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## Socio-Environmental Impacts of the Deactivation and Abandonment of the Municipal Landfill in Lagoa do Carro, Pernambuco: A Case Study

### *Impactos Socioambientais da Desativação e Abandono do Lixão Municipal em Lagoa do Carro - Pernambuco: Um Estudo de Caso*

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**Abstract:** This study analyzes the socio-environmental impacts resulting from the deactivation and abandonment of the municipal landfill of Lagoa do Carro, Pernambuco, Brazil. Although deactivated since December 2020, the site remains a source of environmental degradation and poses risks to public health. The research adopted a mixed-methods approach, including a literature review, field observations, interviews with local residents and fishermen, as well as laboratory analyses of soil, water, and air quality. The results indicate the persistence of environmental contamination, with the presence of microplastics and heavy metals in the soil, exacerbated by the use of the area for livestock grazing and agricultural cultivation. The waters of the Capibaribe River show signs of pollution associated with leachate runoff, identified through planktonic bioindicators. Air quality is also compromised, as evidenced by the darkening of lichens due to the emission of toxic gases from spontaneous fires. From a social perspective, negative impacts on the local community were observed, including the lack of assistance for waste pickers and issues related to strong odors, disease vectors, and contamination of water used for fishing and recreation. It is concluded that the absence of effective environmental recovery measures following the landfill's deactivation sustains ongoing socio-environmental risks, highlighting the need for greater public sector intervention.

**Keywords:** Deactivated landfill; Socio-environmental impacts; Environmental contamination.

**Resumo:** Este estudo analisa os impactos socioambientais decorrentes da desativação e do abandono do lixão municipal de Lagoa do Carro, Pernambuco. Embora desativado desde dezembro de 2020, o local continua sendo uma fonte de degradação ambiental e de riscos à saúde da população. A pesquisa adotou uma abordagem metodológica mista, envolvendo levantamento bibliográfico, observações de campo, entrevistas com moradores e pescadores, além de análises laboratoriais da qualidade do solo, da água e do ar. Os resultados indicam a persistência de contaminação ambiental, com presença de microplásticos e metais pesados no solo, agravada pelo uso da área para criação de gado e cultivo agrícola. A água do Rio Capibaribe apresenta indícios de poluição associados ao escoamento de chorume, identificados por bioindicadores planctônicos. A qualidade do ar também se encontra comprometida, evidenciada pelo escurecimento de líquens devido à emissão de gases tóxicos provenientes de queimadas espontâneas. No âmbito social, observam-se impactos negativos à comunidade local, como a desassistência de catadores e problemas relacionados a odores, vetores de doenças e contaminação da água. Conclui-se que a ausência de ações efetivas de recuperação ambiental após a desativação do lixão mantém os riscos socioambientais, demandando maior atuação do poder público.

**Palavras-chave:** Lixão desativado; Impactos socioambientais; Contaminação ambiental.

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## 1. Introduction

Although large industries linked to global capitalism are primarily responsible for environmental degradation on a planetary scale, it is undeniable that everyday practices also contribute to the intensification of pollution. Seemingly harmless individual actions, such as the improper disposal of waste, produce significant cumulative impacts. These impacts begin at a local scale — streets and neighborhoods — and expand to cities, states, countries, and ultimately the entire planet.

According to the Brazilian Institute of Geography and Statistics (IBGE, 2024), Brazil currently has an estimated population of 212,583,750 inhabitants. If each person disposed of a single plastic bag per day, this would represent more than 212 million bags discarded daily. Many end up in streets, rivers, mangroves, seas, and dumps, worsening pollution and accelerating global environmental degradation. This dynamic highlights the urgent need to rethink everyday practices and adopt sustainable solutions to mitigate environmental impacts.

Driven by consumerism, Brazilians generate, on average, 380 kg of waste per year, according to data from the Brazilian Association of Waste and Environment (ABREME, 2023). The amount of municipal solid waste (MSW) varies significantly among the regions of the country. The Southeast leads in per capita generation, with approximately 449 kg per inhabitant in 2022, followed by the South region, with about 284 kg per inhabitant. These numbers reflect not only the high population but also factors such as industrial advancement, labor precarization, the absence of efficient waste management, and disordered urbanization processes. Added to this is the high production and improper disposal of disposable materials, which further aggravate the problem, emphasizing the urgency of public policies and educational actions aimed at sustainable waste management.

According to the Public Consortium for Solid Waste Management of the Jaguaribe Valley (CONVALE, 2023), approximately 71.7 million tons of solid waste were collected in Brazil in 2022. A large portion of this waste was disposed of in around three thousand dumps, highlighting the persistence of inadequate management and final disposal practices that continue to negatively impact the environment and public health.

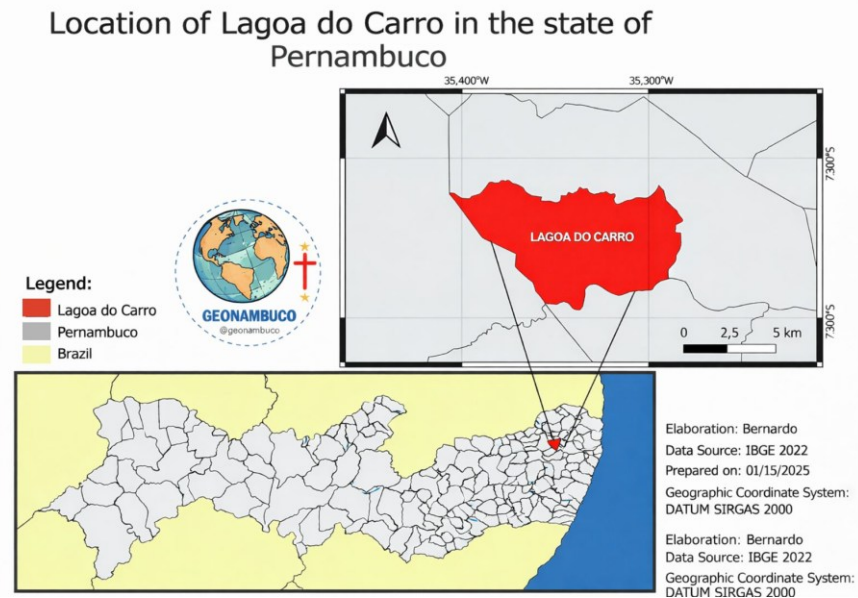
Dumps constitute irregular forms of disposal of municipal solid waste (MSW), carried out in open areas without proper treatment or management. Over time, this practice results in serious environmental damage, such as: air pollution, characterized by strong odors and gas emissions that contribute to the greenhouse effect and global warming; pollution of groundwater and aquifers due to leachate, a liquid resulting from the decomposition of waste (Dias et al., 2008, p. 255); and soil pollution, with the presence of heavy metals and microplastics, which generate imbalances in local fauna and flora.

In addition, dumps pose serious risks to human health, as they favor the proliferation of disease vectors such as cockroaches, scorpions, and rats — whose urine can transmit leptospirosis — as well as *Aedes aegypti* mosquitoes, which transmit dengue, chikungunya fever, and the Zika virus (CONVALE, 2023). Associated with these issues are also the risks faced by environmental agents (waste pickers), who survive from collecting waste under precarious conditions, without adequate protective equipment, and are constantly exposed to contaminated materials, broken glass, medical syringes, and the disease vectors themselves.

Law No. 12,305/2010, which established the National Solid Waste Policy (PNRS), mandates the closure of all open dumps and determines that waste must be disposed of in an environmentally appropriate manner, in controlled sites such as sanitary landfills. However, this reality is still far from being achieved: thousands of dumps remain active in Brazil.

Another recurring problem is the closure of dumps without the adoption of environmental recovery measures. In such cases, the environmental liability remains, with leachate polluting groundwater, the continuous emission of greenhouse gases, the proliferation of disease vectors, and the persistent degradation of the soil. The lack of public investment and effective penalties for those responsible for non-compliance with the legislation contributes to the worsening of this scenario. As provided by Law No. 12,305/2010, after the closure of a dump, the site should be restored, with the proper transfer of waste to controlled sanitary landfills and specific treatment.

The municipality of Lagoa do Carro, located in the Zona da Mata Norte of Pernambuco (Figure 1), has experienced this problem. Like many Brazilian cities, it has suffered impacts resulting from the inadequate disposal of solid waste. Its open-air dump, located to the south of the municipality, approximately 200 meters from the banks of the Capibaribe River, was officially closed in December 2020.



*Figure 1 – Location of the city of Lagoa do Carro – PE.  
Source: Authors (2024).*

This irregular disposal of waste over decades has generated significant environmental impacts, a reality that is repeated in several Brazilian municipalities and in other parts of the world. As pointed out by Dias et al. (2008, p. 251), the continuous increase in the generation of solid waste is associated with the consumption model of industrial society, which, by creating needs and intensifying consumption, increases both the quantity and complexity of the waste produced, worsening the environmental impacts of its final disposal.

The Lagoa do Carro dump operated for approximately forty years, dating back to before the city's emancipation, when it was still a village. Reports from residents indicate that its origin dates back to the construction of the Lagoa do Carro dam: the waste generated by engineers and workers settled in nearby villages began to be deposited in this area, which over time also started to receive urban waste. The dump eventually covered approximately 33.3 hectares (Figure 2), featuring irregular topography and the presence of slopes and uneven terrain resulting from the random deposition of municipal solid waste.

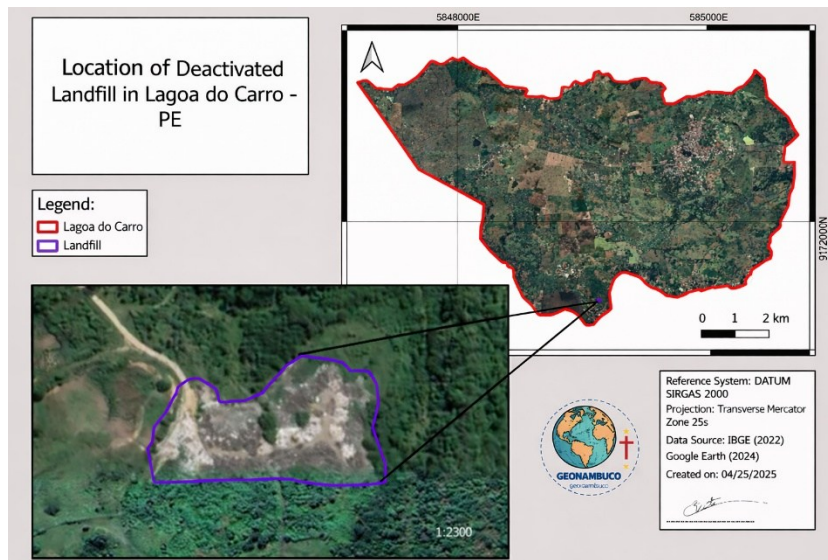


Figure 2 – Location of the Deactivated Dump in the city of Lagoa do Carro.  
Source: Authors (2025).

Currently, it is observed that no environmental recovery technique has been effectively applied in the area. Only machinery was used to push and bury part of the waste, breaking up piles and covering the residues (Figure 3):



Figure 3 – Vegetation cover of the dump.  
Source: Environmental and Sustainability Management of Lagoa do Carro – PE (2022).

This inadequate management resulted in the degradation of vegetation cover, soil compaction and contamination, and the limitation of natural regeneration, constituting an environmental liability that remains active in the region.

## 2. Methodology

The research adopted a qualitative and quantitative approach, with a deductive-dialectical character, combining different techniques of data collection and analysis.

### 2.1 Bibliographic review

A literature review was conducted covering scientific articles, technical reports, environmental legislation, and other relevant sources. This review provided the theoretical basis for understanding the environmental impacts related to the deactivation and abandonment of dumps, as well as guiding the critical analysis of the data obtained in the field and in the laboratory.

## 2.2 Field survey

Technical visits were carried out to the area of the deactivated dump, with direct observations and photographic records. The objective was to identify and map environmental impacts, such as changes in the soil, presence of waste, generation of leachate, and disease vectors. Soil and water samples were also collected for analysis. Georeferencing techniques were used to map the study area.

## 2.3 Soil and water analysis

The analyses made it possible to identify changes in the soil, such as the presence of microplastics and heavy metals, as well as indications of water pollution. Water samples from the Capibaribe River, collected near the dump, were examined in the UPE-CMN laboratory, focusing on planktonic bioindicators.

## 2.4 Semi-structured interviews

Interviews were conducted with different social actors:

- Fishermen from the local colony, to understand how pollution interferes with fishing activities;
- Waste pickers, who reported their experiences during the operation of the dump;
- Residents of the Vila da Barragem community, near the dump;
- Representatives of the Municipal Government of Lagoa do Carro – PE, through the Department of Environment and Sustainability, to obtain information about the process of closing the dump.

## 2.5 Data analysis

The collected data were processed in an integrated manner, combining statistical techniques applied to quantitative information and content analysis for qualitative data. This step made it possible to assess the extent of the environmental and social impacts resulting from the dump.

## 3. Results and Discussion

The synthesis of analyses and field observations shows that, even after its deactivation, the Lagoa do Carro dump continues to generate significant socio-environmental impacts. The presence of exposed waste, compacted soil, gas emissions, leachate runoff, and the proliferation of disease vectors were recurrently observed during field visits. These elements confirm that simple deactivation, without the adoption of effective environmental recovery measures, does not eliminate the problems generated by environmental liabilities.

According to information from the municipality's Department of Environment and Sustainability, after the closure of the dump, some initial measures were adopted, such as the preparation of a Degraded Area Recovery Plan (PRAD), the fencing of the area, the relocation of waste picker families who lived on-site, and the creation of temporary emergency assistance. The association of waste pickers was also formalized, although this organization is currently no longer active. The fencing of the area, in turn, was removed by the population itself, who began using the space for vegetable cultivation and cattle raising, intensifying soil contamination and hindering environmental regeneration.

The Municipal Government also reported the hiring of the company Capibaribe Obras de Saneamento (CTR), located in Passira – PE, to receive the municipality's urban solid waste in a controlled sanitary landfill. However, it was found that selective waste collection is not effectively practiced by the local population, due to the lack of environmental education policies and community awareness initiatives. As a result, a large portion of recyclable waste is disposed of together with organic waste, reducing the income of waste pickers and overloading the final disposal system.

Currently, the area of the former dump is in a state of abandonment, marked by topographic irregularities, exposed waste, and the absence of adequate vegetation cover. Comparative photographs between the time of closure and the current situation illustrate the continuous degradation, confirming that no environmental recovery techniques have been implemented (Figure 4 and Figure 5).



*Figure 4 – View of the municipal dump of Lagoa do Carro after closure (2020).*  
*Source: Department of Environment and Sustainability of Lagoa do Carro – PE (2020).*



*Figure 5 – Current view of the municipal landfill of Lagoa do Carro (2025).*  
*Source: Authors (2025).*

Another relevant aspect identified refers to the continued presence of waste pickers at the site even after its deactivation. These workers continued collecting recyclable materials in an informal and precarious manner, which resulted in a high concentration of glass shards and non-recyclable waste scattered across the area. This situation exposes waste pickers to physical and biological risks, in addition to further compromising the area's recovery process.

At the same time, the local community continues to face social and environmental problems resulting from the dump. Air pollution caused by spontaneous burning and strong odors, combined with soil and water contamination, directly affects the population's quality of life. Furthermore, the absence of continuous public policies undermines both environmental sustainability and social justice in the municipality.

After the closure of the dump, waste pickers continued to remove recyclable materials, which is why the area currently stands out for its large amount of glass shards and non-recyclable waste.

### 3.1 Air Analysis

Lichens are symbiotic organisms formed by the association between fungi and algae or cyanobacteria. Because they are extremely sensitive to air pollution, they are important bioindicators of air quality (Marcelli, 2006). Their hygroscopic nutrition, that is, through the direct absorption of gases present in the atmosphere (Pereira, 2014), causes them to accumulate pollutants such as metallic ions, radioactive elements, carbon dioxide, and methane. As a result, they undergo visible changes, such as darkening and deformation, in response to environmental quality degradation.

According to Braz (2020), lichens can be used both in biomonitoring and in the bioindication of environmental changes, given their high sensitivity to atmospheric alterations. In the area of the Lagoa do Carro dump, the presence of darkened and poorly developed lichens was observed, indicating the emission of toxic gases associated with spontaneous burning. These burnings are favored by the large amount of flammable materials at the site, such as glass, organic waste, and accumulated gases, in addition to high temperatures that contribute to involuntary combustion.

The images below illustrate this reality: a lichen collected in the dump area (Figure 6) and a photographic record of spontaneous burning (Figure 7). Both reinforce the relationship between the degradation of lichen vegetation and the emission of toxic gases in the environment.



*Figure 6 – Lichen collected in the area of the Lagoa do Carro dump – PE.  
Source: Authors (2024).*



*Figure 7 – Record of spontaneous burning at the Lagoa do Carro dump – PE.  
Source: Authors (2025).*

Through bioindication, defined as the use of living organisms to assess the quality of an environment (Markert; Breure; Zechmeister, 2003), it is concluded that the air in the studied area presents a high level of pollution, mainly resulting from the recurrent burning of waste and the decomposition of materials deposited in the deactivated dump.

### **3.2 Soil Analysis**

Microplastics (MPs) are plastic particles with a diameter smaller than 5 mm, resulting from the improper disposal of plastic materials and the fragmentation of waste over time. Due to their high persistence in the environment, they accumulate in soil, water, and even in the air, representing one of the main emerging pollutants of today.

These particles alter the physical and chemical properties of the soil, such as structure, nutrient retention, and enzymatic activity, in addition to compromising the health of microorganisms, insects, and plants. Studies indicate that MPs can reduce soil fertility, alter plant development, and pose risks to human health, especially through bioaccumulation in food chains (DE Souza Machado et al., 2019; Rillig; Leifheit; Lehmann, 2021).

At the Lagoa do Carro dump, field analysis revealed a significant presence of microplastics in the soil, visible to the naked eye and confirmed through magnifying glass observation (Figure 8). The risk becomes even more concerning due to the presence of cattle in the area, as these animals consume contaminated plants, enabling the transfer of plastic particles into the human food chain through meat and milk.

Another observed aspect was the presence of fruit trees at the site, such as papaya trees (Figure 9 and Figure 10). Considering that these plants absorb nutrients directly from the soil, there is a risk of accumulation of heavy metals and microplastics in the fruits, increasing the possibility of human contamination through the consumption of these foods.



*Figure 8 – Soil sample from the Lagoa do Carro dump observed under magnification.  
Source: Authors (2025).*



*Figure 9 – Papaya tree cultivated in the area of the Lagoa do Carro dump – PE.  
Source: Authors (2024).*



Figure 10 – Another record of a papaya tree cultivated in the area of the Lagoa do Carro dump – PE.  
Source: Authors (2024).

These results reinforce the need for public policies focused on environmental monitoring and soil recovery in areas previously occupied by dumps, since contamination can persist for decades and compromise both local ecosystems and public health.

### 3.3 Impacts on the Local Community, Fishermen, and Other Regions

In the vicinity of the deactivated dump is the Vila da Barragem community, where a colony of fishermen resides and is among the groups most affected by the pollution of the Capibaribe River. In interviews, fishermen reported that leachate from the dump flows directly into the riverbed, especially during rainy periods, contaminating the water used for fishing and leisure. This area is considered by them one of the most productive, due to the lentic waters formed after the dam.

With an approximate distance of 200 meters between the dump and the river, the leachate carries heavy metals, organic matter, fungi, and bacteria into the aquatic environment, intensifying the process of artificial eutrophication. This phenomenon, resulting from the excess of nutrients (nitrogen and phosphorus) present in organic matter, compromises aquatic fauna and flora, reduces dissolved oxygen in the water, and causes fish mortality (Costa et al., 2006). The excessive proliferation of the aquatic plant *Eichhornia crassipes* (water hyacinth) was observed in the region, reinforcing the severity of the process.

Artificial eutrophication generates not only environmental impacts but also serious social problems. Many fishermen, lacking alternative sources of income, continue to be exposed to contaminated water, which can cause skin diseases and fungal infections. Field observations confirmed the presence of fungi on the nails of several fishermen, attributed to continuous contact with polluted water (Figure 11).



Figure 11 – Nail of a fisherman from the local community showing signs of fungal contamination.  
Source: Authors (2024).

In addition to the direct impacts on the health and livelihood of fishermen, the population of Vila da Barragem faces daily strong odors and smoke resulting from spontaneous burning at the dump, compromising the community's quality of life.

Another aggravating factor is related to local tourism, one of the main economic activities of the municipality. The Engenho Ápua bridge, located over the Capibaribe River, is frequently visited by tourists and residents, who use its calm waters for leisure and recreation. However, as it is located only 1.34 km from the dump, the area suffers direct contamination from the runoff of waste and leachate (Figure 12).

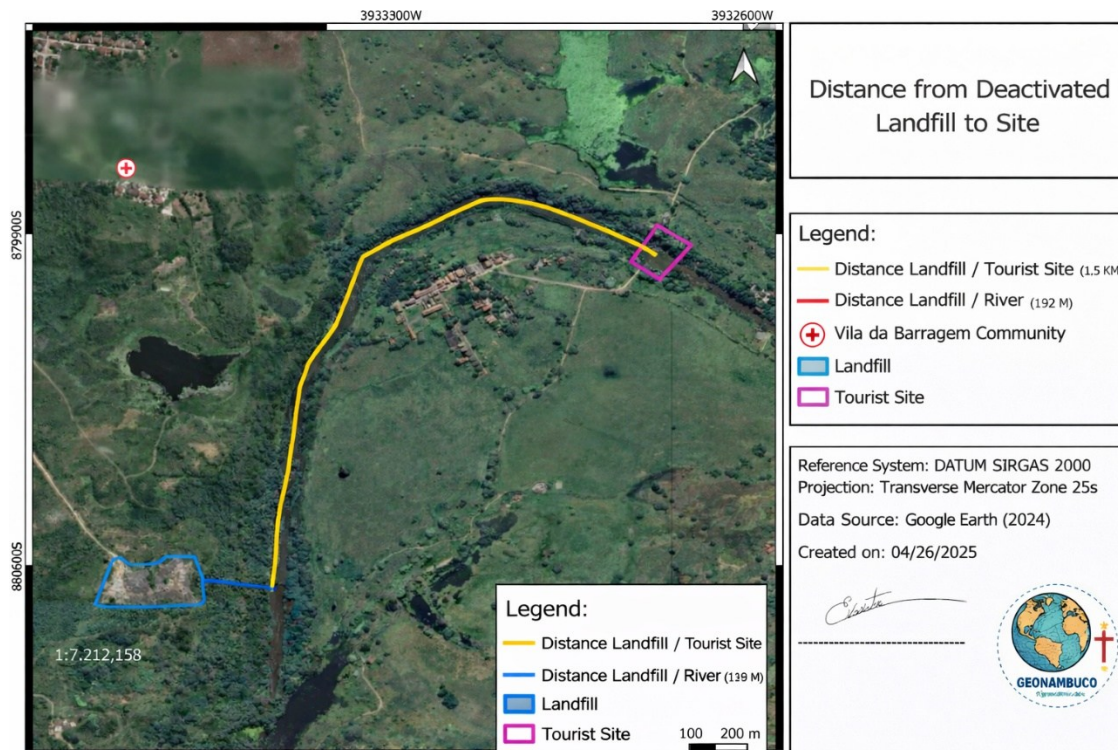


Figure 12 – Distance between the dump and the tourist site at Engenho Ápua.  
Source: Authors (2025).

The environmental impact caused by the dump extends beyond municipal boundaries. Following the course of the Capibaribe River, the pollution reaches neighboring cities such as Carpina, Paudalho, São Lourenço da Mata, Camaragibe,

and Recife, until it flows into the Atlantic Ocean. In Carpina, for example, contaminated waters are dammed at the Petribú Plant reservoir and used in industrial sugar production processes before returning even more polluted to the river.

This trajectory shows that the environmental liability of a deactivated dump is not restricted to the local space, but spreads on a regional scale, compromising ecosystems, economies, and the health of thousands of people along the Capibaribe basin.

### 3.4 Water Analysis

The analysis of water was essential to understand the effects of the deactivated dump on the Capibaribe River, especially considering its proximity to the waste disposal area.

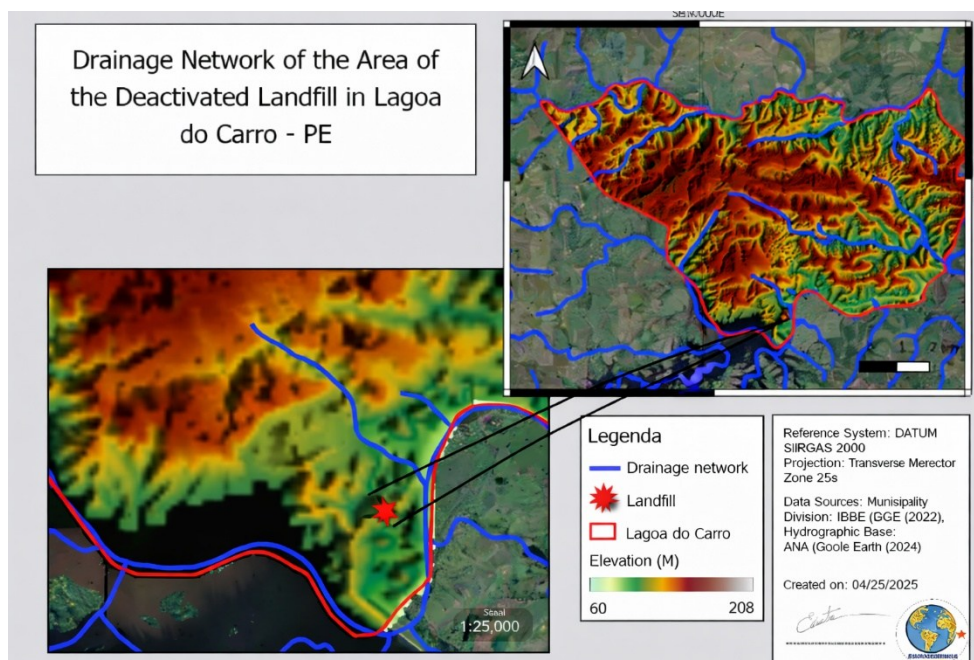


Figure 13 – Topography of the area of the deactivated dump in Lagoa do Carro – PE.  
Source: Authors (2025).

As illustrated by the map, rainwater flows across the dump, carries contaminants, and drains directly into the river, which is used by the population for fishing, leisure, and informal supply. To assess water quality, a sample was collected at the tourist site located approximately 1 km from the dump, on the banks of the Capibaribe River.

The sample was analyzed in the UPE–CMN laboratory, in partnership with Prof. Dr. Viviane Lúcia dos Santos Almeida Melo, using a plankton net specific for freshwater. Fifty liters of water were filtered and concentrated into 50 mL, from which 2 mL were analyzed on a slide.

The analysis revealed the presence of eight taxa and twenty-five planktonic individuals, including:

- Species indicative of pollution, such as *Arcella vulgaris* (protozoan) and *Microcystis* sp. (cyanobacteria) (Figure 14);
- Bioindicator species of good water quality, such as *Copepoda cyclopoida* (Figure 15), as well as copepod nauplii, rotifers (*Epiphanes macrourus*), and other microcrustaceans.



Figure 14 – Phytoplankton of the genus *Microcystis* identified in the water sample.  
Source: Authors (2025).



Figure 15 – *Copepoda cyclopoida* identified in the water sample.  
Source: Authors (2025).

The simultaneous presence of organisms tolerant and sensitive to pollution indicates that the water has an intermediate level of quality, with signs of contamination, but still preserving relative planktonic diversity. Although no immediate risk to human health was identified from this analysis, the results show a process of environmental imbalance, which tends to worsen if mitigation and monitoring measures are not implemented.

#### 4. Final Considerations

This research demonstrated that, even after its official deactivation in December 2020, the municipal dump of Lagoa do Carro – PE continues to generate significant socio-environmental impacts, affecting both the local ecosystem and the quality of life of the surrounding population.

The analyses carried out indicated the presence of contaminants in the soil, water, and air, resulting from the absence of effective environmental recovery measures. The soil showed microplastics and heavy metals, which compromise its fertility and, due to the use of the area for fruit cultivation and cattle raising, increase the risk of human contamination. The water of the Capibaribe River, impacted by leachate runoff, showed signs of artificial eutrophication, with consequences for aquatic fauna, local fishermen, and tourism, an important economic activity in the municipality. The air analysis, based on the observation of lichens and recurrent burnings, reinforced the atmospheric deterioration caused by waste decomposition and the emission of toxic gases.

From a social perspective, there was an intensification of the vulnerability of former recyclable material collectors, who lost their main source of income without receiving sustainable alternatives for economic reintegration. The disorganization of selective waste collection and the low level of environmental education among the population further aggravate this scenario, compromising the effectiveness of public solid waste policies.

Given the above, it is concluded that the mere deactivation of dumps does not represent a solution to the environmental and social problems arising from them. It is essential that municipal and state governments adopt more stringent measures, including:

- strict compliance with the National Solid Waste Policy (Law No. 12,305/2010);
- investments in technologies for the recovery of degraded areas;
- strengthening of selective waste collection and socioeconomic inclusion of waste pickers;
- continuous educational actions articulated with the community.

Only through a joint effort between the public sector, civil society, and the private sector will it be possible to move towards sustainability and environmental justice, transforming environmental liabilities into opportunities for ecological recovery and social development.

## References

- ABREMA – WASTE AND ENVIRONMENT ASSOCIATION. Panorama 2023 – Part 1. Available at: [https://www.abrema.org.br/wp-content/uploads/dlm\\_uploads/2024/03/Panorama\\_2023\\_P1.pdf](https://www.abrema.org.br/wp-content/uploads/dlm_uploads/2024/03/Panorama_2023_P1.pdf). Accessed on: Nov. 29, 2025.
- BRAZIL. Law No. 12,305, of August 2, 2010. Establishes the National Solid Waste Policy; amends Law No. 9,605 of February 12, 1998; and provides other measures. Brasília: Planalto, [2010]. Available at: [http://www.planalto.gov.br/ccivil\\_03/\\_ato2007-2010/2010/lei/112305.htm](http://www.planalto.gov.br/ccivil_03/_ato2007-2010/2010/lei/112305.htm). Accessed on: Jul. 29, 2024.
- BRAZ, S. N. Lichens as bioindicators of environmental quality in edge areas of urban forests. 2020. 114 p. Dissertation (Master's in Sustainability) – Pontifical Catholic University of Campinas, Campinas, 2020.
- CONVALE – PUBLIC CONSORTIUM FOR SOLID WASTE MANAGEMENT VALE DO JAGUARIBE UNIT II. Open dumps: a problem that deserves attention. Available at: <https://convale.ce.gov.br/informa/17/lixoes-um-problema-que-merece-atencao>. Accessed on: Nov. 29, 2025.
- COSTA, I. A. S.; SANTOS, A. P.; SILVA, A. A.; MELO, S. G.; MENDONÇA, J. M. S.; PANOSSO, R. F.; ARAÚJO, M. F. F. Feeding and reproductive ecology of the main fish species of Lagoa do Piató, Assu, RN. FAPERN Journal, v. 1, n. 4, Oct./Nov. 2006. Available at: <http://adcon.rn.gov.br/ACERVO/FAPERN/DOC/DOC00000000010485.PDF#page=14>. Accessed on: Nov. 29, 2024.
- DE SOUZA MACHADO, A. A. et al. Microplastics can change soil properties and affect plant performance. *Environmental Science & Technology*, v. 53, n. 10, p. 6044–6052, May 21, 2019. Available at: <https://pubs.acs.org/doi/10.1021/acs.est.9b01339>. Accessed on: Nov. 29, 2024.
- DIAS, Marilza do Carmo Oliveira; PEREIRA, Mauri César Barbosa; DIAS, Pedro Luís Fuentes; VIRGÍNIO, Jair Fernandes (Org.). Manual of environmental impacts: basic guidelines on environmental aspects of productive activity. 2nd ed. Fortaleza: Banco do Nordeste, 2008. 322 p.
- IBGE – BRAZILIAN INSTITUTE OF GEOGRAPHY AND STATISTICS. Economic statistics 2024. Available at: <https://www.ibge.gov.br>. Accessed on: Nov. 29, 2025.

MARCELLI, M. P. Lichenized fungi. In: XAVIER FILHO, L. et al. Biology of lichens. Rio de Janeiro: Âmbito Cultural, 2006. p. 25–74.

MARKERT, B. A.; BREURE, A. M.; ZECHMEISTER, H. G. Definitions, strategies and principles for bioindication/biomonitoring of the environment. In: MARKERT, B. A.; BREURE, A. M.; ZECHMEISTER, H. G. (Org.). Trace metals and other contaminants in the environment. Amsterdam: Elsevier, 2003. v. 6, p. 3–39.

PEREIRA, I. M. C. Monitoring pollutant emissions from biodiesel-powered engines through the use of lichens. 2014. Dissertation (Master's in Geography) – Federal University of Pernambuco, Recife, 2014.