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EVALUATION OF SIMULATED LANDFILL SETTLEMENT WITH DIFFERENT TYPES OF COVERS UNDER THE CONDITIONS OF AÇAILÂNDIA – MA

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ABSTRACT

Settlements are defined as absolute or relative descending vertical displacements of the soil. They can compromise the stability of the landfill, affect its operation and, respectively, increase the risks of failures and can cause damage to the environment and public health. Studying this parameter allows the development of monitoring and diagnostic strategies for effective management aimed at managing the operating time of each waste receiving area. In view of this, the present work aims to evaluate the settlements of a simulated sanitary landfill with different types of covering. Thus, this research was carried out at the State University of the Tocantina Region of Maranhão UEMASUL - Açailândia Campus. To this end, the experiment area was prepared with leveling of the land and installation of the overlapping of three reinforced concrete shackles of 0.46 m and with a total height of 1.40 m, the total area with 10 m² having 9 (nine) experimental cells with different layers of roofs (asphalt, coconut fiber, yellow ipê, civil construction tailings (RCC), gypsum, crushed pruning and clay soil). In general, it was verified through the monitoring that took place in 210 days that the lysimeters had changes both due to the time factor, seasonality and degradation of organic material. Thus, it was observed that the roofs of milled material (asphalt) and demolition construction waste (RCC) roofs maintained the occurrence of settlement for all monitoring periods. Thus, the evaluations of experimental cells and the influence of the different types of cover layer are of paramount importance for the understanding of the behaviors of landfills.

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INTRODUCTION

The growing flow of waste production and the deposit of garbage in inappropriate places constitute a powerful public and environmental health issue (Ferreira *et al.*, 2019). The significant increase in the production of solid waste (SR), resulting from the population increase and the consumption habits characteristic of the capitalist model, causes socio-environmental issues when it is not managed correctly.

These problems include water, soil, and air pollution, the spread of vectors, health problems, difficulties in basic sanitation, and the appearance of diseases (Gouveia, 2020). About 66% of municipal solid waste (MSW) is directed to sanitary landfills and controlled landfills in Brazil. The vast majority of these landfills receive this waste without going through a sorting or pre-treatment process (Brasil, 2019). Most municipalities in Brazil adopt this strategy, sending their urban solid waste to a single outdoor disposal point, characterized as a dump (ABRELPE, 2016).

Thus, any method of solid waste management must be started through a study in order to know the characteristics, fundamentally the mass of waste generated and its gravimetric composition. To obtain these parameters, the study called physical characterization of the residues is carried out. This study proves to be an important tool in the management of MSW, allowing the characterization of the best actions and the feasibility of initiating new technologies for the treatment and disposal of this material, with the aim of environmental sustainability for better socioeconomic management (Feam, 2019).

According to (ABNT NBR 6122:2019), settlements are defined as absolute or relative descending vertical displacements of the soil. The measurement of vertical and horizontal displacements and the calculation of the characteristic settlement velocity are some of the tools for estimating the stability of waste landfills, the measurements are also useful to know and evaluate the mechanical and biodegradation processes of the waste mass (Fayer *et al.*, 2019).

In consensus with Ferreira *et al.* (2022) the cover layer in landfills plays a significant role in the proper management of urban solid waste, with the main objective of minimizing environmental effects and mitigating public health risks that may arise from the exposure of waste to the environment that is present in our surroundings.

These layers perform essential functions, including the prevention of rainwater infiltration into the waste, avoiding the formation of excess leachate and the emission of

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polluting gases, also avoiding the dragging of waste due to the action of the wind. Research on settlement in landfills is essential to ensure the safety and effectiveness of these structures.

Settlements can compromise the stability of the landfill, affecting its operation and increasing the risks of failures that can cause damage to the environment and public health. Studying these parameters allows the development of monitoring and diagnostic strategies for effective management aiming at managing the operating time of each waste receiving area.

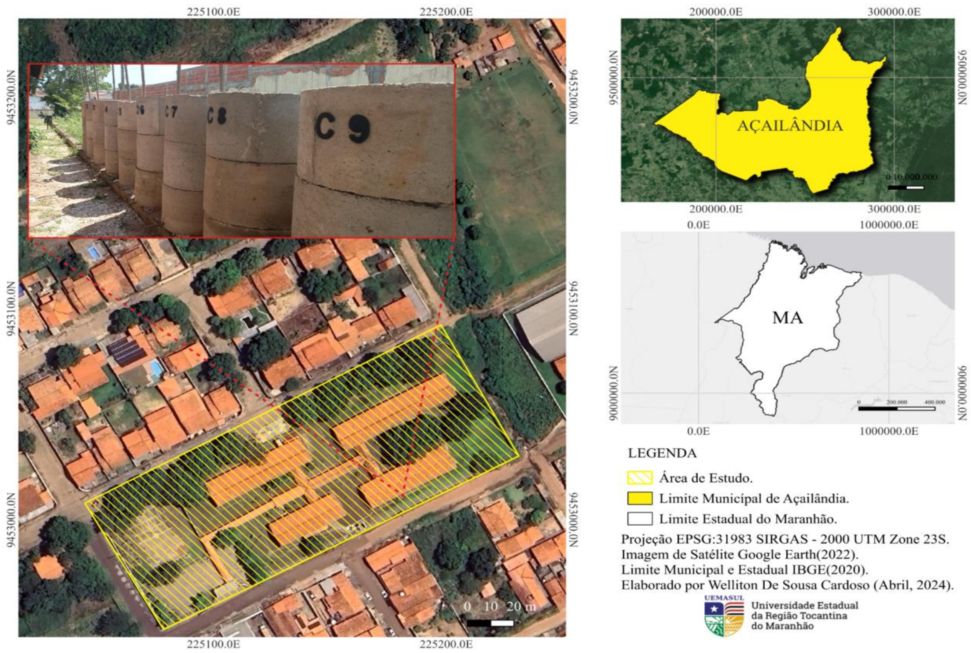
In the state of Maranhão, the municipality of Açailândia, although it is the fourth largest city with GDP in the state, according to IBGE (2019), still has its urban solid waste in dumps. Therefore, the present work aimed to evaluate the settlements of the simulated sanitary landfill with different types of cover by means of experimental cells established in the conditions of the city of Açailândia-MA.

METHODOLOGY

STUDY AREA AND SAMPLE COLLECTION

The present study was developed at the State University of the Tocantina Region of Maranhão - UEMASUL, in the municipality of Açailândia in Maranhão. As shown in (figure 1) below.

Figure 01 - Study area of the experimental lysimeter in Açailândia - MA.



Source: Authorship, 2024.

The lysimeter construction procedure was carried out in five stages. The first stage began with the mapping of the area. Then, the experiment area was prepared with leveling of the terrain and installation of the overlapping of three reinforced concrete shackles of 0.46 m and with a total height of 1.40 m. Subsequently, the sealing process and installation of drain pipes for leachate drainage was carried out.

The third stage was developed in the filling of the base layers, which was done by means of 20 cm of soil layer and 20 cm of gravel layer. The fourth stage was developed in the installation of the monitoring equipment of the experimental cell, consisting of the implementation of the piezometer, settlement plates, and drain tubes for leachate collection. The lysimeter filling was developed through the addition of solid materials, consisting of the addition of 30 cm of organic material and a top layer of 40 cm of soil in addition to 20 cm of different layers of covers (asphalt, coconut fiber, yellow Ipê seedlings, civil construction tailings (RCC), gypsum, crushed pruning and clay soil (white) shown in table 1.

To fill the 30 cm of organic material, approximately 180 kg of organic waste were added (with bean straw, corn leaves, pineapple peels, pumpkins and other fruits and vegetables, in addition to pruning residues and leaves). Acquired at the municipal fair of Açailândia, as described in (figure 2).

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Figure 2 - A; Measurement of 20 cm for lysimeter layers. B; Experimental cells. C; Filling of the experimental cell with a layer of gravel. D; Installation of piezometers. And; Gravel layer. F; Soil layer. G; Structuring layer of organic matter. H; Coconut fiber cover layer. I; Asphalt cover layer. J, K and L; Verification of installed equipment.

Source: Authorship, 2024.

The lysimeter system was composed of different monitoring instruments, such as; Open tube piezometers, MTK-2526 four-gas detector, flow plate, discharge plates and skewer thermometer model-GULterm 180°C. Thus, the piezometer was installed vertically with a height of 2 m, being inserted in the lower base of the lysimeter with a diameter that runs along the entire length of the experimental cell, and the piezometer is an important instrument for monitoring liquids generated in landfills (Figure 3).

The settlements installed in this study consist of a galvanized stainless steel bar 1.80 m high and 10x10 cm at the base, with the purpose of monitoring the higher densities generated by the external and internal variables of the lysimeter.

The geotechnical monitoring was carried out periodically, the parts monitored in this study constituted the monitoring of settlements, gases and liquid levels, temperature and climatic variabilities were monitored. Settlement monitoring was carried out in an average time of 15 min, observing the variations between the nylon line fixed at the top of the base of the shackle and the settlement track vertically. The monitoring took place during the period from January to August 2024. Rainfall data were obtained through information provided by CPTEC/INPE.

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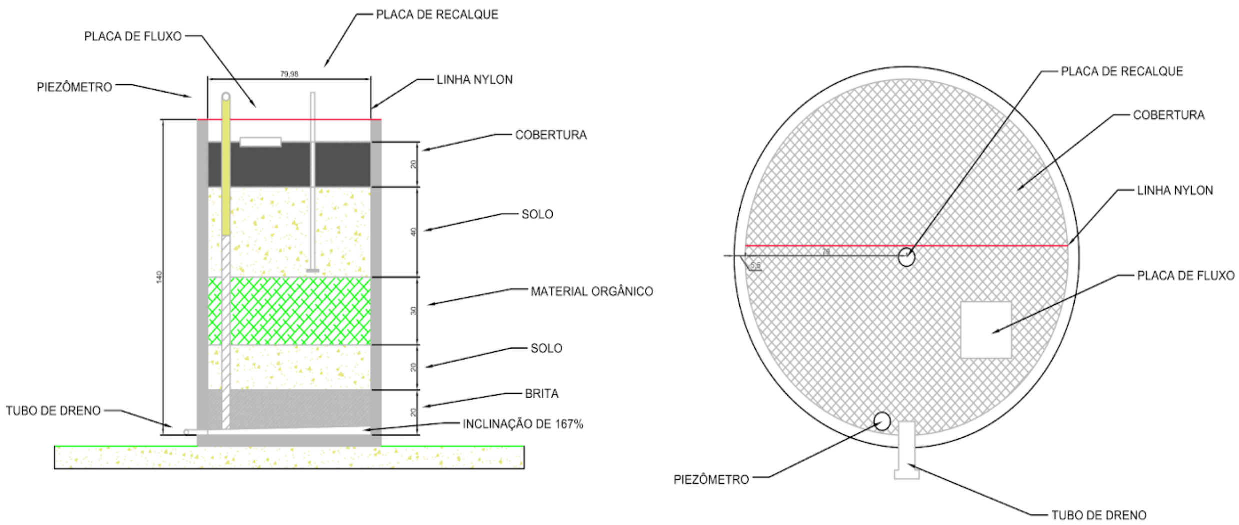
Figure 3 - Schematic drawing of the experimental cell.



Source: Authorship, 2024.

For data analysis, the settlement decay equation (%) represented in (equation 1) was elaborated.

Equation (1) $\left[\frac{M2-M1}{M1}\right] X\ 100$

Where:

M1: initial cm of settlement.

M2: cm end of decay.

The following equation was used for the analysis of settlement velocity.

Equation (2) $v = \frac{\Delta f}{\Delta t}$

Where:

Δf: Final emphasis.

Δt: Time in days.

Table 1: List of treatments used in the lysimeters.

Treatment	Coverage
P1	Asphalt
P2	Coconut fibre
P3	Yellow ipe
P4	Gypsum residue
P5	Construction waste
P6	Crushed pruning
P7	Only clay (Pack)

Source: Authorship, 2024.

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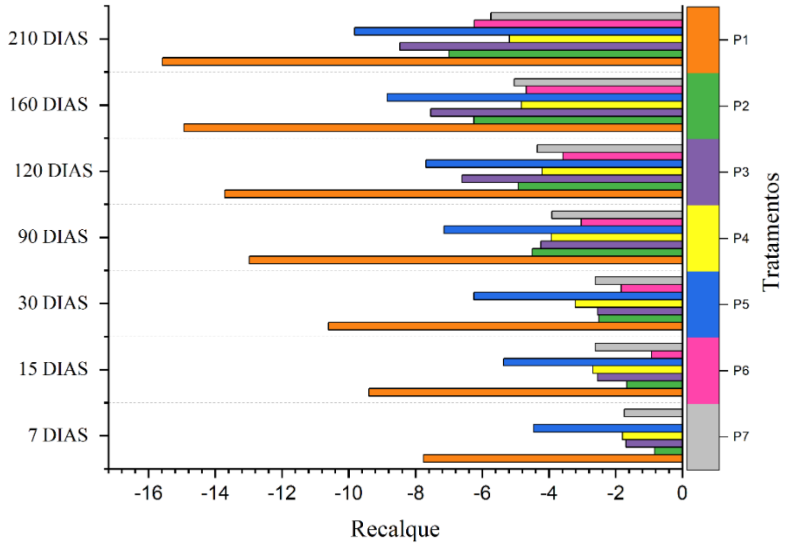
RESULTS

In this study, densities occurred in a period of 210 days were evaluated. According to Figure 4, the settlement variations as a function of time reported the highest settlement values P1 (15.59%), P5 (9.82%) and P3 (8.47%). For this study, all plates were evaluated for the same period in days and subjected to the same climatic conditions.

Figure 4 - Evolution of settlements as a function of time.



Source: Authorship, 2024.

It is observed in (Figure 4) that the highest values of densification occurred were for the P1 (asphalt layer), P3 (Ipê layer) and P5 (civil construction waste layer - RCC) plates. The layers of roofs with a higher degree of density P1 and P5, being able to exert a degree of immediate compaction.

The total settlement of a soil layer is composed of three components: the undrained settlement, or immediate settlement, which is related to the shear elastic deformations at constant volume. Soon after the application of the load, the primary densification settlement, which usually represents most of the total settlement, and the secondary compression settlement, which refers to the deformations observed at the end of the primary densification process (Pereira *et al*., 2019).

In addition to other internal and external factors, such as internal temperature of the layer compositions, precipitation and humidity can contribute decisively to the occurrence of settlements. For the P3 plate, this expressive change is possibly due to the contribution of the Ipê cover layer, given by the growth of the roots, causing movements and causing settlements, in addition to internal and external factors mentioned above.

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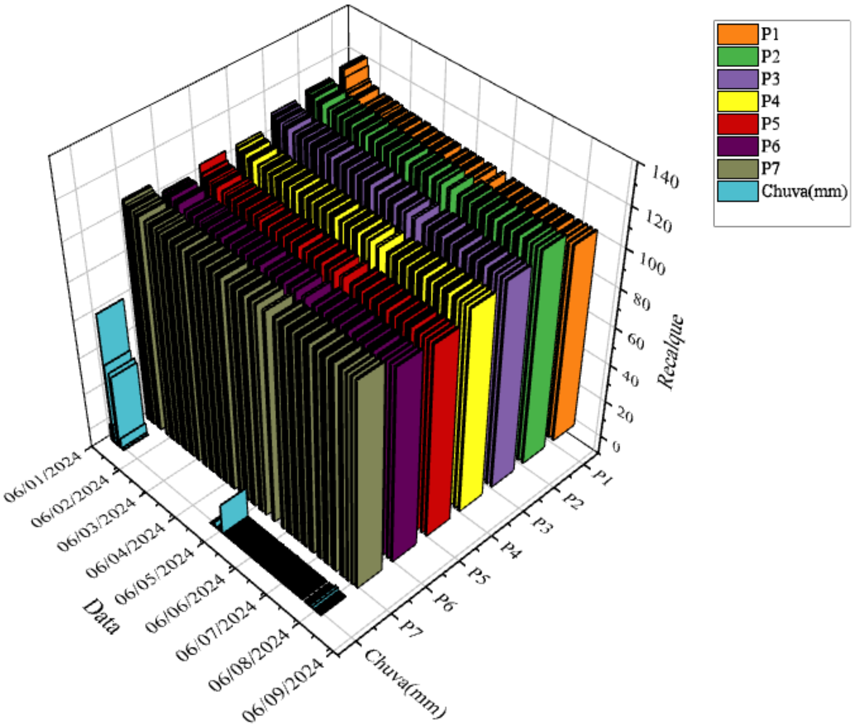
Figure 5 - Settlement as a function of rain (mm).



Source: Authorship, 2024.

It is noted that one of the elements that influence settlements is the rain factor, which is evident in (figure 5) the high volume of rain recorded on day 3 of monitoring, totaling 70.2 millimeters of rain. This indicates an acceleration of the decay rate of the plates.

DISCUSSION

It can be seen that the monitoring of settlement in the period of 7 days, where the highest densities obtained in the plates (P1, P4 and P5) were verified. In contrast, it was expected that the P4 board (gypsum layer) would present this same progression because it is a material with a relatively high density load compared to the other layers. Its settlement speed time was shorter in relation to the plates (P1, P3 and P5). It was verified in (Figure 6) that the mean discharge velocity (VDR) for plate P4 (VDR4) was 0.26 cm/day. In contrast, plate P1 had a velocity of 1.11 cm/day (VDR1) and plate P5 had a velocity of 0.64 cm/day (VDR5).

For the 15-day monitoring analyses, a progression of settlement velocities was observed for the plates (P1, P4 and P5) in which the highest values in this period were observed. On the other hand, the plate (P1) verified the greatest decay in the first 15 days, for this cell the cover material superimposed on the lysimeters was (asphalt layer), being a

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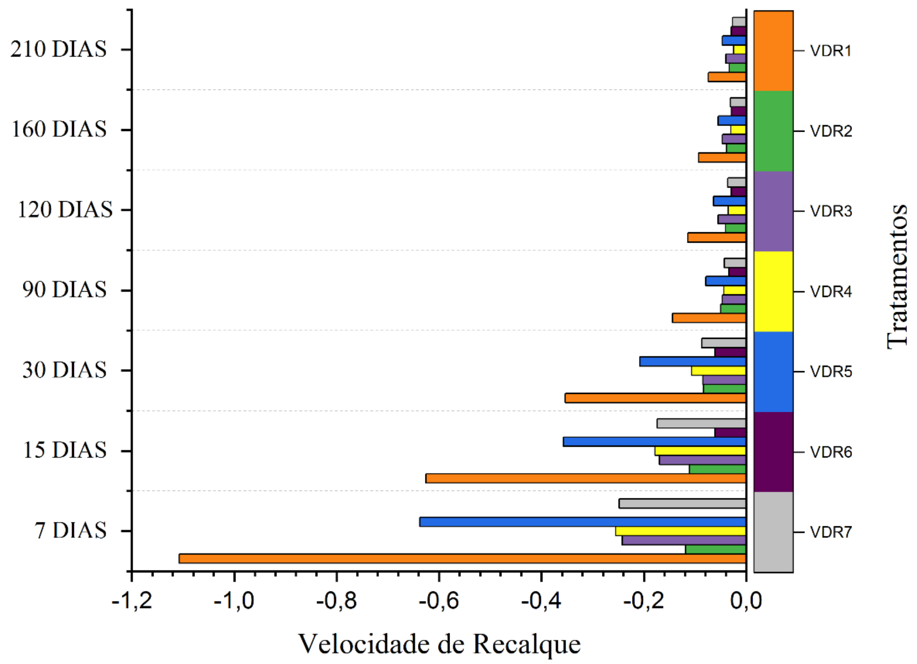
component with a high degree of load compared to the other cover of the study. In addition, with the intense rain in this period in parallel with the weight of the layers, they contributed significantly to the carryover of settlement, which justifies the intense decline in densities observed in (Figure 6).

Figure 6 - Speed of settlements.



Source: Authorship, 2024.

After 30 days of observation, it was noted that the highest settlement values were for the plates (P1, P4 and P5). The increase in settlement for plate P4 (VDR4) was 0.11 cm/day. The highest settlement activity occurred in the first 30 days of monitoring, similar results were observed in the study carried out by Oliveira *et al*. (2016), who evaluated the settlements that occurred in an experimental lysimeter, considering the influence of climatic conditions and the composition of the waste. The authors found higher settlement values in the period of 30 to 90 days of monitoring, corroborating the behavior that occurred in the present study.

It is observed that the plaques (P4, P5 and P6) after the 60-day period in the dry period, obtained a brief stabilization. Because they were not influenced by water masses, the structure of the lysimeters resisted a longer time for the occurrences of settlement, contributing decisively to this stabilization.

During the 90-day period, marked by a period of primary settlement, high values were observed in the plates (P1 and P5). In addition, the plates (P2 and P3) also showed a

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slight increase in densification. After 90 days, plate P2 showed significant settlements of 4.50%, a behavior that was maintained in the subsequent periods. Since temperature is a primary factor in the alterations of the anaerobic processes of organic matter, therefore, it can influence the densification of the lysimeters. The time factor favors the degradation of waste, especially organic waste, passing from the solid to liquid phase and later to the gaseous phase. Thus, the dissipation of neutral pressures of liquids and gases causes changes in the settlement levels of the experimental cells.

The biological degradation of solid waste in landfills generates empty spaces within the mass of waste, resulting in settlement. These settlements are characterized by the vertical and horizontal displacements that occur in the mass of waste (Van Elk *et al*., 2018).

Following the 120 days of monitoring, the highest values in this period were for the plates (P1, P3 and P5). The P3 plate (Ipê layer), its settlement speed for the period of 120 days was (VDR3) 0.06 cm/day similar to (VDR5) with 0.06 cm/day.

For the period of 160 days, the highest values occurred in the plates (P1, P3 and P5). For the P2 plate (coconut fiber layer), its decay occurred progressively, with a greater increase in the periods of precipitation. The average settlement velocity for this plate that occurred in the rainy season occurred in the first week of monitoring was VDR2 0.12 cm/day in the period of 7 days for the period of 160 days VDR2 0.04 cm/day.

At 210 days, the highest values for the plates (P1, P3 and P5) were verified. Expressive settlements were recorded for P6 plate (crushed pruning layer) after 210 days of monitoring with 6.24% settlement. Its settlement rate ranged from (VDR6) 0.00 cm/day in the first week to (VDR6) 0.03 cm/day after 210 days.

In addition, it was observed that for the monitoring of the 210 days, the P4 board (gypsum layer) had the lowest settlement value (5.18%) of the study covers, its settlement speed was 0.26 cm/day for the first week and after 210 it was 0.02 cm/day recorded for densifications. On the other hand, the Plate (P4) obtained significant changes in the rainy season, for the dry period the settlement was intended for its stabilization as observed in (figure 5).

In parallel, the analogous behavior was verified for the P7 plate (clay soil), in its settlement speed was observed, which in the first weeks 0.25 cm/day, indicated greater movements after 120 days 0.04 cm/day as settlements with 210 days of (5.75%). An opposite effect is highlighted for P4, where movements were significant in the first months of monitoring, on the other hand, in treatment P7, there are greater movements in the last months of monitoring. It is possible to relate the distribution of the surface load, unlike other less dense covers (crushed pruning or coconut fiber) the gypsum forms a more homogeneous and dense cover, which redistributes the pressures more efficiently.

The gypsum has a flocculant effect on the soil, reducing the dispersion of clay particles. This effect is widely recognized in sodic soils, but can also be observed in acidic soils. Positive results of the use of gypsum include the prevention of surface crusting and the reduction of densification in subsoil layers (Martins, 2024).

For this treatment, further evaluations are suggested in order to verify the movements in periods with longer duration, since the changes in the settlements can permeate a greater variation over time.

CONCLUSION

Through the monitoring carried out, it can be seen that the lysimeters had changes both due to the time factor, seasonality, and degradation of organic material. Thus, it was observed that the experimental layers of milled material (asphalt) and demolition construction waste (RCC) maintained the occurrence of settlement for all monitoring periods. The experimental layers gypsum residues, demolition construction residues (RCC) and crushed pruning after 60 days in the dry period, obtained a brief stabilization. According to the evaluation, it was found that the experimental layers of clay soil, Ipê Amarelo, had significant settlements after 120 days of monitoring and the experimental layer made with coconut fiber after 160 days, and for the experimental layer of crushed pruning after 210 days of observation. In contrast, it is observed that the gypsum layer registered a lower value in relation to the other study layers.

Therefore, evaluations with experimental cells become of paramount importance for understanding the behavior of landfills and the influences of different types of cover layer. Thus, the collection of data such as these will provide subsidies for future research, the scientific community, the public authorities and the private sector.

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