International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-9, Issue-12; Dec, 2022
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.912.36

Sustainable Management of Organic Waste in the City of Vitória de Santo Antão, Pernambuco, Brazil.

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Received: 22 Nov 2022,
Receive in revised form: 15 Dec 2022,
Accepted: 22 Dec 2022,
Available online: 27 Dec 2022

***Keywords*— Organic waste. Biodigestion. Bioproducts. Circular economy.**

***Abstract*—** *Brazil produces millions of tons of organic waste per year, of which only 1% is reused, the rest is sent to landfills, burned, or released in the open, causing enormous impacts on the environment. Reverse logistics emerged as a promising alternative for mitigating potential impacts from the reinsertion of waste and co-products into production cycles, providing environmental, social, and economic benefits. The final disposition must consider environmentally appropriate alternatives provided for in the National Solid Waste Policy (PNRS), provided that the specific operational norms are observed to avoid damage or risks to public health and safety. Organic waste can also be used to generate bioproducts and electricity, contributing to economic development and environmental preservation. On the other hand, sanitary landfills have limited capacity, high cost and are usually designed for 20-year cycles. Based on these observations, the present work aimed to present sustainable alternatives for the proper destination and treatment of organic waste generated in the city of Vitória de Santo Antão-PE, with the possibility of producing bioproducts for agriculture and biogas for electricity, with a reduction of environmental liabilities generated from organic waste. A study was presented on the sustainable management of waste, seeking its reintroduction in the production chain based on the concept of circular economy and enabling a reduction of pressure on the exploitation of natural resources. This work has waste management guidelines with the possibility of adding value from the transformation of organics into energy and bioproducts, generating work and income. The municipality can become a sustainable hub that will serve as an example.*

I. INTRODUCTION

Public policies and society's concern with environmental issues have promoted companies' support for the implementation of environmental management systems in compliance with legal mechanisms that consider the need to minimize pollution problems.

Currently, in the face of severe natural disasters, there is a great concern of world leaders in search of alternatives for sustainable energy resources and with great potential for diversification of the electric matrix from the replacement of fossil fuels that are becoming increasingly scarce (BATISTA et al., 2021).

With the growing demand for energy, alternatives are sought for sustainable development such as the use of waste for energy purposes, minimizing the impact caused by emissions of polluting gases. Waste can be used for the

generation of bioproducts or intended for electricity generation, contributing to the environment (SILVA et al., 2018).

With the same socio-environmental concern, the use of waste to obtain products with added value has become a practice in several sectors of the economy. In view of the great problem of organic waste that has an economic and environmental character, it is necessary to develop alternatives for the reuse of the large volume of waste generated, in order to boost the productive activity in an economically, socially and sustainably more advantageous way, besides contributing to global needs. Thus, using waste as an energy source means a contribution to the social and economic development of Brazilian citizens (ZAGO E BARROS, 2019).

According to the National Association of Municipal Sanitation Services - ASSEMAE, with data published by the Brazilian Association of Public Cleaning Companies and Special Waste - ABRELPE, Brazil produces about 37 million tons of organic waste per year, of which of this total only 1% is reused and the rest is sent to landfills, burned or released in the open in order to cause huge negative impacts on the environment (ASSEMAE, 2019).

The National Solid Waste Policy (PNRS) was approved in 2010, with guidelines on integrated management and management of solid waste, the responsibilities of generators and public authorities and the applicable economic instruments. One of the most important aspects of federal legislation is to establish reverse logistics (LR) as an instrument of economic and social development, characterized by a set of actions, procedures and means aimed at enabling the collection and refund of solid waste to the business sector, for reuse, in its cycle or in other productive cycles, or other environmentally appropriate destination (BRASIL, 2010). On the other hand, landfills have limited capacity, high cost and are generally designed for 20-year cycles.

Studies have identified the opportunity to support the development of sustainable and integrated waste management in Brazil, with the adoption of mechanized recycling, anaerobic biodigestion and heat treatment of waste, providing subsidies and guidance to public administration agencies and offering business opportunities to its associates, in order to promote the viability of the energy potential of Municipal Solid Waste – USC and the social and environmental benefits that waste energy recovery projects have to leave to present and future generations. Biogas is highlighted for being a promising source of renewable energy, providing adequate treatment for organic waste and avoiding contamination of soil and water (VIEIRA et al., 2019).

Vitória de Santo Antão is a municipality located in the Zona da Mata of the State of Pernambuco, Brazil, located 46 kilometers from the capital Recife. According to the Brazilian Institute of Geography and Statistics (IBGE, 2020), the estimated population was 139,583 inhabitants, being the most populous municipality in the Zona da Mata. The city has several companies in all sectors of the economy, with an excellent industrial park.

Despite the accelerated growth, the municipality does not have a landfill, and it is necessary to transport approximately 100 tons of garbage daily to the city of Jaboatão dos Guararapes, which has a legalized landfill. This was the main reason for choosing Vitória de Santo Antão for a case study of the work, which aims to present a study on the sustainable management of organic waste, seeking its reintroduction into the production chain from the concept of circular economy and reduction in greenhouse gas emissions, aligned with sustainable development objectives (SDGs).

In Brazil, due to the approval of the regulatory framework that instituted the PNRS, reverse logistics and circular economy practices are still reduced. Although there are studies on the implementation of reverse logistics in different productive segments, the contribution in Brazilian cities is still incipient, which endorses the need for and importance of studies in this area (VITORINO, 2018).

The proposal is to offer sustainable alternatives for diversification of the energy matrix and reduction of environmental liabilities generated in cities from organic waste, and, consequently, reduction of greenhouse gas emissions. Organic matter is the predominant fraction in municipal solid waste, with a percentage of around 50% (ABRELPE, 2021).

This work aimed to present a study on the sustainable management of organic waste in Vitória de Santo Antão, municipality of the State of Pernambuco, seeking its reintroduction into the production chain from the concept of circular economy, enabling a reduction of pressure on the exploitation of natural resources. In addition, produce material with management guidelines and value aggregation from the transformation of organic waste into energy and bioproducts, expose proposals for good environmental practices that will allow an ecologically balanced environment, essential for a good quality of life, as well as acquire income from carbon sequestration.

II. METHODOLOGY

The present work was initiated with bibliographical research aimed at analyzing and knowing the theory to be applied, necessary for the presentation of the theme.

Bibliographies of books, newspapers, articles, monographs, dissertations, theses, projects, and legislations containing material describing organic waste management and its transformation into energy and bioproducts were consulted, aiming to obtain knowledge about the subject. The search platforms used were ScienceDirect, Google Scholar and CAPES Journals.

In the field research stage, for the collection of primary data, carried out between the years 2021 and 2022 in the municipality of Vitória de Santo Antão, aspects were identified and analyzed that would allow contributing to the efficiency of waste disposal and transformation in a sustainable way. Administrative documents with environmental reports and licenses, interviews with municipal actors and observations on field visits were used as data sources. At the end of the research, the necessary requirements for the proposals and evaluation of sustainable waste management systems and their reintroduction into the production chain from the concept of circular economy were defined.

The research was carried out inductively, starting from the regional reality for the formulation of explanatory hypotheses and planning of public policies aiming at the proper management of waste generated in the municipality. Standards and legislation, survey of alternatives and feasibility study were considered with the observation of social, economic, political, and technical aspects, in addition to environmental aspects.

The form of disposal of organic waste was evaluated by the population of the city of Vitória de Santo Antão, the form of recycling, as well as the final disposal of these residues, to present a proposal for the use of the waste generated to transform it into energy and bioproducts, involving concepts of circular economy in the region itself.

To be a consistent and sustainable methodology, the development of this work makes it possible to increase social opportunities and the viability and competitiveness of the local economy, increasing income and forms of wealth, while ensuring the conservation of natural resources.

III. RESULTS AND DISCUSSION

From the data obtained in the bibliographic survey, it was possible to propose an analysis of the main national and international references that consider the approach of both technical aspects, as well as social, environmental, and economic aspects, as well as the practice of waste management and the circular economy. Studies related to Brazil under the National Solid Waste Policy (PNRS) were analyzed in greater depth.

The survey carried out in relation to the urban organic waste of the city of Vitória de Santo Antão, presented generation numbers in the order of 100 tons per day, and these wastes were transported to another municipality in Jaboatão dos Guararapes, in the CTR Candeias Landfill. This transportation generates a high cost to the city. On the other hand, landfills have limited capacity, usually designed for 20-year cycles, and may make investment in the medium and long term unfeasible.

Anaerobic biodigestion has represented not only a waste treatment system, but a tool that leads to the rural environment the possibility of producing energy with low investment and little manpower, besides contributing to the preservation of the environment and reduction of greenhouse actions. Cost-benefit ratio and return on investment are key tools in decision making. Another important factor is the production of biofertilizer, an important intake used in agriculture.

This work presents a sustainable alternative to the destination and appropriate treatment of organic waste generated in the city of Vitória de Santo Antão, Pernambuco, Brazil, with the possibility of diversifying the energy matrix and reducing the environmental liabilities generated in the city from organic waste, and, consequently, contributing to the reduction of greenhouse gas emissions.

The theoretical and conceptual aspects about the dynamics of the absence of economic development in many municipalities serve as the basis for this proposal. Economic development and environmental preservation must be preponderant pillars because they contribute to the fight against social inequalities, violence, poverty, hunger, poverty, and environmental pollution. In this respect, developing efficient and practical methods add up to the individual needs of each location and add to a set. The production of biogas and biofertilizer, from organic waste, is becoming an increasingly important process with the production of renewable energy in the urban area and fundamental agricultural intake in rural areas of the countries, observed by the increase in the construction of biogas plants.

The objectives of sustainable development involve very complex relationships between the various dimensions of economic, social, environmental, technological, and institutional reality with processes and dynamics that are not always convergent and combined in time and space.

The model that relates pressure, state, impact and response makes it possible to evaluate the pressures exerted by the logisticactivity of destination of waste on the environment and society's responses to these changes, with the adoption of environmental and institutional policies that meet the longings of an increasingly conscious society,

focusing on the dimensions, environmental, technical, social, economic and institutional. In the study of this Dissertation, environmental indicators have the function of evaluating the management of urban and agro-industrial waste in Vitória de Santo Antão and identifying the alternatives for reinsertion of these materials in a production cycle of transformation and circular economy (VITORINO, 2018).

To constitute a new model where development is considered a vector of primacy, consists in the appointment of new administrative practices, aiming to implement socioeconomic, cultural, and environmental policies, ensuring that all necessary collections are made available for effective social and environmental transformation. These characteristics are related to public policies of solid waste in the states. The PNRS, coupled with other legislation, represents efforts in the implementation of sustainable waste management.

Each municipality has a territorial scale appropriate to the mobilization of social energies and integration of investments that enhance development, either by the small dimensions or by the administrative political adherence it offers, through the municipality and governmental body.

> Especially in the relationship between the economy and the environment there are strong structural constraints, which lead to the relationship of gains and losses, which hinders choices, forcing a path of slow maturation and demanding redefinitions of growth styles.

Table 1 of indicators was proposed as a tool for analyzing waste management and allows synthesizing data related to the environmental, technical, social, economic and institutional dimensions, and contains indicators that represent the most significant information, related to the proposed dimensions. The objective is to present a summary and an overview of the socio-environmental aspects of waste management in the municipality (MARQUES, 2020).

In the present research, data were elaborated based on the analysis of the statements collected through the interviews, as well as the documents provided, perspectives of legislation and technical literature allowed the adoption of technical, economic, and socio-environmental evaluation to analyze the systems of waste transformation and circular economy, proposed through the study of waste management. The method initially had as a reference framework of scenarios the implementation of the PNRS.

The environmental aspect shown in Table 1 refers to the existing legislation and the amount, disposal of waste and potential impacts with the preservation and conservation of the environment. Table 1 shows the technical aspect addressing issues related to the workforce, infrastructure, and technology in the biogas and biofertilizer production process. The social aspect, presented in Table 1, presents the indicators related to the satisfaction of human needs, the improvement of quality of life and social issues according to the circular economy and local development. The economic aspect listed in Table 1 considers investments in the production and management of waste in the municipality, considering the proper disposal and transformation into energy and bioproducts in a sustainable way. It considers the optimization of processes, economic viability, and application of circular economy concepts. In the institutional aspect shown in Table 1, indicators of legal framework and corporate responsibility in economic and socio-environmental actions were suggested (VITORINO, 2018).

Table 1 - Indicators of waste management in the municipality of Vitória de Santo Antão-PE.

ASPECT	DESCRIPTION	INDICATOR	KIND *	UNIT OF MEASURE
Environmental	Legal Aspects (legislation)	Legal mechanisms related to PNRS (laws, decrees)	P	Mechanisms (Organic Law; Environmental Legislation and Federal Law)
	Waste	Waste generation	P	Tons / day (100)
		Amount of waste	R	Tons / day (100)
		Disposal of waste	And	(X) Suitable ( ) Inadequate
	Pollution with the disposal of waste	Potential for human health contamination	I	(X) Yes ( ) No
		Potential for soil contamination	I	(X) Yes ( ) No
		Water contamination potential	I	(X) Yes ( ) No
Technique	Production	Waste generation	P	Tons / day (100)
		Waste treatment / processing	R	Percentage (100%)
		Use after transformation	R	Percentage (100%)
	Human Resources (estimate)	Qualified personnel to work in waste management	R	No people and Training (50)
	Infrastructure	Suitable for waste management	R	(X) Yes ( ) No
Social	Generation of work and income (estimate)	Generation of direct jobs	I	Direct jobs (50)
		Generation of indirect jobs	I	Indirect jobs (150)
Economic	Investment (estimate)	Cost of waste management in the municipality	P	R$ / month (R$ 200,000.00)
		Cost of waste treatment/processing	I	R$ / month (R$ 100,000.00)
		Investment in infrastructure and sustainable waste management	R	R$ 8,500,000.00
	Circular economy (estimate)	Reinsertion of processed waste bioproducts	R	Revenue R$ / month (R$ 450,000.00)
Institutional	Responsibility Socio-environmental	Environmental policy	P	Mechanisms (Organic Law)
		Environmental certification	And	Environmental certificate
		Actions developed - Social Responsibility (estimate)	R	Number of individuals attended (500)
		Actions developed - Environmental Management (estimate)	R	Number of projects served (10)

Source: Adapted from VITORINO (2018).

The Municipal Plan for Social and Environmental Development is a proposal that aims to promote new

opportunities. However, we must admit that sustainable local development is the process of social change and the elevation of society's opportunities, compatibilizing, in time and space, economic growth and efficiency, the integration of new technologies, environmental conservation, quality of life and social equity, starting from a clear commitment to the future and solidarity between generations. This concept contains three large, interconnected sets with different characteristics and roles in the development process.

a) the increase in quality of life and social equity are central objectives of the model of development, orientation and final purpose of all development efforts in the short, medium and long term.

b) economic efficiency and growth are fundamental prerequisites, without which it is not possible to raise the quality of life with equity in a sustainable and continuous manner, representing a necessary, although not sufficient, condition of sustainable development.

c) environmental conservation and the inclusion of new technologies are decisive constraints on the sustainability of development and long-term maintenance, without which it will not be possible to ensure quality of life for future generations and social equity in a sustainable and continuous way in time and space.

However, insisting on this agenda to contribute to significant advances for the municipality of Vitória de Santo Antão should be a daily task, establishing important dynamics, creating absolute tools and compatibilizing actions together aimed at local development. However, the compatibilization between social, economic, and environmental objectives becomes a concrete possibility with scientific and technological advances, a fundamental mediator of the relations of the economy and society with nature and with the environmental awareness of humanity. The combination of these factors allows a redefinition of the interactions between economic dynamics, social structure, and ecosystems, thus restructuring the development model itself. Environmental awareness provides political support for change, and technological innovations redefine and can moderate tensions between the economy and nature.

Thus, the Municipal Plan for Social and Environmental Development proposed here, consists of a transition to a new style of organization of the economy, waste management, society and its relations with work, foreshadowing a society with social equity. This transition from an unsustainable to sustainable style must, however, face and redesign the rigidity and structural constraints, which require time and transformative initiatives of the basis of the organization of society and the local economy, causing social vulnerabilities to decrease and contribute to income generation for the local community, associated with the Sustainable Development Goals (SDGs) in the municipality of Vitória de Santo Antão (FARIAS et al., 2022).

On the other hand, budget restriction in the Federal, State and Municipal spheres is a factor that limits the application of investments in the solid waste management sector. Demonstrating the concern with the efficient management of solid waste at the municipal level and aiming opportunities in the market with the circular economy, in accordance with the National Basic Sanitation Policy and the National Solid Waste Policy, as well as with the technicality, sustainability and economics, this work brings an approach with an operational management model of solid waste and its use for energy generation and biofertilizer in the municipality of Vitória de Santo Antão. The great social challenge is the inclusion of waste pickers in cooperatives with partnerships between government entities and developing actions based on indicators of social, environmental, technological, and institutional aspects. The municipalities have particularities (MARQUES et al.; 2020)

We know that local competitiveness is dynamic and selective and can both express the opening of gaps in international markets and the dispute for spaces in local markets, in the immediate and regional environment, in the segments of greater capacity and locational advantage. Not only to export and integrate globally, but to sell locally at prices lower than those of external products and in a selective and differentiated way, in addition to attracting investments and capital, it is necessary to build local and municipal competitive advantages, based on the potential in economic infrastructure, logistics, human resources, especially education and professional training and technological development as the matrix of this development and the demonstration of the need for more attention on the part of managers for this problem (ALMEIDA et al., 2017).

We can understand that if competitive advantages are created and built with investments and harness ing the potentialities and diversities of each locality, social actors have a fundamental responsibility for the promotion of local development. Municipalities are determining agents for the development of the local economy. Municipalities are responsible for various services or actions that can facilitate or hinder business development, the attraction and permanence of companies, in addition to offering incentives to support business expansion, provide education and training, support the development of small business owners and improve infrastructure maintenance.

The hypothesis of this proposal is to understand between needs, lack of opportunities and the contribution of available technologies to enable methods and works to be created, based on a collective initiative where objectives are common. Its relevance can be glimpsed by the characterization of the real situation of some municipalities, which suffers from the search for concrete, practical and innovative alternatives, with emphasis on the problems of the day-to-day life of families.

In the municipality of Vitória de Santo Antão, there is a predominance of small rural properties producing vegetables, with a family structure of production, especially the cultivation of fruits, vegetables and vegetables that supplies not only the local market but also the capital and other regions. In addition, a large amount of solid organic urban waste is generated by the permanent and temporary population.

Considering that the National Solid Waste Policy (PNRS) establishes as possible environmentally adequate technology of composting and biodigestion waste (BRASIL, 2010), it is possible and desirable to install in the municipality of Vitória de Santo Antão a plant for the treatment of organic solid waste for the generation of bioenergy and biofertilizer, seeking reintroduction in production chains involving circular economy and sustainable management. The installation of this system may bring as results the aggregation of value in the concept of circular economy with the total use of waste, being inorganic (cardboard, glass, plastic, metal, electronic) for recycling and organic for the generation of energy from biogas and biodiesel, in addition to the production of biofertilizer. This last bioproduct may involve local agriculture for plantations less dependent on chemical fertilizers, providing benefits to agribusiness and family farming in a sustainable way.

In economic terms, the estimated generation of electricity from the organic waste of Vitória de Santo Antão will benefit almost 4,000 families. In the field, the economic impact will be greater, with estimated production of 1,500 tons of biofertilizer and aggregation of R$ 4,500,000.00 in the rural area, benefiting local agriculture.

This proposal will also contribute to improving the quality of life of local communities, with the development of selective collections and development of industrial processes of transformation into bioenergy and sustainable bioproducts. A waste treatment and transformation plant could generate increased employment and income, since the forecast is that a project of this size will result in dozens of jobs, not counting the attraction of new business to the city, circular economy, decarbonization programs and increased municipal revenue. The proposal is perfectly characterized in terms of social, environmental, and economic sustainability, fundamentals of the triple bottom line. It will also contribute to the protection and preservation of the environment, since the result of the implementation of waste treatment and transformation system will be the generation of renewable energy and production of sustainable bioproducts (PEREIRA, et al.; 2018).

Therefore, the study of this work aimed to analyze the management of organic waste in the municipality of Vitória de Santo Antão and propose a sustainable management of these residues for the environment, a common good that interests all peoples without distinction.

The construction of social development in a broad project reinforces the need to intensify efforts to ensure satisfactory results at all levels. It is expected, in addition to the inclusion of a new model of solidary economy, local development as an innovative market platform, the growth of the formal and informal economy, the generation of new secondary opportunities, the inclusion of micro and medium-sized enterprises, the strengthening of the local economy and the expansion of the social economic process among all local spheres.

Thus, evaluating the results of this proposed innovation should be the subject of permanent discussion among all representative classes of the municipality of Vitória de Santo Antão, to improve the actions and ensure that the proposed results should be consolidated, as well as their importance attributed in each process applied to the Municipal Plan for Social and Environmental Development.

Despite being a movement of strong internal content, local development is inserted in a broader and more complex reality, with which it interacts and from which it receives positive and negative influences and pressures. Within the contemporary conditions of globalization and intense process of transformation, local development also represents some form of economic integration with the regional and national context, which generates and redefines opportunities and threats, requiring competitiveness and specialization around the problematic issue involving the National Solid Waste Policy and its proper and sustainable destination and/or transformation.

Even when external political or economic decisions play a decisive role in the socioeconomic restructuring of the municipality or locality, local development always requires some form of mobilization and initiatives of local actors around a collective project. Otherwise, it is more likely that the changes generated from abroad do not translate into effective development and are not

internalized in the local or municipal social, economic, and cultural structure, triggering the increase of opportunities, economic dynamism and increased quality of life in a sustainable way.

The sustainable management of organic waste in the municipality, seeking its reintroduction into the production chain from the concept of circular economy and enabling a reduction of pressure on the exploitation of natural resources, was the focus.

This work has guidelines for management and aggregation of value from the transformation of organic waste into energy and bioproducts, exposing proposals for good environmental practices that will allow an ecologically balanced environment, essential for a good quality of life, as well as generating work and income.

This Dissertation shows how the construction of a new concept of organization, where reverse logistics, work, income and the environment are priorities from the implementation of a Municipal Plan for Social, Economic and Environmental Development, with application of concepts in circular economy, and must meet the longings of local society, promoting a universe of opportunities and prospects for promising results, with regard to the consolidation of a local economic platform making the municipality a business center with sustainability and concerned with the environment.

IV. CONCLUSION

For all the above in the present study based on the methodology used, it is concluded that, although Vitória de Santo Antão is among the municipalities of Pernambuco with the highest economic growth, it does not perform a correct management of the waste generated by the population. All organic material generated is collected by collection trucks and transported to the Muribeca Landfill, located in Jaboatão dos Guararapes, Pernambuco, Brazil, resulting in a high financial cost spent by the municipality's government.

The absence of correct waste management carries risks to the health of the population that is exposed to various serious types of diseases. However, it is important to emphasize that solid waste has been the object of public policies and incentive to the execution of works, preparation of planning instruments, as well as the subject of many discussions mainly regarding the new approaches to appropriate technologies. The disposal in landfills, although properly within the established standards, has its problems and inconveniences.

Therefore, this proposition indicates sustainable alternatives for the final deposition of organic waste generated by the population, and by the agro-industrial processes of Vitória de Santo Antão, as well as the possibilities of power generation and bioproducts. The municipality can become a sustainable pole that will serve as an example to all outos.

To raise awareness among public authorities, private companies, and Victorian society about the importance of living in an ecologically healthy environment, is to educate to build a culture of valorization to the life and well-being of all.

ACKNOWLEDGEMENTS

To Technological Institute of Pernambuco.

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