Periódico Eletrônico “Fórum Ambiental da Alta Paulista”
Electronic Journal “Environmental Forum of Alta Paulista”

ISSN 1980-0827 – Volume 20, Number 2, Year 2024

The use of video borescope for inspection of piezometers in landfills

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ISSN 1980-0827 – Volume 20, Number 2, Year 2024

ABSTRACT
Piezometers are devices that measure the distribution of piezometric heads in the waste mass of landfills. These instruments present a critical role in determining the safety of landfill engineering works. However, piezometers require regular inspections, and advancements in technology have enabled the performance of more accurate monitoring within these devices. A depth sensor is used for this monitoring, but there are several challenges when taking measurements. This study aims to evaluate the conditions inside piezometers using a full-scale video borescope technique. The integrity of piezometers was assessed based on real-time images, which allowed the diagnosis of each pipe. This method can detect the presence of gases, obstructions, and damage caused to the piezometers, which may be associated with the evolution of the landfilling operation. The damage may be caused by the enlargement of the cells with the disposal of more waste and covering layers. The study concludes that using a videoscope to inspect piezometers is a low-cost technique that assists in the diagnosis of these instrument conditions.
KEYWORDS: Liquid level. Piezometers. Landfill. Leachate.

1 INTRODUCTION

Leachate from landfills mainly results from the rainwater infiltration into the waste mass, the biodegradation of Municipal Solid Waste (MSW) and the recirculation processes in the cell. Older waste has low hydraulic conductivity, causing the gradual obstruction of drainage systems. Thus, older landfills tend to have higher levels of leachate present within the waste mass. (Zhan et al., 2017). Leachate levels are important indicators of the operational quality of landfills, considering that high levels can cause several engineering problems, such as increasing the probability of leaks through the cover layer, reducing biogas generation, and decreasing slope stability.

Generally, the leachate level monitored in waste mass, commonly called piezometric level, is measured by piezometers, an instrument capable of evaluating the increase or reduction of neutral pressures inside the MSW Cell (Slimani et al., 2017). The technique used to monitor the drainage system of these engineering works is typically assessed indirectly by checking the pore pressures of liquids in the waste mass (achieved using piezometers and level sensors) and their flow (Boscov, 2008).

However, there are challenges in monitoring piezometric levels in landfills. Commonly, to achieve this measurement, a depth sensor activates an audible and luminous signal when it reaches a liquid. In operational terms, there are several problems in performing these measurements, including the deteriorations found in piezometers caused mainly by horizontal and vertical movements that occur in landfills.

Therefore, in addition to effective techniques, a system must be adopted to monitor the leachate level in piezometers installed in the waste mass. This system allows for ascertaining conservation and integrity of the piezometer structure itself. Accordingly, as an alternative to traditional investigation techniques, optical profiling or video borescope can be used. Videoscope is a useful instrument for investigating the construction conditions of wells with the presence of fluids, as well as analyzing the presence of incrustation and the current piezometric level. This is a technique already used for inspection of tubular wells. Camargo Junior et al. (1988), were the pioneers in the matter, presenting the methodology and the technical characteristics of the equipment.

Reginato and Ahlert (2012) used the profiling methodology to verify tubular wells associated with fractured aquifers. The results obtained in the study permitted the identification

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of constructive characteristics and problems. Pádua (2018) used this technique to support determining the circulation conditions in fractured aquifers, which allowed the observation of deep rocks. In monitoring wells, this method can be used to check their physical state, observing the occurrence of failures, such as the presence of foreign materials or obstructions. This study aims to verify the physical integrity of piezometers installed in landfill cells, considering the challenges in monitoring piezometers with deep liquid level sensor.

2 OBJECTIVES

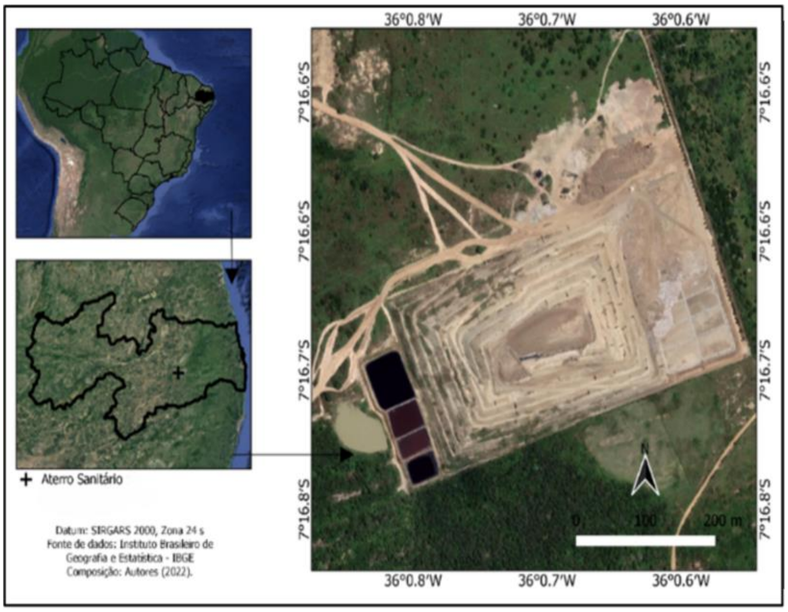
Inspect the physical integrity of the interior of piezometers installed in landfill cells regarding the occurrence of problems in monitoring with a liquid level sensor.

3 METHODOLOGY

3.1 Characterization of the study area

The object of study of this research was a landfill located in the semi-arid region of Paraíba, Brazil. The climate, in this region, is classified as semi-arid, with an average annual rainfall of 802.7 mm/year (AESA, 2019). Figure 1 shows the studied landfill.

Figure 1 – Landfill location map.



Currently, the landfill company under study receives MSW from 71 municipalities. These municipalities are located in the states of Paraíba, Pernambuco, and Rio Grande do Norte. The landfill has an area of 64 hectares, of which 40 hectares are designated for the disposal of MSW. Throughout the course of this research, the active landfill site encompassed three MSW cells, two have been completed while the remaining one was in the operational phase.

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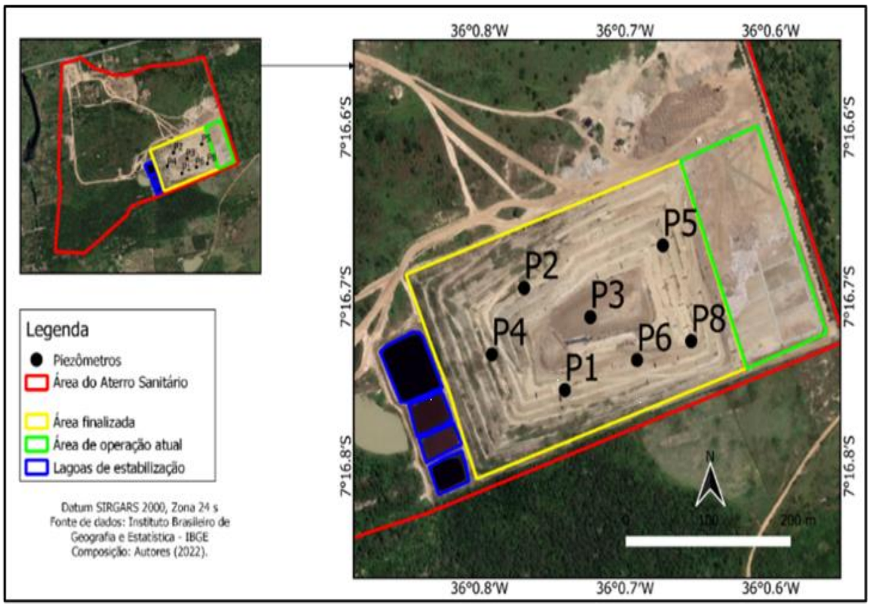
3.2 Optic Borescope

Piezometers are instruments designed to monitor the piezometric level, measuring subpressures or pore pressures within the waste mass (Araújo Neto, 2021). The piezometers installed at the aforementioned landfill are of the Casagrande type. According to Castro (2008), Casagrande piezometers boast several advantages, including their straightforward construction, which translates to lower installation costs. Additionally, they also deliver reliable results and exhibit good durability, ensuring long-lasting installations. The arrangement of the piezometers scattered across the waste cell adheres to the criteria set by operational and design considerations. This allocation can be seen in Figure 2.

Figure 2 - Distribution of Piezometers in the Landfill under study.



At the landfill, two distinct configurations of piezometers have been installed, as delineated in Table 1. The installations were conducted at different points in time, resulting in two sets of piezometer configurations.

Table 1 - Piezometer specifications.

Specifications	Setup 1	Setup 2
Material	Concrete	HDPE
Filter	1 m	1 m
Internal diameter	0.28 m	0.28 m
External diameter	0.37 m	0.37 m

Four piezometers were installed in the cells in 2018, as per Setup 1. As a result of operational changes in 2020, it was deemed necessary to transition to Setup 2, which entailed the replacement of the piezometers with a distinct material. Additionally, piezometers P1 and

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P3 were changed to Setup 2 (Figure 2). Table 2 provides details on the installation date, elevation, and current configuration of each piezometer in the landfill cell under investigation.

Table 2 - Piezometer configuration.

Piezometer	Year of installation	Configuration	Elevation (m)
P1	2018/2020	Setup 1/Setup 2	27.5
P2	2018	Setup 1	21.5
P3	2018/2020	Setup 1/Setup 2	34.0
P4	2018	Setup 1	20.0
P5	2020	Setup 2	12.7
P6	2020	Setup 2	16.5
P8	2020	Setup 2	16.5

*Note: Elevation = height from the bottom to the top of the piezometer.

Piezometric levels are measured through a traditional technique that utilizes an electronic sensor to emit sound and light (Figure 3). Once the sensor of the piezometer reaches the leachate, it emits both audible and visual signals. To determine the piezometric level, the height of the leachate level was measured using a measuring tape in relation to the top of the piezometer. However, inconsistencies were observed in these measurements due to several operational and technical issues. Therefore, alternative methodologies were adapted to investigate the piezometric level and the internal physical structure of piezometers.

Figure 3 - Electronic piezometric level sensor.

Therefore, the methodology proposed and implemented in this research involved conducting a full-scale videoscopy on piezometers that were installed in the cells of the studied landfill.

The procedure was carried out by an industrial camera, which was a generic model obtained from the *mrgo direct store*. This camera was equipped with IP 67 protection, which means it has protection against dust and water resistance to being submerged in water up to 1 meter deep for 30 minutes. Additionally, the camera has an HD resolution of 1280x720 pixels

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and features an LED light that allows for high-quality recordings with satisfactory resolution and color. The video sensor was attached to a durable cable that was 8mm in diameter and 10 meters in length, which allowed for secure and deep viewing of the piezometers.

The camera cable was attached to a USB-C connector, which enabled the equipment to be connected to an Android smartphone using the *inskam* application (from *app-tools*), and this application enabled the simultaneous image processing. Figure 4 shows the video borescope equipment used in this study.

Figure 4 – Video borescope camera.

4. RESULTS AND DISCUSSIONS

During the examination of the piezometers at the landfill site, the assessment of piezometer integrity is a noteworthy outcome of the videoscopy. A thorough analysis of the videoscopy of the six piezometers installed in the landfill revealed that six of them were obstructed, while one had liquid present in it. The inspection also involved measuring the heights inside the piezometers in relation to the covering layer (Table 3).

Table 3 - Observed heights

Piezometer	Observation height (m)	Piezometer Status
P1	7.0	Obstructed
P2	10.0	Liquid detected
P3	5.0	Obstructed
P4	6.0	Obstructed
P5	8.0	Obstructed
P6	3.0	Obstructed
P8	4.0	Obstructed

It has been observed that an obstruction is present in piezometer P1, which has hampered the insertion of the camera probe due to the presence of curvature in the pipe (Figure 5a). The curvature of the pipe and the consequent damage to its walls (Figure 5b) appear to

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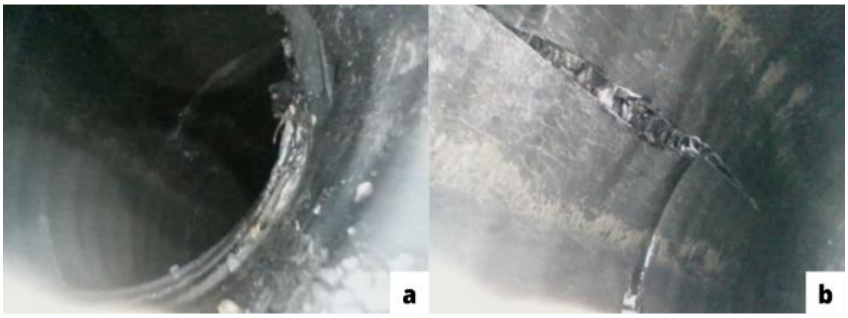
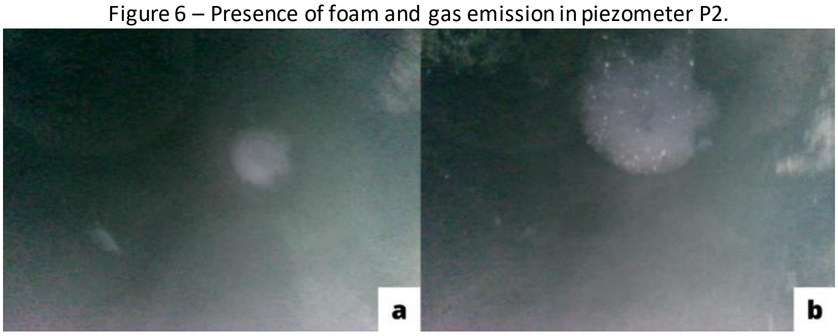
have been caused by the mass movement of waste over time, considering that the pipe was installed in 2020.

Figure 5 - (a) Piezometer P1 possibly bent; (b) Damaged P1 piezometer wall.



During the assessment of the P2 piezometer, it was observed that the presence of gases led to interference in the image at certain moments during the inspection, as depicted in Figure 6a. Further inspection via the videoscope revealed the presence of foam at a depth of 10 meters in the pipeline, which represents and confirms the existence of leachate in the piezometer P2 (Figure 6b).

Figure 6 – Presence of foam and gas emission in piezometer P2.



The analysis of Figure 5 indicates that the piezometer P2 has no obstructions along its length, thus enabling the use of conventional liquid level sensors for monitoring the piezometric level due to the unrestrained access to the interior of the pipe.

However, a high piezometric level was detected approximately 10 meters below the cover layer. These levels may be attributed to the occurrence of gas bubbling within the piezometer. Through a detailed videoscope inspection (Figure 6), the bubbling of gases in side Piezometer 2 was observed, indicating the presence of these gases.

Upon visualizing the interior of piezometer P3, an obstruction was discovered at a depth of 5 meters (Figure 7a). The inspection revealed a curvature in the pipe, as seen in Figure 7b. This deformation resulted from the displacements of the waste mass. Consequently, conventional measurements for piezometric levels are not practical or feasible. Therefore, the landfill operators should exercise caution and take necessary measures to determine the precise piezometric level at this point in the Cell.

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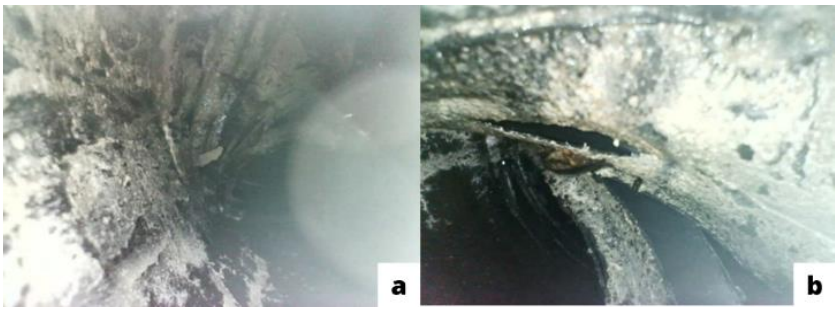
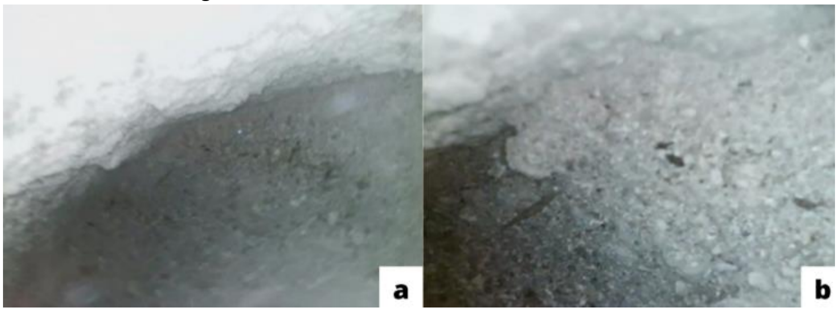
Figure 7 – Obstruction in the P3 Piezometer.



The P4 piezometer, one of the earliest installations in the cell, employs setup 1 with concrete compound in its structure (Figure 8a). Upon examination of the videoscopy images, it was observed that the pipe was obstructed due to soil accumulation within it, as demonstrated in Figure 8b.

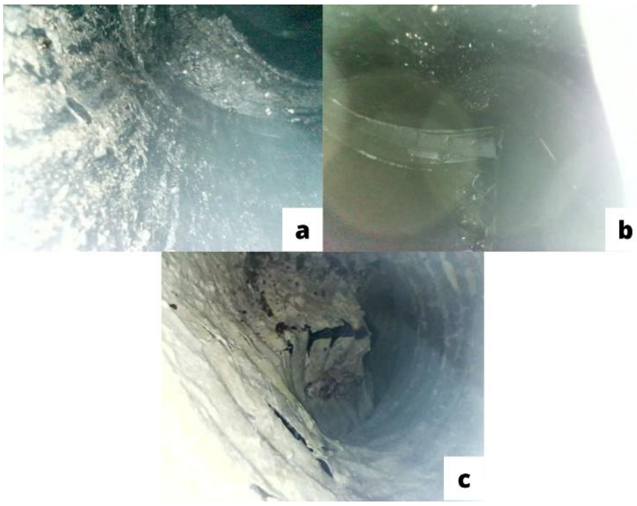
Figure 8 – Soil obstruction in the P4 Piezometer.



Several potential factors may have led to the obstruction of the P4 piezometer. The primary cause is likely to be the impact of displacements and settlements sustained over four years of the landfill operation, which may have resulted in the rupture of the concrete pipe. Additionally, the presence of soil inside the piezometer suggests that tube occlusion may have arisen during the application of the covering layers.

By utilizing videoscopy to visualize internal images of piezometers P5 (Figure 9a), P6 (Figure 9b), and P8 (Figure 9c), it was possible to observe the sealing of the pipes, which may have resulted from the displacements that occurred in the waste mass within two years of installing the piezometers.

Figure 9 - Obstruction in the Piezometer: (a) P5, (b) P6, and (c) P8.



Inspection of piezometers P5, P6, and P8 reveals some particularities inside the pipes in Figure 8. Point P5 presented an obstruction at 8 meters caused by damage to the walls of the piezometer, which quelled the video examination (Figure 9a). At a depth of 3 meters, piezometer P3 is impeded. Figure 9b permits visualization of the damage to the pipe walls, obstructing the passage of the camera at greater depths. Another fact about this piezometer is the presence of gases, which fog up the camera lens, making it difficult to analyze the images.

Figure 9c refers to piezometer P8, which presented an obstruction at a depth of 4 meters. The piping in this location has encrustations, observed from the change in the usual color of the piezometers. Another significant detail in the examination is the presence of decomposing organisms on the surface of the occluded area.

The physical integrity of the piezometers inside an MSW cell allows the piezometric level monitoring and, therefore, the pore pressure analysis. Figures 5 to 9 reveal that the piezometers are mostly damaged, except P2. This issue could lead to complications in identifying the actual neutral pressure level inside the waste mass and may cause a reduction in the safety factor in slope stability analysis.

4.1 Results analysis

The damage observed in landfills may be attributed to the operational evolution of landfill cells over time as more waste and cover layers are added. During this process, deformations occur, causing movements in the waste mass, which may compromise the integrity of the piezometers. This may lead to the fracturing of the pipes, making it unfeasible for the sensor to reach the leachate level. Through these fractures, liquid from higher layers may have entered the drain filter and contributed to an increase in the piezometric level.

The videoscopy images were analyzed to identify possible failures in the piezometers. Monitoring the level of liquids inside the landfill is crucial to evaluate the pore pressures inside the waste, which assists in geotechnical stability analysis (Catapetra and Simões, 2016).

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In some cases, pockets of gas trapped in the cell may escape through the piezometer tube during measurement, spouting leachate and affecting the reading feasibility (Boscov, 2008). This issue poses a particular problem when the instrumented piping is obstructed since it causes errors in measurements, making periodic measurements of neutral pressure in the waste mass unfeasible.

Clogging or obstruction of the horizontal drainage system could also cause an increase in piezometric levels. For Feng et al. (2019), an increase in the piezometric level, induced by a drainage system obstruction, would increase the saturation and pressure of liquids in landfills, reducing the safety factor. Therefore, constant monitoring of the level of internal pore pressure is necessary to control whether there is a large infiltration of rainwater or leachate that could recirculate in the waste cell.

5. CONCLUSION

Piezometers perform an essential role in the geotechnical monitoring of landfills. The regular inspection of liquid levels in these instruments becomes impractical in the event of faults, which can compromise the geotechnical inspection of the landfill cell integrity and stability. The inability to track pore pressure evolution in waste mass can pose a significant challenge in ensuring the safety of landfills. On the other hand, videoscopy is a cost-effective technology that can be easily utilized to inspect the internal physical integrity of piezometers. Therefore, this technology works as a feasible alternative for monitoring pore pressure and the internal structure of piezometers in landfills.

This scenario highlights that it is crucial to address monitoring challenges by considering feasible alternatives such as installing new piezometers.

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