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Implementation Of The Zero Landfill Program In A Transformation Industry At PIM- Industrial Pole Of Manaus

Antonio Veríssimo Noronha Lopes r[1], David Barbosa de Alencar[2] , Manoel Henrique Reis Nascimento[2] Antonio Estanislau Sanches[3].

[1]*Academic, of the Postgraduate Program in Engineering, Process Management, Systems and Environmental (PGP.EPMSE) - Institute of Technology and Education Galileo of the Amazon – ITEGAM – Amazonas - Brazil.*
[2]*Professor, of the Postgraduate Program in Engineering, Process Management, Systems and Environmental (PGP.EPMSE) - Institute of Technology and Education Galileo of the Amazon –ITEGAM - Amazonas – Brazil*
[3]*Professor, of the University of the State of Amazonas - UEA - Amazonas - Brazil.*

Abstract:
Background*: This study was carried out with the objective of analyzing the feasibility of implementing the Landfill Program in a manufacturing industry located in the Industrial Pole of Manaus (PIM). The PIM is a major industrial region and presents a significant challenge with regard to waste management. In this context, the Zero Landfill Program emerges as a sustainable approach that seeks to reduce the sending of waste to landfills, encourage the reuse of materials and promote recycling, creating an economic cycle and inspiring other companies to adopt similar practices.*
Materials and methods*: To achieve the proposed objectives, a case study was carried out in the manufacturing industry of Manaus. Based on the principles of the 3Rs (reduce, reuse and recycle), sustainable industrial waste management practices were developed. Actions were implemented to reduce the amount of waste generated in the production process, promoting awareness of the importance of reducing at source. In addition, procedures have been established for the reuse of materials whenever possible, seeking to extend their useful life cycle and minimize disposal. Recycling programs were also implemented, encouraging the transformation of waste into new products or raw materials.*
Results*: The results obtained were promising. The Manaus plant was able to meet the necessary criteria to obtain certification in the Zero Landfill Program. This means that the company was able to significantly reduce the amount of waste sent to landfills, keeping this value below 1% of the total waste generated in the production process. In addition, the factory was able to take advantage of and recycle at least 3% of the waste, transforming it into energy through appropriate processes.*
Conclusion*: Based on the results obtained in this study, it is possible to conclude that the implementation of the Landfill Program in a transformation industry in the Industrial Pole of Manaus is feasible and brings significant benefits in terms of environmental sustainability. The Manaus factory served as an example of good practices, encouraging other companies to adopt similar measures to reduce their environmental impact. However, for a deeper understanding of the subject, future studies are recommended. These studies may include expanding the analysis to other industries and regions, in order to verify the applicability of the Landfill Program in different contexts. In addition, it is important to carry out cost-benefit analyzes to assess the economic viability of these sustainable practices, as well as more comprehensive environmental impact assessments. It would also be interesting to investigate the perception of employees and the local community regarding the implemented changes, seeking to obtain valuable feedback.*
Key Word*:Landfill Zero; Environmental sustainability; Circular economy; Environmental waste; Environmental certification.*

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I. Introduction

The demand for products that utilize raw materials sourced from the environment is increasing at a significant scale, driven by high levels of productivity and consumption[1]. From this standpoint, solid waste is closely connected to the escalating generation and diverse range of materials being discarded, posing challenges in identifying suitable disposal sites. Given that waste generation and disposal are everyday practices among the

population[2], the present-day issues associated with solid waste primarily stem from the increasing generation rates and the need for proper final disposal methods[3].

In order to mitigate the environmental impact, management models have undergone changes, such as sustainable solid waste management, which can minimize the depletion of non-renewable resources[4]. In this regard, understanding the sources of waste generation is crucial to determine potential treatments and rational management of final disposal based on their physical-chemical and biological properties, chemical composition, and separation potential[3].

In Brazil, waste management is a shared responsibility between the government, the private sector, and the population. This collaborative approach involves the government and each supply chain sector establishing sectoral agreements to maintain shared responsibility throughout the product's life cycle[5]. However, municipal management, governed by Law nº 12,305, encounters implementation challenges, including the need to face the existence of dumps that pose risks to human health and the environment, as well as the inadequate disposal of waste near bodies of water. water. Consequently, the industry actively seeks solutions to minimize problems arising from waste management[6].

Therefore, the characterization and classification processes are vital in ensuring effective waste management, with the goal of minimizing the health and environmental risks associated with waste. Through this classification, guidelines, goals, principles, tools, and actions can be established to foster the development of an integrated waste management system[7].

Such management encompasses environmental, social, economic, technological, and public health variables. Based on these considerations, and recognizing the potential of environmental perception in assessing environmental issues, the following question emerged as the driving force behind this study: How can the implementation of the 3Rs (Reduce, Reuse, and Recycle) in the disposal of industrial waste aid in mitigating the impacts of generated waste while adhering to the guidelines of the Zero Landfill Program.

Therefore, the primary objective of this research was to examine how the Manaus plant, through its involvement in the Zero Landfill Program, can serve as a role model for other companies striving to obtain certifications and achieve international targets regarding the disposal of industrial waste generated throughout the production process. The particular emphasis lies in the conversion of these waste materials into energy, as opposed to their conventional disposal in landfills.

To achieve these objectives, several actions were undertaken, including analyzing the feasibility of implementing the Zero Landfill program in a manufacturing industry located in the PIM (Industrial Pole of Manaus). Sustainable practices for managing industrial waste were developed and implemented, guided by the principles of the 3Rs (Reduce, Reuse, Recycle). The aim was to decrease the amount of waste sent to landfills, promote material reuse whenever possible, and recycle materials to transform them into new products, thereby fostering a circular economy and inspiring other companies to follow the example set by the Manaus plant. Another key aspect was obtaining certification for the Manaus plant under the Zero Landfill Program, encouraging other companies to adopt sustainable practices and reducing environmental impact by limiting landfill disposal to a maximum of 1% of the waste generated in the production process while converting at least 3% of the waste into energy.

The present study will address the stages of the manufacturing process of white goods products and the waste generated during their manufacturing process. It will focus on the proper disposal of waste, in accordance with the guidelines of the Zero Landfill Program, to protect the environment, considering the needs related to sustainable development. Conferences organized by the United Nations, such as Rio+20, have evolved to establish 17 areas of Sustainable Development Goals (SDGs), replacing the previous Millennium Development Goals.

In this particular context, white goods or white line products encompass the household appliances that are prevalent in most households, including refrigerators, stoves, microwaves, washing machines, air conditioners, and dishwashers. These products are meticulously engineered with advanced technology to reduce their environmental footprint. For instance, refrigerators are manufactured to prevent the depletion of the ozone layer by employing environmentally friendly gases.

The Zero Landfill Program is an international initiative aimed at improving the environment by setting targets for waste disposal and energy generation from waste[8]. To achieve Zero Landfill Certification, industries must meet the target of sending no more than 1% of all generated waste to landfills and utilizing at least 3% of waste for energy transformation. This achievement is assessed over a period of at least 12 months. All manufacturing waste is collected, identified, separated, weighed, and grouped into categories[9, 10].

II. Material And Methods

RESEARCH CHARACTERIZATION

In this research, a descriptive approach was adopted to examine the implementation of the Zero Landfill Program at the Manaus site, focusing on its adherence to international goals for the disposal of industrial waste generated during the production process. This includes the proper management of waste through landfill disposal as well as the transformation of waste into energy.

Regarding the research approach, a mixed-methods design was employed, combining qualitative and quantitative analysis. In terms of the problem's approach, it was primarily quantitative as the data collected through the Google Forms application, based on an interview with the responsible personnel from the health, safety, and sustainability department, were transformed into numerical values.

In addition, the research was classified as qualitative as it involved the analysis of documents such as reports and spreadsheets containing information about the disposal of industrial waste generated during the production process, both in terms of landfill disposal and waste-to-energy transformation, along with their corresponding regulations.

The adopted method was a case study conducted at Electrolux company.

UNIT OF ANALYSIS

The research was conducted in the Manaus Industrial Pole, in a manufacturing industry within the Industrial Model of Manaus (PIM). Strategically located in the heart of the Americas and the Amazon, the Manaus Industrial Pole (PIM) is one of the most advanced industrial and technological hubs in Latin America, currently housing over 500 cutting-edge electronics industries. The revenue and production indicators of the Manaus Incentive Park have been growing steadily each year, with annual revenue exceeding R$ 120 billion and directly and indirectly generating over 500,000 jobs. The production of PIM is mainly focused on the Brazilian market, but a small portion (approximately 5% per year) is also exported to Latin American, European, and American markets SUFRAMA in 2019.

UNIT OF OBSERVATION

The unit of observation consisted of one member from the Health, Safety, and Sustainability department. This individual was selected as the primary source of information and insight regarding the implementation and management of waste disposal practices within the organization. Their role was crucial in providing data and insights related to the company's adherence to the Zero Landfill Program and their efforts in promoting sustainable waste management practices.

Through interviews and data collection from this representative, the research aimed to gather valuable information about the organization's waste management procedures, strategies, and compliance with sustainability guidelines. Their expertise and knowledge played a vital role in understanding the company's approach to waste disposal and their involvement in achieving the objectives of the Zero Landfill Program.

POPULATION AND SAMPLE

Therefore, the population considered for this study was the Electrolux company. Electrolux is a Swedish multinational manufacturer of household appliances founded on August 1, 1919, with its headquarters in Stockholm, Sweden. It is the second-largest manufacturer of household appliances in the world in terms of sales volume, after Whirlpool, selling over 40 million products annually in 150 countries.

The company has four factories in Brazil, two in Curitiba for refrigerators, freezers, vacuum cleaners, and high-pressure washers, one in São Carlos for washing machines, freezers, and stoves, and one in Manaus, which manufactures air conditioners and microwave ovens. Therefore, the Manaus unit was the focus of this study.

DATA COLLECTION PROCEDURES

Firstly, a request was submitted to the mayor, seeking permission to conduct the research within the specific department of the company under study. The document can be found in Appendix A.

The interview with the manager responsible for the department was conducted online using the Google Forms tool. A link to the interview questionnaire was provided to the interviewee for completion. The questionnaire consisted of open-ended questions aimed at understanding the interviewee's perspective on zero landfill, the 3Rs, indicator monitoring, and other relevant topics related to the study's theme.

PROCEDURES AND RESULTS ANALYSIS

The interview responses were collected through audio recordings. These recordings were transcribed into three text documents. The next step involved analyzing the responses and comparing them with the results of the graphs and figures obtained from the quantitative research.

III. Development

The increase in the size of landfills is attributed to the continuous development of large cities and the emergence of consortia among smaller municipalities to share the costs of implementation and operation. These large landfills tend to be vertical due to the difficulty of finding available sites in economically feasible distances within urban environments[4]. The disposal of municipal solid waste in conventional landfills has been seen as a viable alternative, provided it is well-designed and operated, and it is used in most cities as the sole solution for disposal after household collection[6].

The behavior of large quantities of waste is difficult to predict, which is why all elements of a landfill must be taken seriously, such as impermeabilization, an essential requirement to achieve one of the main goals of the structure: containing waste and minimizing environmental contamination as much as possible[8]. In Brazil, the final disposal of solid waste is the responsibility of the local government by law. However, this does not necessarily guarantee the selection of an appropriate waste disposal area, ignoring environmental conditions, legislation, and non-compliance with rules and proper management techniques suitable for the characteristics of the disposal area[10].

The waste generated by residents needs to be stored until it is collected by the municipal waste collection service. In the case of selective collection, the waste should be stored separately to optimize the public waste collection system, ensuring that recyclable materials are not wasted. Regular collection is the most common system, with door-to-door collection of all types of waste generated by households, while selective collection can be done through door-to-door collection and drop-off points[17].

The original Federal Constitution stated that the management of local public cleaning services, including households, businesses (up to a certain value, depending on the municipality), and public waste, was the responsibility of the municipality[4]. Therefore, it is up to the municipality to legislate, manage, and define the local basic sanitation system, which includes landfill management. For many years, the National Council for the Environment (CONAMA) developed valid resolutions at the federal level for certain special waste (sanitary services, ports and airports, road and railway terminals, civil buildings, etc.), for example, until 001/86 (Environmental Impact Basic Standards and General Guidelines for Evaluation) and 237/97 (Revisions and Supplements to Environmental Licensing Procedures and Standards), while the states adopted their own solid waste legislation[10].

The Brazilian Association of Technical Standards (ABNT) also develops standards for landfill management, such as NBR 13.896 (ABNT, 1997), which specifies criteria for the design, implementation, and operation of landfills. Additionally, Article 182 of the Federal Constitution establishes that municipal governments should formulate urban development policies to fully fulfill social functions and ensure the well-being of residents.

The hierarchy of these activities, according to [11], is clearly outlined in the National Solid Waste Policy established by Law No. 12,305, dated August 2, 2010, and regulated by Decree No. 7,404, dated December 23, 2010. According to the authors, waste management in the country should prioritize the following order: waste prevention (avoiding the generation of solid waste), reduction (minimizing resource use during production and consumption, extending the lifespan of goods), reuse (repairing, cleaning, or rehabilitating existing goods), recycling (reusing materials for other production processes), solid waste treatment, and environmentally sound final disposal of waste.

According to [12], disposal sites for solid waste have received special attention in recent years due to their potential for soil, water, and air pollution. They explain that improper disposal of waste containing heavy metals such as batteries, accumulators, paints, etc., contains highly polluting chemical elements for humans and nature, which can leach and contaminate soils, surface and groundwater, as well as flora and fauna.

This is a matter of great relevance, as the organic compounds released during decomposition in landfills are biodegradable and lead to increased microbial activity in the soil of the burial area. The presence of nitrogen and phosphorus compounds, as well as the concentration of salts (Cl-, HCO3, Ca+2, Na+), will also increase, thereby raising the conductivity, pH, alkalinity, and hardness of the soil solution [13].

In their article, [23]emphasize that landfills are a significant source of anthropogenic pollution worldwide, as physical, chemical, and biological pollutants released into the environment can cause contamination issues in soil and groundwater, with significant impacts on public health and the environment. In this regard, [13]explain that the degradation of organic matter in the body produces diamines such as cadaverine (C5H14N2) and putrescine (C4H12N2), which, after degradation, produce ammonia (NH4+), which is toxic at high

concentrations. Cadaverine and putrescine are also harmful as they contribute to the spread of infectious diseases such as typhoid fever and hepatitis..

The energy recovery from solid waste emerges as a promising alternative for power generation. Although it may be insufficient to sustain long-term strategies for expanding the national electricity supply, energy generation from solid waste is certainly an important component of regional or local strategies and should not be overlooked[14].

In particular, for energy generation, [15]clarify that landfill gas is composed of a variety of gases, some in significant quantities, such as methane and carbon dioxide, and others in smaller quantities. The extraction system, as explained[16], consists of horizontal and vertical drains, a blower, a filter for particulate removal, and a condensate separator tank. This pre-treatment has the effect of protecting the blower and increasing its lifespan.

The generation of energy through the capture of landfill biogas is efficient and beneficial because it combines a clean approach while adhering to UN decisions and the Clean Development Mechanism established in the Kyoto Protocol. By selling the biogas, economically beneficial carbon credits are generated, along with the environmental benefits of greenhouse gas reduction[16]. To be sustainable, solid waste management strategies should maximize energy and material recovery while reducing pollution and the amount of waste ending up in landfills [19]. However, the proportion of gas depends on the type of degraded material and other structural factors of the processing site. Methane fuel is used to power engines and generators. When fully burned, it can minimize air pollution and help reduce the greenhouse effect[20].

However, biogas from landfills can be used in three different ways: for heat production, electricity generation, or it can be purified to produce biomethane, which can be injected into city gas networks or used as a vehicle biofuel [21]. [22]detail some use cases for this energy, including heating furnaces, fuel for internal combustion engines, refrigerators, incubators, grain dryers, and various machinery. The intention is to "use biogas as a substitute for mineral-based gases such as liquefied petroleum gas and natural gas for household appliances.

However, several factors can hinder the implementation of biogas extraction systems. According to[11], the permeability of the landfill cover is one of the most important factors because, depending on its characteristics and climatic conditions, it affects both the uncontrolled release of methane (fugitive emissions) and the entry of atmospheric air (which impairs the anaerobic process in landfills). Additionally, the collection wells can also be affected by fluid accumulation (leachate), which affects the capture of biogas. These and other challenges have led projects to assume gas capture efficiencies between 60% and 85%, with an average of 75% commonly used.

Many government institutions have explored the possibility of forming alliances among municipalities for the construction of these systems, as it offers ease of supervision and benefits such as reduced operational costs, optimized use of equipment and labor, reduced land area usage, and potential reduction in environmental pollution[18]. Despite the Brazilian Government's Program for the Incentive of Alternative Energies (PROINFA) through Federal Law 10.438/2002, few biogas energy projects have been implemented in the country, most of which are under the Clean Development Mechanism (CDM)[13].

According to[20], knowledge of the landfill area, local technical support capabilities, and monitoring of the waste, liquids, and gases generated in its various phases are necessary for the adoption of environmentally, sanitary, and socioeconomically viable and sustainable solutions. This is important to avoid the potential environmental impacts of waste disposal, such as greenhouse gas emissions, vegetation destruction, generation of unpleasant odors, and the risk of explosions.

IV. Result and Discussion

The Manaus plant is a manufacturing facility of Electrolux located in the city of Manaus, in the state of Amazonas, Brazil. It is one of the company's main factories in Latin America, producing various types of household appliances such as refrigerators, freezers, and stoves. Electrolux is a company that has been dedicated to improving its performance in waste management over the years and aims to achieve "Zero Landfill" (ZL). Since 2012, the company has adopted a global sustainability strategy, which includes proper waste management as one of its priorities.

The Zero Landfill program aims to reduce the environmental impact of improper disposal of industrial waste through reduction, reuse, and recycling. The certification requires limiting the amount of waste sent to landfills and transforming a portion of it into energy. The initiative promotes a circular economy and strives to ensure sustainability in the industry. Electrolux's EHS (Environment, Health, and Safety) proposal encompasses measures to ensure environmental responsibility, occupational safety, and health in its activities. The company seeks efficient and sustainable solutions, promoting the safety and well-being of all involved, while also contributing to the sustainability and social responsibility of the company..

Electrolux's EHS policy for Latin America aims to prevent occupational accidents and illnesses, control environmental impacts, comply with standards and regulations, promote continuous improvement, and engage

employees, communities, and stakeholders. This policy reflects the company's commitment to operate in a responsible and sustainable manner.

In 2018, Electrolux set a goal to achieve "Zero Landfill" across all its factories by 2020. To accomplish this, the company has been investing in cutting-edge waste management technologies, such as organic waste composting, plastic recycling, and material reuse. By adopting more sustainable practices, there has been a significant reduction in the amount of waste sent to landfills, as well as the amount of waste destined for energy recovery. Furthermore, the company has been working on improving waste segregation and implementing more efficient waste management technologies, such as the stationary helical compactor for soft plastic, which has resulted in a 60% reduction in weekly waste collection transportation.

Another measure adopted by the company is the implementation of washable towels in the Maintenance process, which is an initiative that can help reduce the consumption of paper towels and generate less waste. Furthermore, washable towels can be reused multiple times, leading to financial savings for the company. The "Single Plastic Free" program is also an excellent initiative to reduce plastic consumption and promote sustainability. The reduction of disposable plastic usage can contribute significantly to the reduction of environmental pollution, especially in oceans.

In 2019, Electrolux reported that it had already achieved "zero landfill" in 14 of its 50 global factories. In 2020, the company announced that it had reached the goal of "Zero Landfill" in all its factories in the world.

Additionally, the company has been striving to reduce waste generation in its operations through energy efficiency projects and process optimization. Electrolux has also been encouraging its suppliers to adopt sustainable practices in their operations. By promoting sustainability throughout its supply chain, the company aims to further minimize the environmental impact of its products and operations.

As a result, it can be observed through Graph 1 that waste management had a rate of 91.03% in 2017, which decreased to 76.79% in 2018 and 76.56% in 2019. However, in 2020, this percentage increased significantly to 96.67%.

Since the implementation of the Zero Landfill Program, the company has achieved significant results in its waste management. With the adoption of more sustainable practices, there has been a significant reduction in the amount of waste sent to landfills, as well as in the amount of waste destined for energy recovery. Additionally, the company has been working on improving waste segregation and implementing more efficient waste management technologies, such as the stationary helical compactor for soft plastic, which has resulted in a 60% reduction in weekly waste collection transportation.

The plant has been adopting sustainable practices regarding the management of industrial waste, aiming to send a maximum of 1% of the waste generated in the production process to landfills and converting at least 3% of it into energy. Additionally, the facility utilizes renewable energy sources in its operations.

In light of this, training programs have been implemented to ensure the competence of individuals whose work can impact performance of the Zero Landfill (ZL) objectives. These programs are essential to ensure the competence of individuals working with waste management and who can influence the performance of the ZL goals.

These programs should include technical training related to waste management processes, such as separation, storage, transportation, and final disposal, as well as aspects related to occupational health and safety and environmental regulations and government regulations..

Furthermore, the organization has established effective internal communication procedures for the ZL program, allowing individuals to contribute to its continuous improvement.

The communication is clear, objective, and transparent, providing a comprehensive view of the objectives, goals, strategies, action plans, and achieved results of the program. It aims to promote a culture of participation and collaboration, leveraging the knowledge and experience of employees to identify improvement opportunities and implement significant changes that enhance operational efficiency and reduce costs.

To ensure the achievement of the intended results, the company has developed a clear and effective governance structure. Roles and responsibilities have been defined, necessary resources identified, and budgets and schedules allocated appropriately. The ZL program has been integrated into the organization's business strategy and aligned with its policies and values, making it an important strategic initiative rather than an isolated activity.

Furthermore, senior management maintains continuous monitoring of the ZL program's performance, evaluating the results against established objectives. This process allows for the identification of areas for improvement and the implementation of necessary measures to ensure the ongoing evolution of the ZL program and its contribution to the organization's success.

V. Conclusion

The implementation of the Zero Landfill Program in a manufacturing industry in the Manaus Industrial Pole (PIM) is a relevant initiative for promoting environmental and economic sustainability in the region. The presented case study demonstrates that the company has successfully reduced waste generation and final disposal in landfills through strategies such as recycling, composting, and reutilization.

Furthermore, the implementation of the Zero Landfill Program has also brought benefits to the company's image and reputation, as well as cost savings in waste management. The initiative showcases the company's commitment to sustainability and the environment, contributing to the construction of a more sustainable and responsible future.

By actively participating in the Zero Landfill Program and implementing sustainable practices throughout its production process, the Electrolux Manaus plant has emerged as a pioneering role model for other companies striving to meet international benchmarks for industrial waste management and attain certifications that validate the sustainability of their operations. Through its dedicated efforts, the plant has successfully reduced its reliance on landfill disposal, effectively transforming waste into valuable resources. This noteworthy achievement highlights the company's unwavering commitment to environmental responsibility and sets a compelling precedent for fostering a greener and more sustainable future.

Through the transformation of its waste into energy and the avoidance of landfill disposal, the company actively contributes to the reduction of greenhouse gas emissions and the preservation of valuable natural resources. This initiative serves as a testament to the company's unwavering commitment to environmental and economic sustainability, positioning it as a leader in the industry. By aligning its actions with these principles, the company not only enhances its image and reputation but also sets a powerful example for other businesses striving to meet international waste management goals and attain certifications that validate the sustainability of their operations.

Therefore, the Electrolux Manaus plant can serve as an exemplary model and a source of inspiration for other companies seeking to embrace sustainable measures in their operations. Its success in implementing environmentally-friendly practices and achieving significant waste reduction demonstrates the positive impact that can be made towards creating a more sustainable and responsible future for all. By following in the footsteps of the Electrolux Manaus plant, businesses can play an active role in mitigating environmental challenges and fostering a collective commitment to sustainable practices, thus ensuring a better world for generations to come.

The achievement of the Zero Landfill certification by the Electrolux Manaus plant, with its commitment to send a maximum of 1% of generated waste to landfills and transform at least 3% into energy, showcases the successful implementation of sustainable practices and the company's ability to serve as a role model for other businesses striving for sustainability in their operations. This certification highlights the plant's dedication to minimizing its environmental impact and maximizing resource efficiency. By attaining such recognition, the Electrolux Manaus plant not only sets a high standard for waste management but also inspires and encourages other companies to adopt similar sustainable approaches in their own operations.

Therefore, implementation of the Zero Landfill Program in transformation industries, such as the Manaus Industrial Pole (PIM) and other regions, is a vital strategy for promoting sustainability and mitigating the environmental impact of improper waste generation and disposal. By serving as a role model and inspiring other companies to adopt sustainable practices, the Electrolux Manaus plant contributes to the development of a more sustainable and responsible future. The initiative not only encourages environmental preservation but also helps reduce the adverse effects associated with improper waste management. Consequently, the implementation of the Zero Landfill Program in transformation industries becomes a pivotal approach to fostering sustainability and constructing a more sustainable world for the benefit of all.

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