the tests previously performed at the BJC landfill. The electromagnetic tests and seismic tests allow, in this order, to obtain values of electrical conductivity and values of speed of wave propagation, which allows the determination of the soil conductivity plume limits and changes in the mechanical behavior of the area. In addition to those mentioned in Table 2, more electrical resistivity tests can also be carried out, including previously characterized areas, making it possible to evaluate some properties over time.

5 CONCLUSIONS

In conclusion, the proposed methodology was employed to define a landfill characterization test campaign applied at the BJC landfill in Brazil. Based on the bibliometric research of national and international works, it was possible to spatially catalog and delimit the sampling points already executed to propose complementary tests. The results can be applied to the environmental remediation project and the energy recovery of

the BJC landfill. The method can be replicated for several landfills and dumpsites in similar situations.

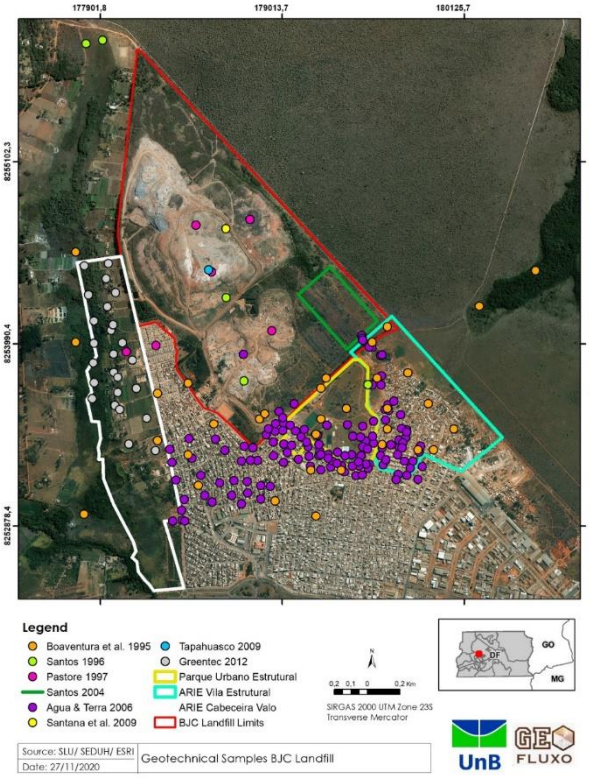

Figure 3. Geotechnical characterization sampling points.

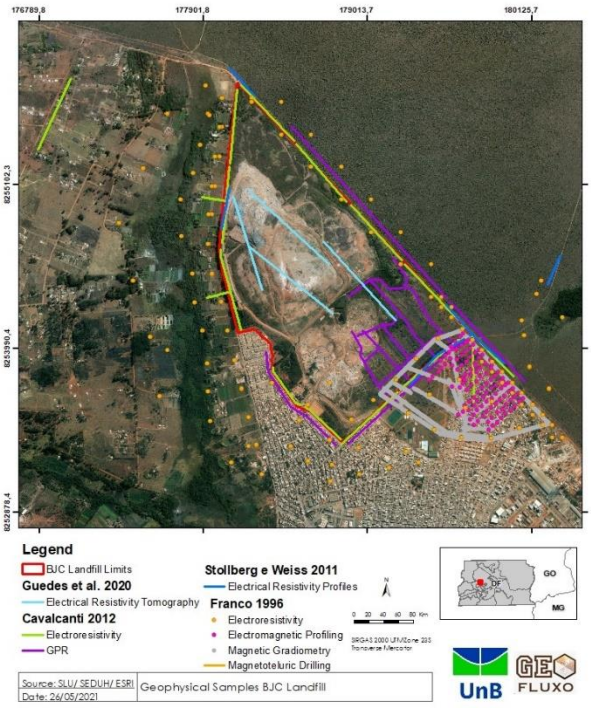

Figure 4. Geophysical tests points.

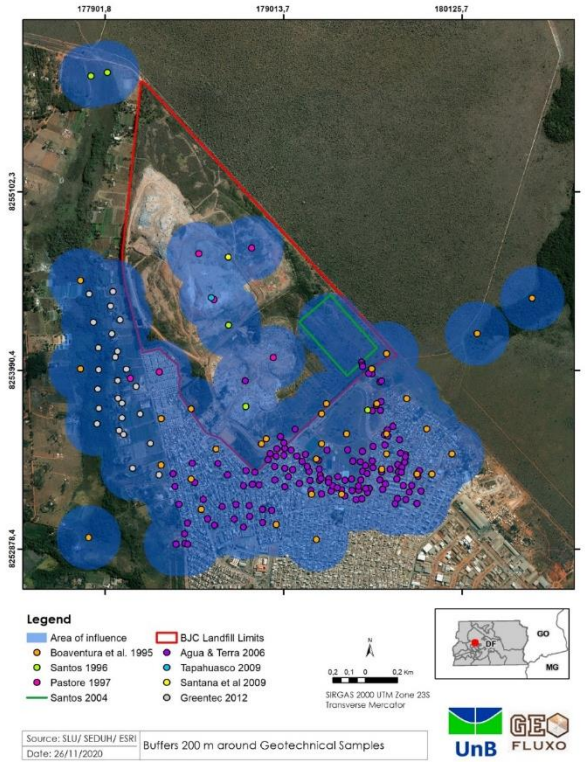

Figure 5. Geotechnical tests with 200m buffer area of influence.

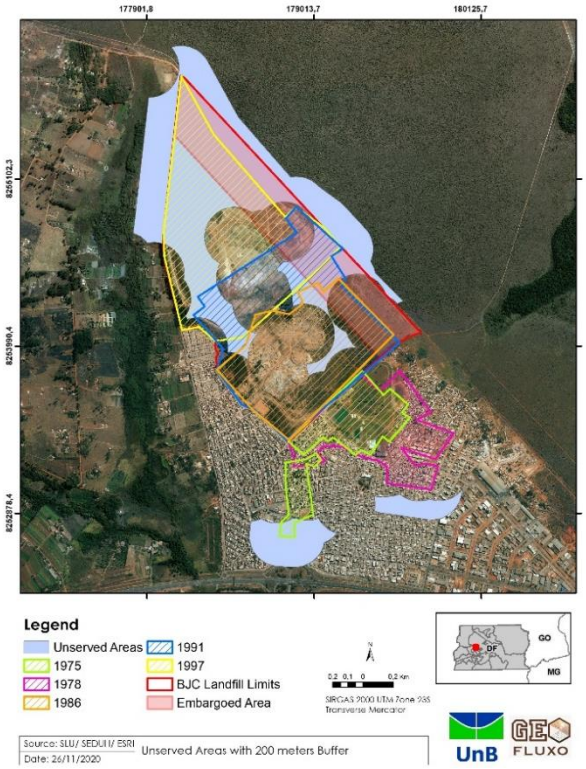

Figure 6. Strategic areas for complementary trials.

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