Chapter 140

Critical analysis of the guandu river basin preservation through sustainable methodologies in combating the burning of solid waste

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ABSTRACT

Given the socioeconomic and environmental importance of the Guandu River in relation to the municipalities of the State of Rio de Janeiro, as well as its respective basin, the propagation of sustainable methodologies for its preservation becomes essential and indispensable for the continuous improvement of sustainable development and, consequently, of the quality of life of its population. Therefore, the present research shows methodologies that could be used in its surroundings, with the potential to provide the reduction or elimination of the practice of burning waste, promoting a Circular Economy, according to the principles predisposed in the Life Cycle Assessment. Works carried out by the company Ciclo Orgânico and the cooperative Coopideal were reported, which denote an excellent waste management, with the development of methodologies for selective collection, composting and recycling, enabling the increase in environmental awareness, social integration, source of income, providing vegetation composites, supporting the carbon footprint and maintaining a sustainable society. In addition, laboratory research was carried out in order to demonstrate a new way of managing organic waste, related to the use of biodigesters, making a 5.5 L benchtop (batch), having inside an elutriate of processed foods, added to waste of swine, in a ratio of 1:2 at the end of 30 days, there was a 70% methane contingent under ideal production conditions within 28 days and an amount of biofertilizer equivalent to the water ratio present in the biodigester, which is also an alternative source of income and enables the improvement of soil and flora quality.

Keywords: Burning Waste, Selective Collection, Biofertilizer and Recycling.

1 INTRODUCTION

The environmental degradation resulting from production systems and consumption models, shows a culmination with environmental crises, having as its genesis the second half of the 20th century [1] [2], with its predatory exploitation of natural resources, associated with an inadequate human management. The intensification of this process, in the last decades, has been presenting itself beyond the capacity of the public power to contain it [3] [4].

The disorderly growth of urban centers, the absence of public policies and the lack of environmental awareness have fostered the development of social problems of considerable negative impact, which have been increasingly frequent in Brazilian society, especially with regard to the inadequate disposal of solid waste [5] [6].

Solid waste is seen as a problem for modern societies, becoming visible, especially in urban areas, due to the large population concentration, enhancing existing environmental problems, as well as contributing to the emergence of too many, such as, damage to public health [7] [8].

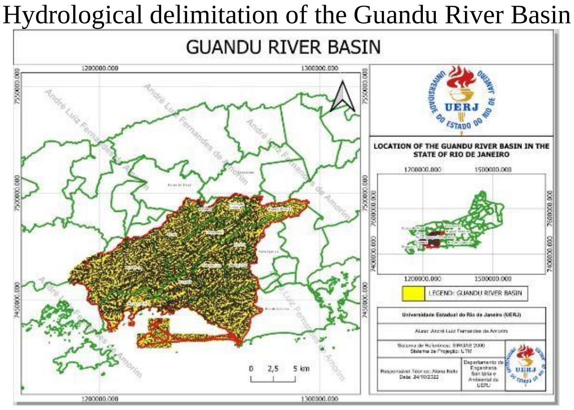
According to the State of Rio de Janeiro, despite the existence of solid waste management methodologies being a reality, such as the existence of sanitary landfills, its inadequate final destination is still a reality present in its various municipalities, bringing numerous socioeconomic and environmental damages [9] [10].

According to the Brazilian Institute of Geography and Statistics (IBGE), associated with data of the Intergovernmental Panel on Climate Change (IPCC) [11], currently in Rio de Janeiro, 83.0% of households have access to direct garbage collection, where 41.6% of garbage is burned and 8.9% burned inside properties, especially those around the Guandu River basin [11] [12].

The absence of environmental education [13] [14], of control methodologies and mitigation of the Guandu River, given the socioeconomic and environmental importance [15] [16], the negative impacts on the ecosystem and the current society, has become increasingly aggravating [17] [18].

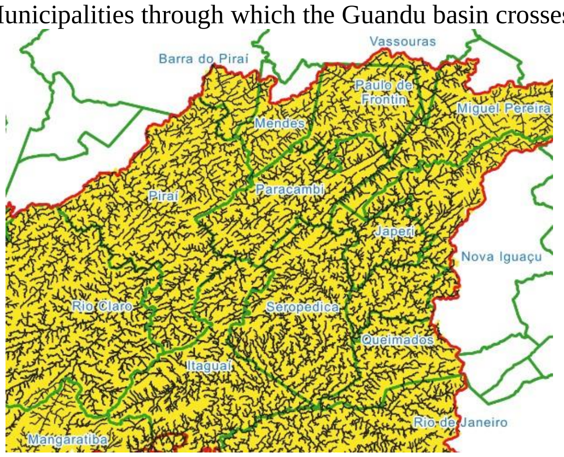
According to the mapping carried out during the research, the Guandu River basin crosses fifteen municipalities (Figure 1) [19], corresponding to Engenheiro Paulo de Frontin, Itaguaí, Japeri, Paracambi, Queimados, Seropédica, Mangaratiba, Mendes, Miguel Pereira, Nova Iguaçu, Rio Claro, Rio de Janeiro, Vassouras (Figure 2), and with its source in the Serra do Mar between Piraí and Barra do Piraí, having an exultation in the Bay of Sepetiba [19] [19].

Figure 1: Hydrological delimitation of the Guandu River Basin [19] [20]



The Guandu River and its tributaries, due to its process of environmental degradation by human activities, associated with the increase in global temperature, lack of rain, population contingent and deficit of sustainable systems, its water availability has been reducing, in addition to the emergence of Geosmina, considerable environmental indicator of the existence of Cyanobacteria [21] [22].

Figure 2: Municipalities through which the Guandu basin crosses [19] [20].



Furthermore, the extrapolation of the Guandu Basin as in Rio Claro and considering the transposition of the Paraiba do Sul River, 90% of the water in the Guandu River ends up suffering contamination from the Paraiba do Sul River [22] [23], which crosses 13 cities [19] [20] where only 21.88% of the sewage is treated, aggravating its contamination, which already suffers from impacts provided by the burning of garbage [21] [23].

In addition to energy generation, the Guandu River provides water supply to the metropolitan area of Rio de Janeiro, with flows in the order of 180 m^3/s, with approximately 148 m^3/s for water availability intended only to supply the metropolitan population of Rio de Janeiro [18] [24].

From this point of view, the position of contaminants in water courses and soil around the Guandu River, considering the local ecology and the society that depends on it, keeping a holistic look at the real and urgent challenges, within its socio-environmental and socio-economic importance, it becomes a matter of significant observance [20] [24].

The burning of residues from in natura garbage in the state of Rio de Janeiro contributes with 10.1% of the chemical compounds, of the 2235 g of equivalent toxicity (TEQ), produced in Brazil in 2008. On the other hand, there was a considerable increase between 2018 and 2020, alluding to an increase of 6.3% [25] [26].

Depending on the burning of garbage, the impacts on the soil and water resources are different, according to physical-chemical and bibliographic studies carried out on the main chemical components caused by the burning of garbage in the surroundings of the Guandu River Basin. The chemical compounds commonly found are Dioxins, Furans, Phthalates, Carbon Dioxide, Sulfur Dioxide, Mercury and Nitrogen Dioxide (Table 1) [27] [28].

Table 1: Impacts of chemical contaminants on ecosystems and human health [27] [28].

Chemical Contaminant	Effects to the Environment
Dioxins and Furans	Persistent pollutants settled in soil and water resources; Bioaccumulation and biomagnification along the food chain, causing different types of cancers in humans.
Phthalates	They impact human health interms of fertility, allergy and certain types of asthma. Usually found in surface water and in groundwater.
Carbon dioxide	They provide deleterious effects to human health and corrosive characteristics. They intensify the greenhouse effect, contributing to the rise in global temperature.
Sulfur Dioxide	They contribute to acid rain, increase the acidity of soil, rivers and lakes. It causes problems in the respiratory system of humans and promotes cardiovasculardiseases.
Mercury	It produces neurological problems and other negative impacts on human health and aquatic species. In the soil it reduces fertility.
Nitrogen Dioxide	Irritation of the nasal mucosa, damage to the lungs in humans. Cause of different types of cancers.

In addition to the information mentioned above in table 1 [27] [28], other considerations can be presented to better clarify the considerable impacts that such substances produced by the burning of in natura garbage can cause to the ecosystem and human health [29] [30].

Due to their mobility, soils and sediments, as dioxins are in food and drinking water, causing serious damage to human health, leading to skin problems, cannot change, nor attend to nervous, endocrine and reproductive functions [28] [29].

Carbon dioxide (CO_2), in turn, in addition to having

2 MATERIALS AND METHODS

2.1 SELECTIVE COLLECT

In the course of the research carried out for around a year, studies on the best management of solid waste became fundamental as an initial perspective for the proper management of solid waste [19].

The choice of selective collection as a preventive methodology for the burning of in natura garbage in urban and rural properties around the Guandu River basin, consists of a planned, organized and systematic action of sorting waste [33] [34], allowing the propagation of an environmental education and a correct analysis of the waste produced, for its future disposal [33] [35].

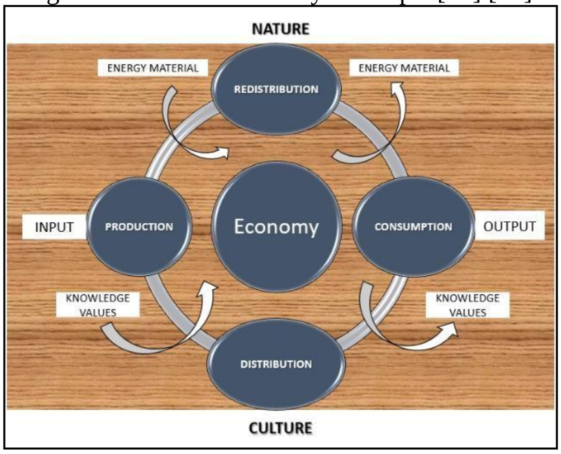
Through selective collection, a Green Circular Economy is promoted, within the concepts and principles predisposed in a Product Life Cycle Assessment [36] [37].

In this sense, the Circular Economy (Figure 3) represents a methodology that prioritizes a reduction, reuse, recovery and recycling of materials and energy, increasing the useful life of products, materials and resources, with a view to the economic model [36]. negative effects on human health and the intensification of the greenhouse effect, contributing to the elevation of the planet's temperature, provides "Sweet Corrosion", causing corrosion of metallic surfaces [31] [32].

Under normal temperature conditions, carbon dioxide does not exhibit corrosive characteristics, however, when dissolved in water, it forms carbonic acid (H_2CO_3), which, once dissociated into the aqueous form, triggers electrochemical reactions when in contact with metallic surfaces, covering the anodic dissolution of the metal and the cathodic evolution of hydrogen causing corrosion [31] [32].

Therefore, the present article has as objective, a critical analysis, associated with fieldwork and laboratory experiments of methodologies that corroborate the prevention of possible impacts caused to the Guandu River and its respective basin during the burning of solid waste.

Figure 3: Circular Economy Concepts [19] [36].



Demystifying the molds of the global economy, exposing guidelines and practices to decision makers, the green circular economy raises the productive potential, preserving a harmonious relationship with the ecosystem, improving the well-being of humanity, maintaining social equality, reducing impacts environment, increasing public and private investments, associated with increasing energy efficiency and sustainable use of natural resources [36] [38].

By means of the Life Cycle Analysis method, it is possible to monitor and demonstrate the interrelationships of the production stages, as well as their respective environmental impacts, providing a continuous improvement of the process, within the cause-effect relationship, for through reverse logistics [38] [39].

Reverse logistics, on the other hand, consists of an instrument of socioeconomic development, characterized by a set of actions, procedures and means aimed at enabling the collection and return of solid waste to the business sector, for reuse in its cycle or in other production cycles, or yet another environmentally appropriate final destination [38] [40]

Therefore, selective collection allows the promotion of reverse logistics, providing the correct separation of organic and non-organic waste, enabling the proper disposal of both [38] [40].

Consequently, this project aims to analyze methodologies already developed in Rio de Janeiro, whose results, which if applied to urban and rural properties around the Guandu River basin, could corroborate the absence or considerable reduction of burning of in natura garbage, with the respective prevention of the emission of contaminants [19].

It is with pleasure and privilege that this research brings the analysis of work carried out by two companies present in Rio de Janeiro, which provide a continuous improvement of the ecosystem and the quality of life of the current society, one referring to the composting process, and another related to recycling of non-organic materials such as plastics [19] [41].

The company Ciclo Orgânico, founded by Lucas Chiab (Figure 4), consists of selective collection and composting of organic waste from homes in Brazil, serving more than 4000 families in 25 neighborhoods of Rio de Janeiro and with 385,830 collections already carried out (Figure 5) [19] [41].

Figure 4: Compost Aeration process carried out by Lucas Chiab [19] [41].

The Ciclo Orgânico propagates the principle of Reverse Logistics [40] [41], through selective collection and composting, since once collected, the waste is taken back to the beginning of the production chain [39] [40], promoting the quality of life of society and the environment, with the production of biofertilizer, organic compost, in addition to other products, with bags and trash cans made of recyclable material [19].

Figure 5: Social integration carried out with society and coordinated by Lucas Chiab [41].

As didactic criteria, in composting there is an appreciation of organic matter, in an aerobic environment, where mesophilic and thermophilic bacteria act in association in phases, before the maturation stage, degrading the organic matter and converting it into humus, which is a waste stable, fertile, rich in nutrients and microorganisms [42], in compliance with the National Solid Waste Policy (PNRS), law 12305/2010 [43].

Bringing a new perspective to issues related to waste disposal in Brazil, prohibiting, among others, the burning of solid waste in the open, recycling, treatment of organic material and selective collection, the National Solid Waste Policy contains instruments for allow advances in the resolution of these with regard to waste management [43].

Once organic and non-organic waste are separated, they can go to recycling companies or cooperatives that provide the resumption of this waste at the beginning of the production chain, as with the Coopideal Cooperative, managed by President Ana Carla Nistaldo (Figure 6) [44].

The cooperative Coopideal, founded in 2011, participates in the Reverse Logistics program "Reciclar Brasil" [45], responsible for about 90% of the recycled material in the country, where the collectors are in the "recycling chain", with a number of more than 388 thousand individuals living as the main occupation, promoting environmental awareness within a recycling production chain [44].

Figure 6: Selective collection and recycling work carried out at the company Coopideal by Ana Carla Nistaldo [44]

The Coopideal cooperative promotes collection, weighing, sorting and processing of non-organic waste [44], for the subsequent return of post- consumer materials to the production chain [39] [40], minimizing environmental impacts with economic viability and cost optimization [36], associated with environmental education programs and consultancy, in the in order to create opportunities for raising environmental awareness in society [39] [44].

Generating dignity for waste pickers and spreading sustainable ideas for the next generations, Coopideal promotes social inclusion by encouraging sustainable practices [44] [45].

2.2 HOME BIODIGESTERS

The process of Biodigestion can be provided aerobically, as it occurs in composters mentioned above, and anaerobically, through biodigesters, these being divided into continuous models, receiving residue daily or every three days and batch, receiving residue every 60 days, with 80% of the tailings being used as biofertilizer and 20% used as inoculum for the next batch [38].

Being hermetic and impermeable equipment that receives organic residues, the biodigesters carry out fermentation of the organic material, within a certain detention time, generating biofertilizer and gaseous mixture products [46] [47], with higher percentages those referring to carbon dioxide (CO_2) and methane (CH_4) [38] [47].

A favorable environment for good Biodigestion, allows the proliferation of bacteria in the fermentation chamber of a biodigester, under criteria of temperature, pH, dilution ratio and a correct biomass carbon/nitrogen ratio [38] [48].

On average, the production time of biogas and biofertilizer in continuous biodigesters is 30 days and batch time is 60 days, but this production is directly related to the production criteria met and the size of the equipment [19] [38].

The present research carried out in the laboratory, aims to find an alternative management and adequate final disposal of organic waste associated with selective collection processes, in addition to composting, produced by the rural and urban population living near the Guandu River basin [19].

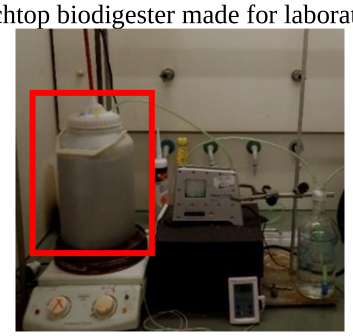
In the laboratory, tests were carried out with the objective of proving the efficiency of homemade biodigesters, providing not only an adequate contingent of biofertilizer, but also the production of biogas, understanding whether this production would be suitable for society [19] [38].

With a view to laboratory research, a benchtop biodigester (Figure 7), similar to a homemade biodigester was reproduced using a reagent container with a total volume of 5.5 liters (L), having opted for a Headspace equivalent to approximately 2.0 liters (L) [19].

As an initial preparation step, the 5.5 liters (L) container was filled, in a 1:2 ratio, with 1.5 kilograms (Kg) of swine waste for 3.0 liters (L) of water added to the elutriate from processed foods (900 milliliters of inoculum). After mixing, a space of 3.5 liters (L) was occupied, leaving 2 liters (L) of headspace [19] [38].

In order to control the pH (6.5 - 8), accelerate the reaction and increase the number of microorganisms in the residue sample present in the fermentation chamber of the biodigester, an elutriate of processed foods was prepared, in order to act as an inoculum of the reaction (900 milliliters), grinding pieces of potato, beans and soy meat [19] [38].

Figure 7: benchtop biodigester made for laboratory work [19].



Biodigestion, once started, will exhibit different temperatures at each stage of production, but all ranging between 30 °C and 37 °C, depending on the type of methodology adopted [49]. In order to avoid wearing out the cover, a fixed support, referring to a rubber tube, was placed with a 5/16 concave rubber washer (Figure 8), normally used for PCV sealing [19] [38].

In order to avoid gas leaks between the fixed support and the hole in the lid [49], the rubber washer was sealed at the ends with silicone glue. Consequently, a clamp (Figure 9) was also inserted, surrounded by two rubber washers of 20 millimeters (mm) of external diameter and 10 millimeters (mm) of internal diameter, reducing the gaps [19].

Figure 8: 5/16 concave rubber washer inserted between the fixed support and the hole in the lid of the container which is acting as a biodigester [19].

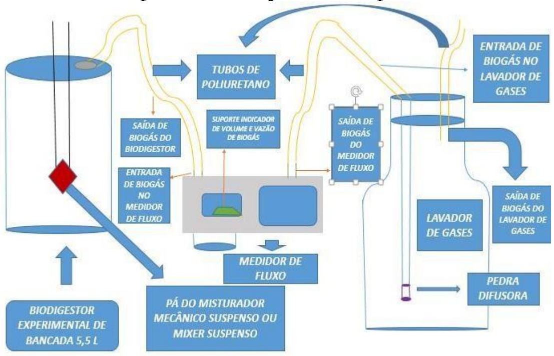
Generally, the pressures inside the biodigesters are usually constant. Its internal pressure is similar to atmospheric pressure, depending on the volume of biogas existing in the headspace [19].

Figure 9: Clamp inserted to prevent gas leaks [19]

Therefore, due to the possible pressures that may be caused to the biodigester, above the clamp and at its ends, hot glue was used as a safety measure [19] [49].

The polyurethane tube was connected to a flow meter (Figure 10), capable of measuring the volume and maximum flow of biogas [19] [49]. This, when transferred to the equipment, is analyzed by the erection of a small gate, moving to a gas scrubber, with the objective of raising the methane level, along the removal of hydrogen sulfide and carbon dioxide [50] [51] .

Figure 10: System developed for didactic purposes (image and schematic drawing), in order to reproduce the Biodigestion generated in a batch biodigester (beat), with the respective analysis of its products [19].



3 RESULTS AND DISCUSSION

As an initial perspective, the work of the company Coopideal exhibits a purpose, in which there is a prioritization of non-generation, including social integration with the collectors of the metropolitan area of Rio de Janeiro for the collection of non- organic waste [19].

At Coopideal, the members currently have the expertise to correctly dispose of the different materials they collect, such as plastic metals, paper, tetra pack, glass, electronics, cooking oils, among others, always with a view to preserving the ecosystem (Graphic 1) [19] [44].

In the course of the works observed in parallel amidst those previously collected by both companies, there was considerable success in the preservation of ecosystems [52] [53], providing the surroundings of the works with the promotion of sustainable harmonization [54] and, therefore, a Green Circular Economy [36] [55], as it concatenates economic development to adequate waste management, promoting manufacturing processes using recyclable raw materials [44].

Currently, Coopideal enables the development of social work with low-income children and alongside the families of the cooperative members

[44] [56]. In addition, it allows the collection of 71 thousand tons of non-organic waste per month, avoiding clogged drains, disposal in dumps, reducing the load in sanitary landfills and the proliferation of diseases or even increasing pollution [44].

Graphic 1: Waste recycled by Coopideal, in percentage, from 2018 to 2020 [44].

The projects developed by Coopideal are an ideal alternative to reduce the burning of waste in natura

[40] [55] , as it propagates environmental education among citizens, in parallel with the social projects developed, bringing benefits to those who participate in them [44] [54], helping to fulfill the objectives of sustainable development and continuous improvement of the ecosystem [39] [57].

However, according to the functions carried out by the Ciclo Orgânico company [41], the research observed, by the year 2022, the removal of more than 3000 tons of organic waste from landfills, converting more than 1800 tons of organic compost in 5 years of work [19] [41].

The actions promoted by the Ciclo Orgânico provide a stimulus for sustainable development, reducing more than 2200 tons of CO2eq and reaching 2537 CO2eq in 2022, currently counting on the participation of 40 professionals in the team working full time, composting in a mechanized way more than 300 tons of waste per month, developing an incredible social integration with the population [19] [41].

Currently with 2007 tons of compost produced, the company Ciclo Orgânico already has 1244 tons of composted vegetation, helping to reduce methane and promoting the development of forest biomass

[19] [41], demonstrating that simple attitudes can be a viable alternative to help reduce global temperature, in accordance with the United Nations (UN) sustainable development goals [57] [58].

With the perspective of a selective collection [33] [35], generating an adequate destination of organic waste and obtaining as a final product a high-quality waste [34] [40], the Ciclo Orgânico allows the maturation of a more accurate environmental conscience [41], leading to the replacement of retrograde thinking, not only of burning of in natura waste, but also the use of chemical fertilizers [56] [58].

Despite the inspiring work that the Ciclo Orgânico exhibits, it is always important to demonstrate other alternatives that can be promoted for the proper management of organic waste to develop a high quality biofertilizer [19] [41].

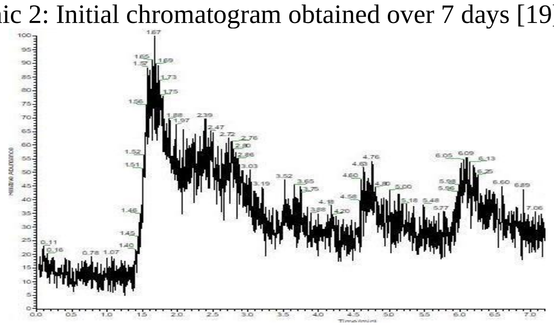
The composting methodology also allows the insertion of a more diversified number of residues [42], but due to the inevitability of larger areas compared to that present in biodigesters, in parallel with the reduced production of biogas, depending on the purpose, the Biodigestion panorama also ends up becoming attractive to society and a viable alternative to the problem of burning organic waste [38] [59].

It is important to note that the use of Biodigestion methodologies does not exempt the importance of those pertinent to composting, both help in sustainable development, boasting different products and advantages to society in each process [38] [42].

In order to understand the efficiency of the use of homemade digesters, in the production of biofertilizer and biogas, a laboratory experiment was carried out using a benchtop digester [38], made of disposable materials, keeping a perspective of material reuse [19] [51].

The analysis of the biogas in the laboratory was related to the production within 30 days [19]. Within 7 days (Graphic 2), the presence of other gases also resulted in the formation of carbon dioxide (CO_2), nitrogen (N_2) and hydrogen (H_2), with an ephemeral amount of methane (6%) and high amounts of CO_2 (> 40%) [38] [60].

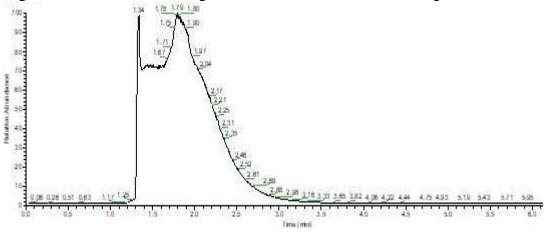
Graphic 2: Initial chromatogram obtained over 7 days [19] [60].



A final observation to this initial analysis was the considerable amount of nitrogen (Nitrogen) existing in the sample, described by the interval of 1.67 minutes (min), which is understandable, since nitrogen was used to expel the oxygen molecules from the Headspace [60]. of the biodigester and those constituents of the water used to start the Biodigestion (along with chlorine, if any) [60].

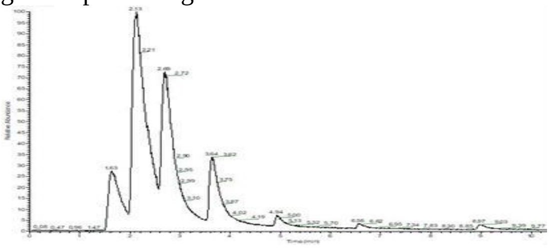
In fact, each stage denotes intrinsic emissions of chemical elements, with methane produced in amounts greater than 60% after 15 days (Graphic 3) of Biodigestion (Graphic 4), reaching its maximum at the end of one month (Graphic 5). Despite the use of swine waste [38], the production of hydrogen sulfide (H2S) was not high, showing a quota of 3% at the end of production [19] [60].

Graphic 3: Methane production over 15 days [19] [60].



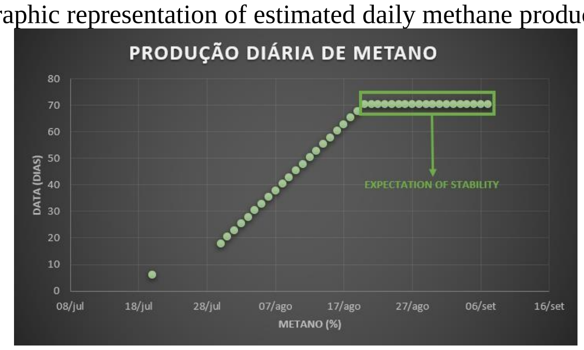
Considering the temperatures, the biodigester on the 28th day of production, denoted an external temperature (34.6 °C) and controlled internal pressure, with a metabolic temperature around 35.3°C [19] [38].

Graphic 4: Intrinsic chromatogram representing the behavior of methane after 20 days of production [19] [60].



Considering that in 10 days Biodigestion allowed an increase of 17.8% of methane, with approximately 2.5% per day, this reaches a level of 70% [38], in case of ideal production conditions, in the course of 28 days [19] [60].

Graphic 5: Graphic representation of estimated daily methane production [19] [60]



However, since the biodigester made was analogous to a batch model, the amount of biofertilizer in liters produced in the fermentation chamber was equivalent to the amount of water present in it, relative to 3.5 liters [38] [61].

Odorless, the Biofertilizer (Figure 11) present in the fermentation chamber exhibited a considerable amount of nutrients and microorganisms [61], being able to contribute to the health of the flora and its nutritional balance, increasing its resistance, vitality, improving the growth of cultures, producing healthy foods, raising the quality of the soil [62] [63] and can come to represent an alternative source of income, concerning the sale of the product [38] [41]

Figure 11: Biofertilizer produced in the fermentation chamber of the Benchtop Biodigester [19] [38].

In the soil, the biofertilizer minimizes the leaching of salts, favorably altering the structure and porosity, maintaining the diversity and balance of microorganisms in its structure [64]. The macronutrients and micronutrients, absorbed by the plants, provide increments to the diversity and richness of the edaphic fauna, with the production of springtails, which are also environmental indicators of soil quality [38] [65].

When correctly dosed, biological fertilizers raise the pH of soils, correcting them to values ranging from 7 to 8, improving the Cation Exchange Capacity (CTC), biological fertility and supporting their mineralization processes, through nutrients and microorganisms. present in its composition [66] [67].

4 OTHER PERSPECTIVES

There is no doubt about the impacts that the total burning of in natura garbage can cause to the ecosystem and the health of the current population in society [68] [69], however some materials, such as furniture and upholstery, are not completely burned during combustion [70].

When sent to the river, associated with other negative impacts generated by anthropic sources, the materials that were not completely burned [70], provide, among others, clogging the galleries, corroborating the contamination of the rivers by the materials that compose it, with possible destruction of the fauna and flora [71] and respective proliferation of disease vectors, such as dengue [72].

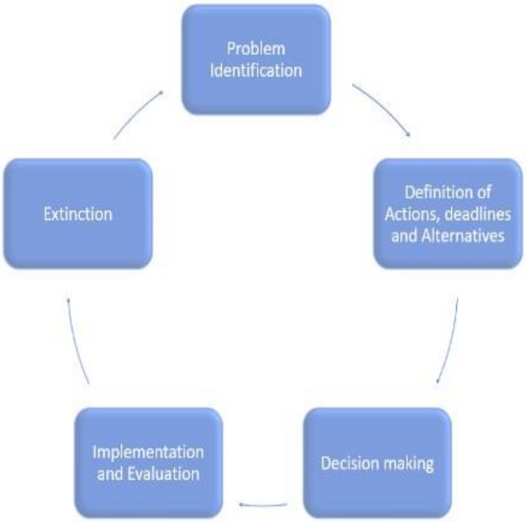
Although this project is based on waste burning prevention methodologies, in order to raise environmental [72] or situational awareness [74] and provide an improvement in the population's quality of life, proposing its uses for homes around the Guandu River basin, another aspect can be addressed, concerning the solid waste that is already in it [19] [75].

In this sense, public policies are relevant in combating the decontamination of the river by different anthropic sources, mainly concerning the burning of waste. Furthermore, they consist of accomplishments carried out by municipal, state and federal governments and their respective institutions in order to preserve the rights of citizens provided for by law [76] [77].

Giving opportunities to improve the quality of life in society, public policies guarantee the common well-being [77], such as the National Environmental Policy (Law No. 6,938/1981) [43], aiming to ensure socioeconomic development, national security interests and protection of human dignity, seeking the preservation, improvement and recovery of the environmental quality necessary for life (Figure 12) [75] [77].

Once policies are in place that enable the social and sustainable development of a region, life in society in the face of the interaction between man and ecosystem becomes viable, fostering sustainable harmonization [73] [74], with rules and laws originating from environmental law, commanding action of governments and the conduct of individuals, in a clear and dynamic way, as an instrument of direct democracy [77] [78].

Figure 12: Public Policy Cycle [76] [77].



In order to reach all social classes, public policies exhibit a development cycle with the perspective of facilitating the evaluation of resolutions, as shown in figure 12 [76] [77]

In this context, this cycle also supports the development of those that would enable the preservation of ecosystems, with the respective debates on environmental planning, the propagation of information on the questioning of influences on the environment and the maturing of the environmental perspective [76] [77].

Therefore, political will becomes an essential tool in combating pollution at different scales, especially with regard to improving the Guandu River ecosystem and its respective basin, through the enactment of laws that allow the emergence of public and private investments to the development of methodology for the prevention and control of ecosystem pollution [76] [77].

Despite the challenges to be faced, there are some considerable advances in protecting the environment [73] [78], such as the bill in progress in the city council in the State of Rio de Janeiro (n°

893/2021), created by councilor Celso Alves Costa, which aims to install ecobarrier systems (Figure 13) in the hydrographic network that cuts through the city of Rio de Janeiro [79] [80].

Law No. 893/2021 will aim to prevent the advance of floating solid waste, which can generate disorders such as floods and flooding, using collection networks at strategic points defined by previously carried out studies, with respective warning systems with danger siren of the arrival of heavy rains and floods that cross the city of Rio de Janeiro [79].

Figure 13: Low-cost ecobarrier built in Paraná [80].

Finally, it is possible to say that the creation of eco- barriers [79] [80] and other projects to protect water bodies and other ecosystems [41] [44] are an excellent tool in waste control, especially for areas around the Guandu River basin, whether caused by incomplete combustion or from other anthropic sources [19] [80].

5 FINAL CONSIDERATIONS

The problem of poor waste management has an increasingly frequent panorama in Brazil, despite the existence of sustainable methodologies for its proper final destination. Furthermore, the burning of solid waste provides a significant source of substances with considerable impact on ecosystems, temperature rise and human health.

The proper treatment and processing of waste allows an advantageous final disposal against the scenario of rising solid waste. Fostering sustainable systems and methodologies, increasing environmental awareness and implementing a Circular Economy in society, in accordance with the principle of Life Cycle Assessment, establishes a respectable scenario in sustainable development, with good prospects.

Given the importance of the Guandu River and its particular basin, the continuous and growing practice of complete or incomplete combustion of waste poses a remarkable risk to the population of the State of Rio de Janeiro, providing opportunities for the emergence of diseases and increasing damage to the environment, in addition to of global temperature and direct and indirect negative impacts on aquatic and terrestrial ecosystems.

From the point of view of prevention and environmental protection, this research demonstrated the merit that solid waste management methodologies, such as selective collection, composting, Biodigestion and recycling, have in order to prevent or eradicate the practice of burning solid waste and respective raising of awareness. society's environment.

In fact, the selective collection methodology can be considered an initial procedure in the waste management and planning process, since its development provides the promotion of a Circular Economy, in accordance with the principles and concepts predisposed in the Life Cycle Assessment and, therefore, in the dissemination of reverse logistics.

The other methodologies are consequences of the proper application of the techniques present in selective collection, having their results, such as obtaining biogas, recyclable products, biofertilizer and other organic compounds, as a source of income for society, but it proposes a continuous improvement of the quality of life. and the current ecosystem, even contributing to the prospect of carbon credits.

Both companies surveyed in this study showed respectable results in terms of solid waste management, promoting social integration, sustainable development, alternative source of income, turning liabilities into assets and considerably reducing impacts on the environment.

With a view to promoting Biodigestion, whether anaerobic or aerobic, it allows for an advantageous final disposal in view of the increase in solid waste, acting in a simple and efficient way in conjunction with pre-existing waste management methodologies.

Biodigestion has a relevant scenario for the sustainable development of a country, with good prospects, inclusion and scientific technological promotion.

As a flexible technology, the biodigester can adapt to the needs of society, and, consequently, it is an adequate process for improving the quality of soil and flora, providing the circulation of wealth and generation of energy, due to the amount of biogas produced in the course of the process.

According to results obtained in the laboratory, the biodigester produced provides a contingent of biofertilizer equivalent to 3,5 L, making it possible to reach pH neutrality levels ($pH = 7.0$), increasing the CTC ($CTC \geq 50$ %), reducing leaching nutrients and providing their fertility

The nutrients present in the biofertilizer, associated with a contingent of organic matter and microorganisms, allow for greater water retention, reducing water stress and enabling soil moisture levels above 35% and below 50%.

Depending on the Biodigestion methodology, based on the data and information obtained in the research, the relevance of its application was perceived. Under ideal conditions, it provides solutions for energy deficits, helps in the remediation of contaminated environments (soils) or provides the preservation of ecosystems, stimulating and promoting the sustainability of a society or country.

Therefore, to solve the problem related to the burning of residues in the surroundings of the Guandu River basin, the methodologies presented proved to be with considerable success in terms of obtaining results, denoting an adequate perspective for the promulgation of sustainable cities and in the impulse for the improvement of the population's well-being.

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