

Environmental Impact Assessment Of A Sanitary Landfill In A Municipality Of The Brazilian Semi-arid Region Using The Leopold Interaction Matrix

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Abstract:

This article proposes an assessment of the environmental impacts of the Cajazeiras landfill in Paraíba, Brazil, using the Leopold Matrix to support strategies for proper solid waste management in the region. An exploratory and descriptive study was conducted, covering both quantitative and qualitative aspects. The results revealed a series of significant impacts, including aesthetic degradation, proliferation of disease vectors, and emission of unpleasant odors. The absence of adequate infrastructure and control exacerbates these issues, threatening local health and environmental quality. Urgent action is needed to mitigate these impacts, with the implementation of measures such as those discussed here. The importance of collaboration among the community, government, and other stakeholders, along with effective public policies and sustainable practices, is emphasized to achieve sustainable solutions and promote a healthy environment for present and future generations.

Keywords: Sanitary Landfill; Environmental Impact; Solid Waste Management; Leopold Matrix; Sustainable Solutions"

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I. Introduction

Developing sustainably, encompassing social, economic, and environmental development, is one of the challenges of the current century. Aligning a country's economic growth, reducing existing social inequalities, and mitigating harmful impacts on the natural environment are goals shared by all managers for society.

The environment is essential for life on Earth; from it, we extract resources and raw materials for the maintenance of terrestrial life. Moreover, this relationship of human-nature exploitation has increased in recent centuries, resulting in damages to the natural environment that may become irreversible.

In recent decades, urban centers have faced a significant problem related to solid waste, with uncontrolled growth over the decades resulting in the formation of large dumps. Population growth and the industrial revolution have played significant roles in this scenario, driving production and consumption on a global scale. Additionally, the technological revolution has also contributed to waste generation, as many consumer products have shorter lifespans (Costa, 2018).

Law No. 12,305/2010, known as the National Solid Waste Policy, establishes that waste must be adequately disposed of in the environment and sets goals for the elimination and recovery of dumps in municipal plans. Initially, the law mandated the eradication of dumps by August 2, 2014 (Brazil, 2010). However, this deadline expired, and new deadlines were set by Law No. 14,026/2020 (Brazil, 2020).

Dumps have remained a persistent reality in many Brazilian municipalities, even after the implementation of the PNRS. The improper disposal of solid waste in dumps generates various environmental, social, and public health problems. The municipality of Cajazeiras, located in the state of Paraíba, faces this challenge, with the existence of a dump that requires an in-depth analysis of its environmental impacts.

According to the PNRS, municipalities would be responsible for building adequate sanitary landfills or establishing partnerships with neighboring municipalities, ensuring environmentally sustainable practices (Costa, 2018). However, these measures were not effectively adopted by several municipalities in Paraíba. The need to extend deadlines for the closure of dumps indicates that the management of Urban Solid Waste has not been effective in most Brazilian municipalities (Assad; Siqueira, 2016; Lomolino, 2017; Domingos, 2022).

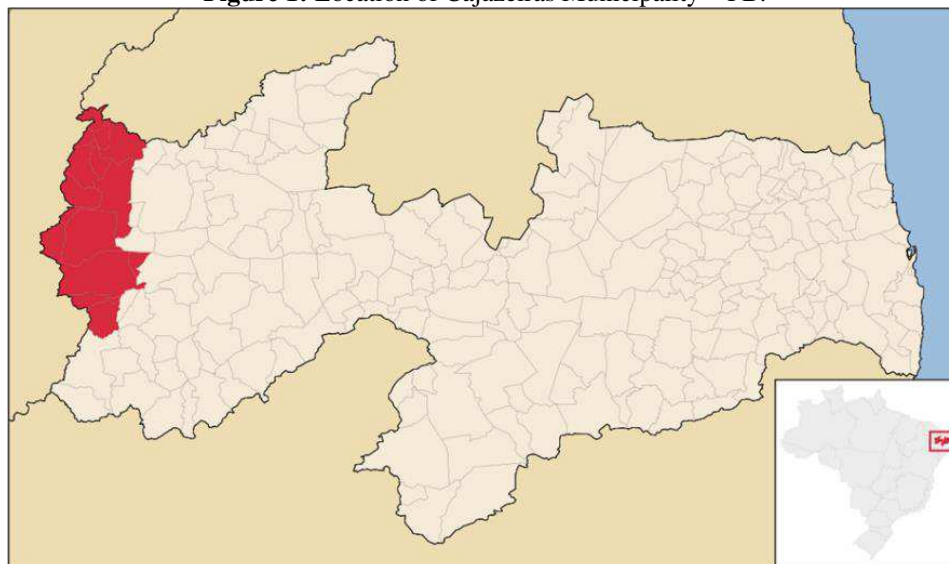
The general objective of this article is to conduct an evaluation of the environmental impacts of the Cajazeiras - PB dump through the Leopold Matrix, aiming to provide subsidies for the development of strategies and actions focused on proper environmental management of solid waste in the municipality.

II. Materials And Methods

The present research is an exploratory and descriptive study with a quantitative-qualitative approach.

The study was conducted in the municipality of Cajazeiras – PB, located in the western portion of the state of Paraíba, belonging to the Mesoregion of the Sertão Paraibano (Figure 1). It has a population of 62,576 inhabitants and a territorial unit of 566 km². Agriculture, industry, and services provision are the most important economic activities (IBGE, 2023).

Figure 1: Location of Cajazeiras Municipality – PB.



Source: Cavalcante et al., 2018.

The first stage of the research involved characterizing the area of the enterprise using Google Earth, as shown in Figure 2. The dumpsite in the city of Cajazeiras – PB, is only 2 km away from the urban center.

Figure 2: Location of the Cajazeiras – PB Dumpsite.



Source: Google Earth, 2023.

The second stage was carried out through on-site visits, where field data collection was conducted. This involved visiting the landfill site to gain a better understanding of its operations.

We utilized equipment such as GPS (Global Positioning System) to record the location, a field notebook to jot down relevant data related to the study area, and the cellphone camera to create an image repository.

The characterization of the environmental diagnosis was conducted using a checklist (SILVA, 1999), which involves identifying the main environmental impacts present in the study area. We observed and recorded all environmental impacts occurring in the region.

The impacts identified were analyzed and classified based on the checklist, followed by a quantitative and qualitative assessment, and subsequent interpretation of the environmental impacts. This interpretation was made considering physical, biotic, and anthropic aspects. The qualitative assessment of environmental impacts was conducted using methods proposed by Silva (1999), classifying impacts according to criteria such as order, value, dynamics, time, plasticity, and space.

To facilitate the visualization of impacts in the study area and contribute to qualitative analyses, we developed a network of impact interactions occurring in the region (Cremonez et al., 2014).

For the quantitative assessment, we utilized the matrix method proposed by Leopold et al. (1971), where impacts are classified based on two main attributes: magnitude (the spatial and temporal scale of an impact) and importance (the intensity of the effect related to a certain environmental factor, other impacts, or specific site characteristics). The impacts are described in Table 1, enumerated horizontally and vertically according to their magnitude and importance, with values ranging from 1 to 10.

Table 1: Attributes and their respective weighting for the Leopold Matrix applied to the Cajazeiras – PB Dumpsite.

Attribut	Variations	Symbolism
Nature	Positive	+
	Negative	-
Origin	Direct	D
	Indirect	I
Scope	Local	1
	Regional	2
	Strategic	3
Temporality	Immediate	1
	Short Term	2
	Long Term	3
Periodicity	Temporary	1
	Cyclical	2
	Permanent	3
Reversibility	Reversible	0
	Irreversible	1
Regularity	Regulated by law or any other legal instrument	5

	Considered for future regulation	4
	Corporate policy, the issue is addressed in the company's policy	3
	Corporate practice: Conduct adopted by the company	2
	There is no regulation or guideline on the subject	1
Magnitude	Low	1
	Medium	2
	High	3
Cause x Effects	Cause generates only one effect	1
	Cause generates two or more effects	2

Source: Guarieiro; Carmo (2021).

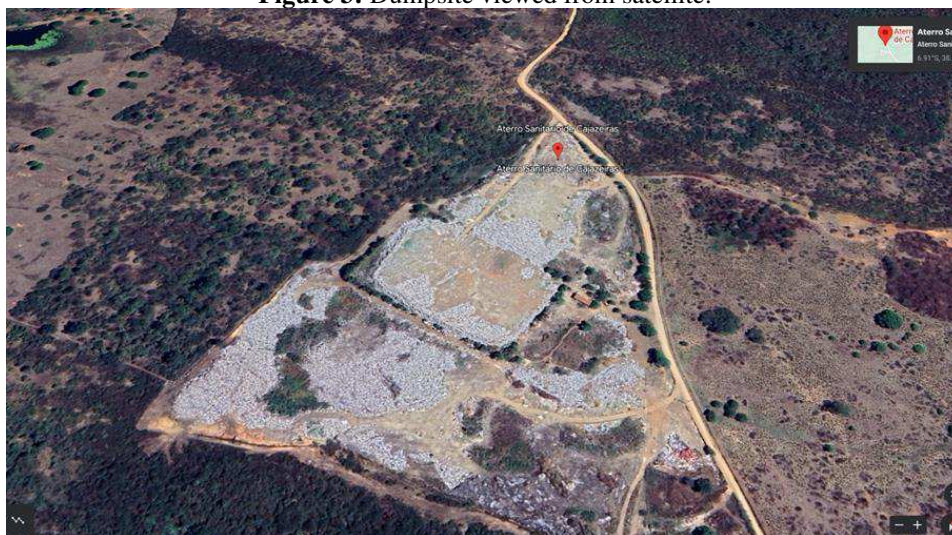
Based on the identified impacts, mitigating measures were proposed that can be applied in the evaluated area with the aim of minimizing adverse impacts.

Additionally, data from the National Sanitation Information System – SNIS, of the municipality of Cajazeiras – PB, were analyzed. It is worth noting that the SNIS is the largest and most important information system in the Brazilian sanitation sector. This System has a database containing information and indicators about the provision of Water and Sewage services, Urban Solid Waste Management, and Urban Stormwater Drainage and Management (SNIS, 2022).

III. Results And Discussions

In the first part of the results, the characterization of the dumpsite and the assessment of impacts in the Cajazeiras – PB Dump were conducted. Figure 3 shows the area designated for the dumpsite in the city of Cajazeiras – PB.

Figure 3: Dumpsite viewed from satellite.



Source: Google Earth, 2023.

The current solid waste management system at the Cajazeiras - PB dumpsite is quite rudimentary, as all materials are accumulated without any segregation based on their origin. Furthermore, the perimeter of the dumpsite is saturated and presents a degraded appearance, clearly not meeting the minimum legal standards for the operation of an open-air dumpsite.

According to Sousa et al., (2019), the main types of waste produced in the city of Cajazeiras – PB, are household waste, commercial waste, industrial waste, health waste, and construction waste. The most common packaging methods are metal drums, cardboard boxes, plastic bags, and sacks. Health service waste, being of a special nature, is packaged in exclusive containers and is the responsibility of the company responsible for collection, TRASH - Coleta e Incineração do Lixo Hospitalar LTDA – ME.

Waste collection is carried out regularly; however, it is still not done with the concern of separating waste through selective collection. Sweeping and cleaning activities of public spaces are performed, as well as regular collection of household waste. Disposal is done in the few available collectors on the streets, using bags, sacks, boxes, and other containers adopted by the population (Sousa et al., 2019).

The household collection and urban cleaning services cover all central streets, achieving 100% coverage. Collection occurs daily, following a simple circuit, from collection to final disposal. However, the

current system is limited to sweeping, cleaning public spaces, collecting household waste, and its disposal in the dumpsite (Sousa et al., 2019).

Overall, the area directly affected by the dumpsite facilities consists of a radius of 5 km from the designated site, as the final disposal of solid waste occurs without any treatment.

In terms of the distance that contamination can spread from a dumpsite, it depends on various factors. However, generally, the effects of contamination can be observed in an area several kilometers around the dumpsite. It is important to note that contamination can continue to spread over time, especially if adequate remediation measures are not taken or if the dumpsite is in operation for an extended period, as shown in Figure 4:

Figure 4: Road alongside the Dumpsite.



Source: Research Data, 2023.

On the way to the dumpsite, a significant amount of litter scattered along the road was noticeable. This lamentable scene demonstrates the lack of environmental awareness and the absence of adequate measures for solid waste management in the city. The litter present on the roadside represents an additional environmental problem, as it can be washed away by rain, contaminating the soil and nearby bodies of water, as well as posing a risk to local wildlife. Furthermore, the sight of scattered litter contributes to an unpleasant landscape and damages the image of the area.

Around the dumpsite, there is a Societe arena and some ponds (Figure 5) that the population usually uses to feed animals in cattle and sheep farming.

Figure 5: Societe arena adjacent to the dumpsite and Pond near the dumpsite.



Source: Research Data, 2023.

Para Mucelin et al., (2004), there are important issues that can ensure protection against the migration of solid waste into the environment. Waste decomposition is another problem, as it releases gases and liquids that affect the quality of natural resources (air, water, and soil). The black fluid, with a foul odor, has a high contamination capacity and is called leachate. When crossing the established boundaries of the area, the material can cause negative impacts on the environment by penetrating the soil and flowing into the pond, potentially causing a series of problems in the physical environment and natural resources of the region.

In addition to causing complications for the physical environment, by exceeding the limits of the dumpsite area, leachate can affect the water quality of rivers and tributaries, leading to epidemic outbreaks among the population who use water from these sources. It is worth noting that the Cajazeiras dumpsite is close to the riverbed. The accumulated waste produces a liquid called leachate, which has a dark color and unpleasant odor, and reaches groundwater (aquifer, water table). Furthermore, there are environmental impacts on soil, air, visual, social, and the imbalance of fauna and flora. The result of this set of impacts is degradation, which reduces or prevents the ability of environmental resources to naturally restore themselves, that is, significant alterations (Araújo, 2008).

The presence of people in the environment is noteworthy, as they assist their parents in collecting materials for recycling, as it is through waste management that they support their families, as shown in Figure 6.

Figure 6: Presence of people in the dumpsite.



Source: Research Data, 2023.

The collection of recyclable materials is an essential activity for environmental preservation and sustainability promotion. By collecting and sorting waste, these individuals contribute to reducing the amount of garbage sent to landfills, preventing soil and water contamination, and conserving natural resources.

Unfortunately, the figure also highlights the vulnerability of these workers, especially when children are involved in this activity. The need to help support their families often prevents them from accessing formal education and better opportunities.

It is important to emphasize that child labor is a violation of children's rights and should be combated. Children have the right to play, study, and develop fully in a safe and healthy environment. Therefore, it is crucial to offer alternatives and opportunities for these families to have adequate income without resorting to child labor.

In the specific context of the Cajazeiras dumpsite, it is common to encounter a strong odor due to the decomposition of organic waste present. The lack of proper waste management, such as the absence of composting processes or adequate treatment, can lead to the release of unpleasant odors.

Dumpsites are places where waste is improperly disposed of, without environmental control and effective measures to protect human and animal health. These sites pose a serious threat to the environment, air quality, groundwater, and the health of people living nearby.

The presence of vultures and other animals is common in dumpsites, as these locations provide a source of food for them, as shown in Figure 7:

Figure 7: Presence of Animals in the Dumpsite in large quantity.



Source: Research Data, 2023.

Vultures, for example, are attracted to food scraps and organic waste present in the garbage. These animals play an important role in nature as they help clean and recycle organic materials, but their concentration in dumpsites can pose risks to health and the environment.

The presence of vultures and other animals in dumpsites can raise concerns related to the transmission of diseases, such as the spread of bacteria and viruses present in the waste. Additionally, exposure to these unhealthy environments can lead to respiratory problems, dermatological issues, and other adverse health conditions.

Another issue observed in the Cajazeiras – PB dumpsite is the occurrence of wildfires, as shown in Figure 8:

Figure 8: Smoke from the dumpsite covering the entire city of Cajazeiras – PB.



Source: Research Data, 2023.

The occurrence of fires in the Cajazeiras - PB dumpsite is something that happens frequently. Environmental crimes are of alarming proportions, and the lack of control over wildfires causes significant damage to fauna and flora, compromising air quality and consequently human health. This situation leads to the emergence of various diseases, especially respiratory ones.

The toxic smoke from the fires in the Cajazeiras dumpsite in Paraíba represents a serious problem for human health. The burning of solid waste releases harmful and polluting substances into the air, which are inhaled by people living nearby or exposed to the smoke.

This toxic smoke contains a variety of dangerous chemicals, such as fine particles, sulfur dioxide, carbon monoxide, nitrogen oxides, and volatile organic compounds. Inhaling these substances can cause a range of health problems, especially related to the respiratory system.

The fine particles present in the smoke are particularly concerning as they are small enough to be deeply inhaled into the lungs. They can irritate the airways, exacerbate pre-existing conditions such as asthma and chronic obstructive pulmonary disease (COPD), and increase the risk of developing respiratory infections.

Additionally, toxic gases released during wildfires, such as carbon monoxide, can interfere with the transport of oxygen in the blood, causing shortness of breath, dizziness, headaches, and even poisoning in more severe cases.

Continuous exposure to toxic smoke from wildfires in the Cajazeiras dumpsite can lead to the development of chronic health problems such as chronic respiratory diseases, cardiovascular diseases, irreversible lung damage, and even cancer. It is important to note that toxic smoke not only affects people living near the dumpsite but can also spread to more distant areas depending on weather conditions. This expands the negative impact on the health of communities.

In the second part of the results and discussions, the Leopold Matrix was applied to the Cajazeiras dumpsite in Paraíba, which is an essential approach for assessing and mitigating the environmental impacts caused by this solid waste disposal area. The Leopold Matrix is a widely used tool for environmental analysis and management, providing a structured framework for evaluating the effects of a particular activity on the environment.

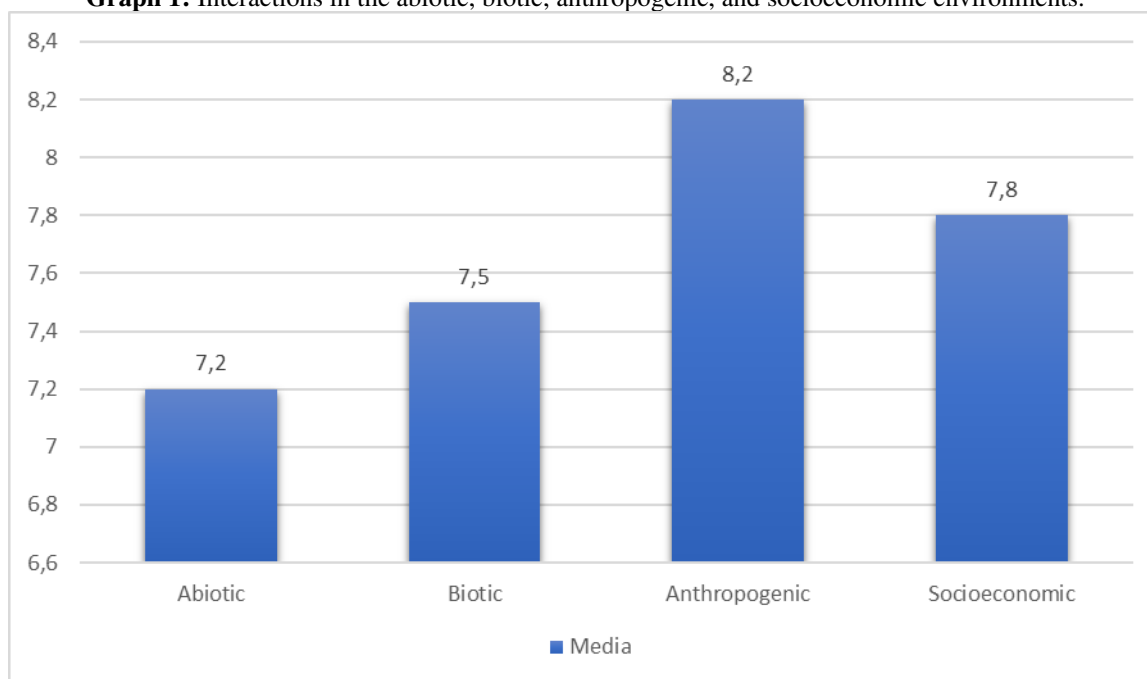
Table 2: Interaction Matrix for the Identification of Environmental Impacts.

Magnitude of Impacts	Nature		Origin		Abrangence			Temporality		Periodicity		Reversibility		Magnitude			Cause And Effect			
	Positive	Negative	Direct	Indirect	Local	Regional	Strategic	Immediate	Short Term	Long Term	Temporary	Cyclic	Permanent	Reversible	Irreversible	Low	Medium	High	Generates An Effect	Generates More Effects
1-3: Low importance																				
4-6: Medium importance																				
7-10: High importance																				
Suppression of native vegetation		X	X		X				X				X	X			X			X
Reduction of biodiversity		X	X		X				X				X	X			X			X
Air pollution		X	X		X				X				X	X			X			X
Water contamination and pollution		X	X			X			X				X	X			X			X
Soil pollution and degradation		X	X		X				X				X	X				X		X
Emission of atmospheric pollutants		X	X				X	X					X	X				X		X
Visual pollution		X	X		X			X					X	X				X		X
Risk of accidents		X		X	X		X						X	X				X		X
Pollution of neighboring areas		X		X	X		X						X	X				X		X
Disruption of wildlife		X		X	X			X					X	X			X			X
Increase in erosion processes		X	X		X					X			X	X			X			X
Odor emissions		X	X		X			X					X	X				X		X
Pollution of community areas		X		X	X				X				X	X				X		X
Risk of contamination of residents		X	X		X				X				X	X				X		X
Presence of disease vectors		X		X		X							X	X				X		X

Source: Research Data, 2023.

It was found that the dumpsite in the city of Cajazeiras, PB, results in various negative impacts. The lack of care for these waste materials leads to increased erosion processes, soil compaction, contamination of the water table, and even a reduction in the capacity to sustain and naturally develop flora.

Graph 1: Interactions in the abiotic, biotic, anthropogenic, and socioeconomic environments.



Source: Research Data, 2023.

When analyzing and considering that a single impact can affect more than one environmental medium simultaneously, a total of 15 environmental impacts were identified. From this identification, it was observed that the most affected medium was the anthropogenic, with a score of 8.2, followed by the socioeconomic with 7.8, abiotic with 7.5, and finally, biotic with 7.2.

These results indicate that the impacts caused by inadequate solid waste management mainly affect the medium influenced by human activities, such as infrastructure, health, quality of life, among other socioeconomic aspects. Additionally, the abiotic and biotic mediums are also affected, impacting the physical environment, such as soil and water, and local biodiversity.

These findings highlight the importance of adopting effective measures to mitigate the environmental impacts caused by inadequate solid waste management. It is necessary to implement policies and practices that promote awareness, environmental education, and proper waste management to minimize the negative effects on the various affected environmental mediums. Only through integrated and sustainable actions will it be possible to reduce these impacts and ensure a more balanced and healthier environment for present and future generations.

IV. Conclusion

The findings of this study reflect the importance of understanding and assessing the negative effects caused by improper solid waste management in the city of Cajazeiras, PB. The use of the Leopold Matrix as an analytical tool provided a comprehensive view of the impacts on different environmental media, allowing for a more precise and informed evaluation.

It was found that the Cajazeiras landfill presents a series of significant environmental impacts. Aesthetic degradation, proliferation of disease-transmitting vectors, generation of unpleasant odors, emission of volatile and toxic organic gases, and open burning of waste are some of the identified problems. Furthermore, the lack of adequate infrastructure and control measures exacerbates these impacts, endangering the health of local communities and compromising the environmental quality of the region.

It became evident that the current final waste disposal system, supposed to be a sanitary landfill, has turned into a completely disordered garbage heap. This realization reinforces the need for emergency actions to mitigate the impacts on-site and in its vicinity, in order to protect people's health and preserve the environment.

According to the National Solid Waste Policy, it is essential to eradicate and recover landfills within a certain deadline, aiming to reduce environmental impacts and health risks for the population. However, this goal

has not yet been achieved in Cajazeiras, PB, demonstrating the need for greater commitment and investment in solid waste management.

To minimize the environmental impacts of improper disposal in the landfill, it is essential to adopt measures that cover all stages of the system, from production to correct waste disposal. Actions such as spreading, covering, and daily compacting of waste, enforcement to prevent open burning, maintenance and monitoring of drainage systems, distribution of personal protective equipment, and waste sorting can significantly contribute to mitigating the impacts.

In addition to immediate actions, long-term planning is necessary, involving the implementation of selective collection, the establishment of a recycling facility, and a composting plant. These measures would not only reduce the amount of waste sent to the landfill but also generate jobs and income for the population, besides minimizing the environmental impacts associated with improper solid waste management.

In summary, the assessment of the environmental impacts of the Cajazeiras landfill through the Leopold Matrix reinforces the urgent need for interventions to address the identified problems. The implementation of mitigating measures, such as those proposed above, is crucial to reverse the current situation and promote proper solid waste management.

It is important to note that actions must be accompanied by a joint effort from the community, government, and other stakeholders involved. Public awareness of the importance of proper waste separation, active participation of recyclable materials collectors, and adoption of sustainable practices are essential for the success of the proposed measures.

Furthermore, the creation of effective public policies, with incentives and financial support for the implementation of proposed solutions, is essential. Collaboration among different sectors of society, such as companies, non-governmental organizations, and research institutions, also plays a crucial role in seeking sustainable solutions.

Therefore, the assessment of the environmental impacts of the Cajazeiras landfill through the Leopold Matrix provided a comprehensive and informed view of the problems faced. Based on this information, efforts can be directed towards the implementation of corrective and preventive measures, aiming to reduce negative environmental impacts and promote a healthier and more sustainable environment for present and future generations.

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