International Journal of Advanced Engineering Research and Science (IJAERS)
Peer-Reviewed Journal
ISSN: 2349-6495(P) | 2456-1908(O)
Vol-9, Issue-7; July, 2022
Journal Home Page Available: https://ijaers.com/
Article DOI: https://dx.doi.org/10.22161/ijaers.97.26

Waste Management in Brazil and Implications of the Most Applied Techniques in The Management Process

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Received: 10 Jun 2022,

Received in revised form: 08 Jul 2022,

Accepted: 14 July 2022,

Available online: 25 July 2022

***Keywords*— Environment, Management, Waste.**

***Abstract*— *Objective: this work aimed to investigate aspects of waste generation in Brazil and the main waste management techniques that are reported in the literature. Methodology: the methodology used comprises a literature review, where recent works were used in order to expose the current scenario of the Brazilian context, as well as waste management techniques used more widely. Results and Discussion: through the information collected, it was possible to note that Brazil has a high generation of waste, with about 216 tons per day throughout the national territory. In Brazil, the most used form of management refers to the use of sanitary landfills, however, landfills require complex management, in addition to a grandiose strip of land. In this way, solutions such as incineration can contribute to waste management both in Brazil and in the world, since it considerably reduces the volume of wa-ste. Other alternatives reported in this study include bioremediation, recycling and composting. It is also noteworthy that re-cycling, despite being a highly effective method, leads to severe contamination problems, which makes the plants need to have strict controls for cleaning and care, avoiding the contamination of employees. Final considerations: several measures can be adopted, but they must consider the context in which the cities and the respective State are located, in order to obtain lower costs and greater efficiency.*

I. INTRODUCTION

In recent years, pollution problems have increased significantly both in magnitude and in diversity, leading society to warn about such complications and become aware of their potential scratchs. Ribeiro and Mendes [1] and Liden et al. [2] report that issues related to different issues related to contamination and degradation of the environment have become increasingly important in the lives of the world's population, resulting in the changing certain paradigms related to the use of natural resources, waste disposal and the need to rethink consumerism. As a result of the social pressure generated, decision makers are expected to demonstrate a growing political will to solve problems, working together with solidly trained experts who need to offer solutions [3]. Currently, subjects on this subject are found in practically all the media, which, in a way, helps to form the population's opinion about this setback. However, although they help in the promotion of knowledge and forms of "rational" use, these media do not provide a formal culture on the subject, which often leads to the adoption of solutions that, although popular, are not always adequately technical, economically and socially viable. In order to propose solutions that not only "sound good", but that can be put into practice and, above all, that improve and preserve the environment, it is necessary to have, among other characteristics, a good technical knowledge of both the problem and the options for solutions. suitable. It is necessary to document experiences about problems that occurred and how they were solved to take advantage of this knowledge [4].

Waste and its management are environmental vectors on which it is possible to carry out specific actions that do not involve great efforts, and which, in turn, provide a high environmental benefit. Commercial establishments such as markets, for example, begin to integrate environmental measures into their daily lives, establishing new strategies that favor the improvement of the image and greater competitiveness in the sector. In this sense, commercial establishments, in partnership with public bodies, whenever possible, play an important role in adopting measures that contribute to improving the management of the waste they generate, without losing the quality of their service [5].

Another factor that makes the relevance of the topic perceptible is the creation of laws that specifically deal with waste management in Brazil, such as Law 12.305/2010 (National Solid Waste Policy), which provides guidelines and observations on how to the handling of these materials, their destination, disposal and recycling should be carried out, mainly considering the reduction of the environmental impacts caused by these residues. Therefore, the present work aims to describe the main waste management models that are used in the world, in addition to understanding the intrinsic aspects of each process, its advantages and disadvantages [6].

Solid waste management is understood as a system that includes cleaning, collection, selection, transport, final disposal and use of community waste [7]. However, most Municipalities only partially and moderately cover the processes of collection, transport and final disposal of generated waste. From the 1970s onwards, the adverse impacts on health and the environment produced by urban solid waste began to become evident, and they do not undergo adequate management. Solid waste generated in Brazilian municipalities, in most cities, does not receive adequate treatment, being collected by truck and later taken to sanitary landfills, where they are deposited.

One feature that highlights the sector's problem is due to the fact that landfills are reaching their maximum capacity in several regions [8]. This is because not all cities have the technical capacity to create and manage their own landfill; so, sometimes, a landfill receives waste from several cities, requiring an optimized management that avoids soil and groundwater contamination, as well as meets safety prerequisites.

In view of this, for good waste management, it is also necessary to adapt the process of transporting this material from a city to a more distant landfill. This transport is commonly carried out in non-specific trucks, where this material, compacted, is transported with minimum safety conditions, which may bring a risk of contamination in cases of accidents or fire, depending on the residue and the weather conditions at the time of transport.

Based on this context, it becomes relevant to know and discuss the most recent techniques used in waste management that can be applied to the Brazilian context, indicating alternatives to reduce the generation of solid waste, its destination and recycling measures, whose final objective is to minimize environmental impacts and reduce the volume thrown into sanitary landfills.

In view of the above, the present work aimed to investigate aspects of urban solid waste management in Brazil, as well as to identify the most modern solid waste management techniques that are being applied in different contexts, pointing out alternatives that aim at environmental preservation and reduction volume of waste thrown into landfills and into the environment.

II. METHODOLY

A narrative and critical review of the biomedical literature was carried out. In the SciElo, Scopus, Web of Science, google academic, CAPES periodical databases. We used articles published in English, Spanish, French and Portuguese from the last ten years were searched.

III. SOLID WASTE MANAGEMENT

The substantial increase in the generation of urban solid waste, due to the population growth of consumer societies, has constituted a major environmental problem. The collection and final disposal of this waste become a problem that is difficult to solve, with consequent risks of soil and surface and underground water pollution, with implications for the quality of life of the population [9]. The model of economic and social development adopted by most countries since the Industrial Revolution, based on the strong expansion of household consumption, stimulating industrialization and generating employment and income, accelerated the process of depletion of natural resource reserves, putting jeopardize the stability of terrestrial ecosystems. Solid waste management is a worldwide problem for big and small cities. Factors such as population growth, population concentration in urban areas, inefficient development of the industrial and/or business sector, changes in consumption patterns and improvements in the standard of living, among others, have increased the generation of solid waste in cities. The steps that constitute the management of this solid waste are: generation, storage, collection, transport, transfer, treatment and final disposal [10]. The international report released in 2016 by the United Nations Environment Program (UNEP), the Global Waste Management Outlook, estimated that 2 billion tons of waste are produced worldwide and that almost 50% of these are not disposed of properly. proper. With regard to the importance of the high generation of solid waste and its inadequate management, there are the consequent environmental and health problems, which have been accentuated in recent years due to the increase in population and production and consumption patterns. Garbage not only generates an unpleasant image in the countryside and in cities, but also contaminates the soil, water and air and, due to its confinement, occupies large spaces, which is why it has become a social and public health problem [11].

Solid waste management comprises all functional or operational activities related to the handling of solid waste from the place where it is generated to its final disposal [12]. According to the deposition and type of waste, different techniques are used for waste management. They can vary from person to person, from place to place, and from country to country, since the technologies involved in the processes must be considered, as well as the existence of trained professionals to perform the related tasks. In Brazil, more than 50% of solid waste generated in households is organic. Such a profile is typical for countries with large agricultural production and food waste, and decentralized composting is an option increasingly considered to address such waste. In addition to reducing the volumes that would be disposed of in landfills, it reduces the demand for transport, impacts to the environment, among others, being an environmental education tool [13]. The National Solid Waste Policy (PNRS) has as one of its objectives the observance of the following order of priority: "Non-generation, reduction, reuse, recycling and treatment of solid waste, as well as the environmentally adequate final disposal of waste" [14]. It structures a whole set of scaffolding on which the reconstruction of everything related to the sector must be supported, until now, matters very disseminated in the multiplicity of official entities. The PNRS is theoretically based on a practical and coherent guiding philosophy, which should provide the basis for sectoral planning and management that includes, as a reason for being, the protection of the environment and its resources and that of communities, all within a framework geosystemic and integrated. The Diagnosis of Urban Waste Management – 2015, compiled by the National Secretariat for Environmental Sanitation of the Ministry of Cities, revealed that, of the 77,997,025 tons of waste that arrived at some processing unit (landfills, controlled landfills, dumps, sorting, etc.), only 0.3% was directed to existing composting units in the country [3] [15]. In this context, the integrated and sustainable management of solid waste must start from the premise of avoiding, as much as possible, the generation of waste. When it is not possible to carry out this action, the waste that has been generated must follow an order of priority: be reused, recycled, treated and disposed of. Therefore, the act of disposing of waste is considered the last option, and only what is rejected should be landfilled, that is, everything that could not be recycled or treated [16].

IV. SANITARY LANDFILE

Landfills are an important part of any municipal waste management system, irrespective of other waste disposal solutions used. Even cities that recycle much of their waste, or rely heavily on incineration, need to deposit residual ash in landfills. Landfills are mature and proven waste management techniques. However, they are still quite uncommon in some low- and middle-income countries, due to the costs involved in infrastructure and operation and inadequate regulatory oversight. In these areas, it is very common to find uncontrolled or open-air dumps without basic environmental controls, putting public health and safety at risk [17]. Worldwide, nearly 40% of all waste discarded goes to some type of landfill. The rate is even higher in upper-middle-income countries, at 54%. Along with open-air landfills at 33%, landfills are the most common form of waste disposal. They require a design (as opposed to open dumps) and must be constructed and operated with care to ensure they do not create problems that threaten human or ecosystem health [18].

A properly designed landfill includes an area of land with an impermeable lining at the bottom. The coating prevents liquid contaminants (leachate) from coming into contact with groundwater (aquifers) and seeping into the soil. Slurry forms from moisture from garbage or rainwater that flows into the landfill, and must be collected and treated. In a well-managed landfill, waste is compacted to save space; a covering material is applied over the waste regularly to control odor, spread litter and other nuisances; and gas control systems are used to capture flammable landfill gas that forms as organic material decomposes within the landfill [19].

Several aspects must be considered and one of them is the landfill capacity. Landfills are generally built to last approximately 30 years; however, they must be scaled to account for anticipated changes in local waste generation levels as the population grows or household income levels increase. Ideally, the plan should create and fill a cell every 18 months – 2 years before it is closed and used as a landfill gas for energy [19].

The location of a landfill is geographically isolated from residential areas, airports and drinking water aquifers. Depending on the area served by the landfill, proximity to railway lines or roads capable of handling heavy truck loads or volumes may be required. The selected site must be evaluated by engineers and geologists to ensure low risk of floods, earthquakes and landslides. Access to a regular supply of roofing material is also critical. Communities near the selected site should be consulted to understand and address their concerns before the facility begins operating. Some communities may need to be resettled once a site is selected, and must be compensated for any loss of land, livelihoods or cultural identity caused by the settlement [20].

Landfill life can be extended if recyclables and organic materials are removed or recovered before the waste reaches the landfill, and will likely result in lower costs. This can be done at the community level, at a materials recovery facility, or at the landfill itself. Landfill operators could benefit from partnering with waste pickers at the landfill site to ensure that these materials can be diverted, and must ensure that livelihoods are not displaced without making alternative provisions for them [21].

In order for a landfill to function properly, specialized labor is required, in addition to equipment that reduces the use of masonry tools or utensils, such as: pneumatic wheelbarrows, shovels, pickaxes, hoes, bars, wood compactors. In addition to forks or rakes and roller-compactor. The number of these tools depends on the number of workers, which in turn depend on the amount of solid waste to be buried in the landfill. In the transport of covering material or waste, in the cells already built, it is recommended to place some boards on the surface of the landfill, in a linear way to facilitate the movement of the forklifts, especially in the rainy season, thus improving the performance in the operation [22].

In manual landfill, as the name implies, all operations are based on work performed by workers from the municipality or the community. The number of workers needed depends on the amount of solid waste to be buried, the weather conditions and the form of construction of the landfill, among others. It is also necessary to have a cleaning manager or supervisor who has the necessary knowledge to direct this work in constant operation [23].

Unlike manual landfills, mechanized compaction landfills are the appropriate technology for medium and large municipalities, which produce a daily amount of garbage that would not be feasible to be handled entirely by hand. Generally, one or two compactor tractors work in the mechanized landfill to carry out the work of placing, compacting and covering the waste; and the excavations and transport necessary for the supply of new roofing material [24].

Maintenance work can be done manually or with the support of machines, depending on the availability and need of these machines (for example, digging ditches manually or with a backhoe), thus aiming to obtain the greatest efficiency of the respective landfill [25].

Advantages and disadvantages

Below (Table 1) some advantages and disadvantages are mentioned in relation to the implantation of the sanitary landfill as a form of waste management, being one of the most convenient alternatives for Brazil. Siqueira and Assad [26] emphasize that it is essential to allocate adequate financial and technical resources for their planning, design, construction, operation and maintenance. Despite many advantages, the landfill also brings with it several disadvantages that make its implementation demand a high level of specialization and care. The first disadvantage to be mentioned, as shown in Table 1, refers to the acquisition of land, which constitutes the first barrier to the construction of a sanitary landfill, due to the opposition that arises from the public, caused in general, according to Lima et al., [27] by factors such as, for example, regarding the generation of landfill gases and leached liquids, as caused by the biological decomposition of degradable organic matter, chemical oxidation, decomposition and transport of organic materials and inorganic due to the action of infiltrated water and existing percolation, movement of the material by molecular diffusion, differential settlements, etc. If not well managed, people who live around the landfill suffer the consequences of bad smells, birds, percolating liquids, increased traffic of collection trucks and so on.

Table 1 - Advantages and Disadvantages of Landfills [27.]

Advantages
•Initial capital investment lower than necessary to implement any of the treatment methods: incineration or composting; •Low cost of operation and maintenance; •Economic advantages for the Municipality, because with the proper management of the sanitary landfill, the land can be used to the fullest. Waste compaction and planned construction increase landfill life and allow for longer land use; •Better protection of the environment (drainage and treatment of leached water, gas drainage through chimneys, waste cover) avoids the problems

of incineration ash and non-decomposing material in compost; •Less nuisance and pollution for citizens: proper management starts with the selection of land for the landfill, which should not be close to inhabited places, however, when a landfill is well managed, it can be close to the urban area, thus reducing the transportation costs. And facilitating community oversight; •Greater safety for workers (defined slopes, compaction of garbage, lower risk of falling waste, less contamination in the work environment); •It allows the recovery of methane gas, which is an alternative source of energy. •It allows the recovery of land considered unproductive or marginal, making it useful for the construction of a park, leisure area, sports field, etc.; and •It is flexible in that it does not require permanent and fixed installations, and also because it receives larger amounts of additional waste with little addition of personnel.
Disadvantages
•Lack of knowledge about the sanitary landfill technique; •The term "sanitary landfill" is associated with "open dump"; •The evident distrust of local administrations; and •The rapid urbanization process that increases the cost of the few available land, having to locate the sanitary landfill in places far from the collection routes, which increases the transport costs.

Finally, through the information presented, it can be said that the implementation of the sanitary landfill is highly conflicting both in terms of approval by the authorities and in the perception of citizens, and can be an interesting management alternative when implemented in conjunction with other forms of management as the recycling process.

V. RECYCLING

Recycling consists of reusing the solid waste generated in order to obtain from them a raw material that can be incorporated directly into a production or consumption cycle. It is an activity that involves the use of energy to obtain new products in a recycling plant. The importance of recycling can be associated with mitigating indiscriminate cutting of trees, reducing air, water, and soil pollution and, ultimately, living on a pollution-free planet [28], involving a series of steps to in order to give the proper destination, as shown in Figure 1.

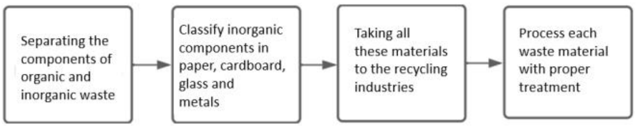

Fig. 1 – Stages of the recycling process [28].

One of the alternatives to solve the problem of pollution and contamination of the environment is through recycling, where waste is collected and transformed into new materials that can be used or sold as new products or materials. raw materials such as paper, cardboard, glass and metals, among others [28]. The adoption of measures to conserve natural resources such as minerals, water and wood guarantees a sustainable and ideal use [29]. Recycling minimizes pollution All forms of pollution in the modern world emanate from industrial waste. The recycling of industrial waste, such as plastics, cans and chemicals, contributes to significantly reducing pollution levels, as these wastes can be reused in the production of new products or used in other recycling processes. use, reducing reckless disposal, in addition to being able to contribute to the generation of jobs [20].

It is important to point out that the proposal to consider recycling as a niche for innovation and entrepreneurship gains more strength when verifying that in Brazil abundant inorganic residues are produced daily, which go to the garbage collector, where they could be used to create new products and subsequent commercialization, generating income that can be invested to cover expenses of a small industry or any other business that operates in this field. Recycling old and used materials into reusable products greatly reduces the chance of suffocation in landfills. This is beneficial because it helps to minimize soil and water pollution, as landfills greatly contribute to environmental degradation [7].

However, it is also worth mentioning that although they contribute to the sustainability process, some recycling processes, although they reduce the release of toxic waste, cannot eliminate this process, and may also emit greenhouse gases because once the same waste recycling industries burn few fossil fuels. Despite being extremely advantageous, recycling also has some disadvantages, so that it is not always profitable, making it interesting to develop processes and/or use other more profitable technologies with less damage, depending on the waste material generated. In addition to recycling, one of the techniques that has drawn attention is composting, which aims to use organic waste as a source of nutrients for use in vegetable gardens, plantations and other agricultural activities [29].

VI. COMPOSTING

Composting is the controlled aerobic biological decomposition of organic matter into a stable humus-like product called compost. It is essentially the same process as natural decomposition, except that it is enhanced and accelerated by mixing organic waste with other ingredients to optimize microbial growth [26]. According to Valente et al. [30], composting is a process of controlled aerobic decomposition and stabilization of organic matter under conditions that allow the development of thermophilic temperatures, resulting from a calorific production of biological origin, obtaining a stable, sanitized final product, rich in humic compounds and whose use in the soil does not pose risks to the environment. The potential benefits of composting manure and other organic waste are improved manure handling; reduced odor, flies and other problems; and reduction of weed seeds and pathogens. According to Souza et al. [31], during composting, as a result of the action of microorganisms, carbon dioxide, energy and water (in the form of steam) are released. Part of this energy is used for the growth of microorganisms, the rest being released as heat. Consequently, the material being composted heats up, reaches a high temperature, cools down and reaches the maturation stage. After maturation, the organic compost will be ready, consisting of resistant parts of organic residues, decomposed products and dead and alive microorganisms. Compost applied to land improves soil fertility, tillage and water holding capacity. It is also odor free and can be stored for long periods. These qualities make it suitable for use in agriculture or for sale [10]. The use of biodigesters has the advantage of producing sustainable energy that ends up reducing the producer's costs with other energy sources, being also sustainable from an environmental point of view, since it reduces the amount of polluting waste in the environment [32]. Biodigesters can be used for the three types of animal production (cattle, poultry and swine), but they are more frequently used for cattle and swine, which, because they have a higher production of manure per animal per day, have a greater production of biogas [33].

Composting is easily adapted to agricultural operations because crops generally produce adequate amounts and types of waste for composting, have adequate land, will benefit from the application of compost to the soil, and already have the necessary equipment available [34].

Key elements in planning a composting facility include conducting site investigations and developing the recipe design, facility design, waste utilization plan, and an operation and maintenance plan. As composting is a relatively flexible process, it is necessary to decide between alternative methods, locations and materials. The decision depends on the management and economic aspects of the farm or the place where the plantations take place, as well as the physical limitations of the place. The planner needs to present the different alternatives to the owner so that the owner can make the final decision [26].

Regarding the composting process, this is carried out by a diverse population of predominantly aerobic microorganisms that decompose organic matter to grow and reproduce. The activity of these microorganisms is stimulated through the management of the carbon-nitrogen ratio (C:N), oxygen supply, moisture content, temperature and pH of the formed compost pile. Properly managed compost increases the rate of natural decomposition and generates enough heat to destroy weed seeds, pathogens and fly larvae [37]. The composting process there is an acceleration of the decomposition of organic matter, triggering a sudden increase in temperature (thermophilic phase) due to an intense proliferation of microorganisms (fungi and bacteria). of pathogens (total coliforms and bacteria of the genus Salmonella) and weed seeds.

The initial stage of composting is marked by temperatures below the mesophilic phase, depending on the ambient temperature and the temperatures of the material in the compost mixture. A short period of delay is typical at the beginning of the composting process, before the temperature starts to rise rapidly. This latency period is the time required for the development of the microbial population [38]. As the temperature varies (Figure 2), the conditions become unsuitable for some microorganisms and, at the same time, they become ideal for others [26]. The active composting period has three temperature ranges. These intervals are defined by the types of microorganisms that dominate the pile during these temperatures, as shown in Figure 2, and are called the mesophilic and thermophilic phases. Mesophilic temperatures are between 20 and 40°C and thermophilic above 40°C [39].

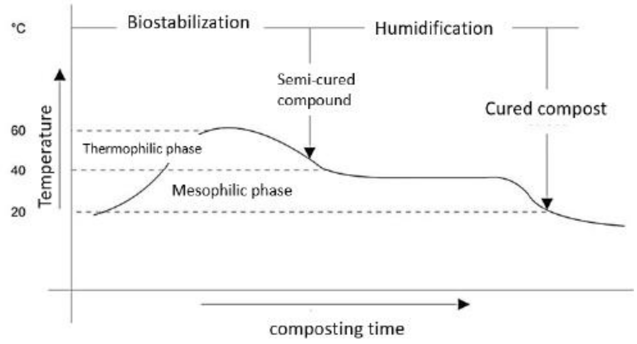

Fig. 2 - Compost temperature range [39].

From an ecological and industrial point of view, the main advantage of using compost is that it allows us to safely eliminate and recycle many types of biodegradable organic waste into inputs for agricultural production, avoiding environmental pollution problems that would trigger their abandonment or dumping. Other advantages refer to the fact that it allows a second use of organic matter, recovering and recycling it. In addition, the amount of Urban Solid Waste (MSW) that goes to landfills and treatment plants is reduced, avoiding problems of soil contamination or the emission of harmful gases into the atmosphere [40]. According to Sena et al., [41], composting favors land productivity is favored without the need to apply other synthetic chemicals, which is why it produces a series of effects with very favorable agro-biological repercussions, improving physical properties. - chemical properties of the soil, since, in the chemical sense, it provides macronutrients such as N, P and K, in addition to micronutrients, and improves the cation exchange capacity of the soil. It also has the factor of the organic matter supplied to contribute favorably to improve the stability of the structure of agricultural soil aggregates, increase the permeability to water and gases and contribute to increase the water holding capacity of the soil through the formation of aggregates.

VII. INCINERATION

Incineration means the act of burning something until there is nothing left but ashes. An incinerator is a unit or facility used to burn used waste and some other different type of waste until it is finally reduced to just ash. An incinerator is constructed of strong, well-insulated material so that, during combustion, extreme heat is not lost, but contained. Heat is left inside the kiln so that all waste inside the incinerator plant can be burned very quickly and efficiently. But when heat is not well contained, waste is not burned completely with the expected level of efficiency [42].

Incineration refers to a process of direct controlled burning of waste in the presence of oxygen at temperatures of around 8000°C and higher, releasing thermal energy, gases and inert ash. To avoid the shortcomings of conventional incinerators, some modern incinerators use higher temperatures of up to 16,500°C using auxiliary fuel. This reduces the volume of waste by almost 97% and converts some inorganic contents, such as metal and glass, into inert ash [43]. The net energy yield depends on the density and composition of the waste. Relative percentage of moisture and inert materials, which increase heat loss; Ignition temperature; size and shape of constituents; combustion system design, etc. In practice, about 65% to 80% of the energy content of organic matter can be recovered as thermal energy, which can be used for direct thermal applications or for energy production with the help of steam turbine-generators [44].

Although incineration is widely used as an important method of waste disposal, it is associated with some polluting discharges that are of environmental concern, albeit in varying degrees of severity. Fortunately, these can be effectively controlled by installing proper pollution control devices and through proper furnace construction and combustion process control [44].

The basic operational steps of a waste incineration plant can include the following steps, as pointed out by Silva et al., 45 in Figure 3:

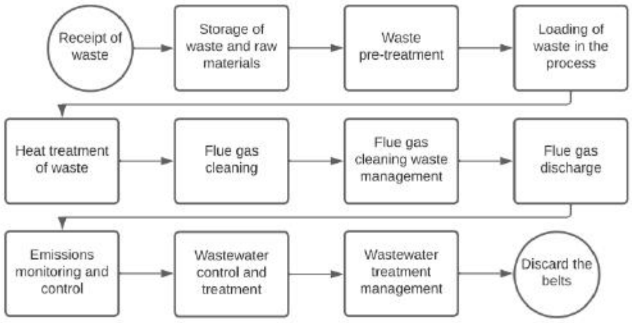

Fig. 3 – Solid waste processing steps in an incineration plant [45].

It is important to note that several technologies are required for the operation of a Municipal Solid Waste (MSW) incineration plant. The main residue from RSM incineration is slag. The amount generated depends on the ash content of the waste. In the combustion process, the volume of waste from high-income cities will, by experience, be reduced by approximately 90% and the weight by 70% to 75%. For low-income areas, the amount of ash in the waste can be high; for example, in areas that use coal, wood or similar for heating. In addition to the slag, the plant generates residues from more or less advanced processes for cleaning dry, semi-dry or wet flue gases. The amount and its environmental characteristics will depend on the technology applied [46].

One of the most attractive features of the incineration process is that it can be used to reduce the original volume of fuels by 80% to 95%. Controlling air pollution remains a major issue in the implementation of incineration for solid waste disposal. In Brazil, the cost of the best available technology for the incineration plant can reach 35% of the project cost. The cost of control equipment, however, will depend on existing air pollution regulations in a given least developed country [47].

Regarding the use or disposal of ash, modern waste incineration facilities differ in technical solutions, but it can be assumed that emissions are kept within the limits of legal restrictions, regardless of the composition of the incinerated waste. This suggests that, despite a site-specific approach, the model is quite general with regard to emissions to air and water, for plants working under the same legal restrictions. Waste products, additive consumption and energy recovery are more site specific [48]. Companies and researchers have been investigating ways to treat ash waste from facilities. Ash consists of residue left in the combustion chamber (bottom ash) and its pollution treatment devices (fly ash). Post-treatment of ash produced by low-temperature combustion chambers, such as fluidized beds, usually involves vitrification at high temperatures to immobilize the metals [49].

The main objective of ash treatment is to prevent the toxic constituents of the ash, especially dioxins, furans and heavy metals, from escaping into the environment after disposal. Solidification through vitrification or application of various chemicals is another means of decreasing the chances of metal leaching. Phosphate has been shown to stabilize heavy metals in dust that results from vitrification of incinerator ash. Ash treatment is a much more mature technology than reuse [50]. The bottom ash produced at the plant resembles clinker ash and, after mechanical separation of ferrous and non-ferrous metals, has a relatively high density (typically 2.25); and according to reports, contains less than 2% carbon and less than 1% fines. The leach test of toxicity characteristics based on the EPA standard showed that the metals in the bottom ash are not leachable [48].

Regarding the advantages that can be cited considering the above, it is known that incineration is an efficient way to reduce the volume of waste and the demand for landfill space. Incineration plants can be located close to the center of gravity of waste generation, reducing the cost of transporting waste. Using the ash from RSM incinerators for environmentally sound construction not only provides a low-cost aggregate, but further reduces the need for landfill capacity. In particular, incineration of waste containing heavy metals and so on should be avoided to maintain adequate slag quality. The slag quality must be checked before use. Energy can be recovered for heating or energy consumption [50].

All waste disposal alternatives eventually break down organic materials into simpler carbon molecules such as CO2 (carbon dioxide) and CH4 (methane). The balance between these two gases and the time period for the reactions vary depending on the alternative. Incineration provides the best way to eliminate methane gas emissions from waste management processes. In addition, energy from waste projects provides a substitute for fossil fuel combustion. These are two ways in which incineration helps reduce greenhouse gas emissions [1].

As far as disadvantages are concerned, an incineration plant involves heavy investments and high operating costs and requires local and foreign currency throughout its operation. The resulting increase in waste treatment costs will motivate waste generators to look for alternatives. In addition, waste incineration is only applicable if certain requirements are met. The composition of waste in developing countries is often questionable in terms of its suitability for automatic combustion. The complexity of an incineration plant requires qualified personnel. In addition, waste from flue gas cleaning can contaminate the environment if not treated properly and should be disposed of in well-operated, controlled landfills to avoid soil and surface pollution.

VIII. BIOREMEDIATION

The term Bioremediation is divided into two parts: "bios" means life and refers to living organisms and "remediation" means solving a problem. "Bioremediation" means using biological organisms to solve an environmental problem, such as contaminated soil or groundwater. Bioremediation is the use of live microorganisms to degrade environmental pollutants or to prevent pollution. In other words, it is a technology to remove pollutants from the environment, thus restoring the original natural environment and preventing further pollution [51]. According to Leonel [52], bioremediation can be defined simply as a biological process of decontaminating a contaminated environment. Bioremediation as a technique can include biodegradation as just one of the mechanisms involved or applied in the bioremediation process. Only some of the contaminants are biodegradable and only some of the microorganisms can degrade a fraction of the contaminants. Therefore, it would be worthwhile to study the biodegradation potential of microorganisms. Morais Filho & Coriolano [53], report that although microorganisms have been used for the treatment and transformation of waste for at least a century, bioremediation is considered a new technology for the ecologically correct decontamination of polluted environments. As a popular case of application of this technology, municipal wastewater is microbiologically decontaminated under controlled conditions so that, depending on the metabolic activities of microorganisms, different activated sludge systems and fixed films are applied in wastewater treatment facilities. Waste and pollution can be permanently eliminated). Treatment residues are generally harmless products and include carbon dioxide, water and cellular biomass [54].

In bioremediation, living organisms such as microorganisms (bacteria, fungi and algae) or plants are used to degrade and detoxify harmful pollutants present in the environment and convert them into CO2, H2O, microbial biomass and metabolites (by-products that are less toxic than than the original compound) [55], as shown in Figure 4.

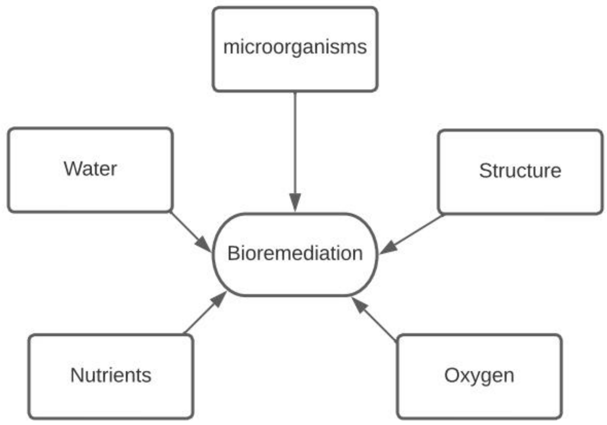

Fig. 4– Principle of bioremediation [55].

These microorganisms may be native to this contaminated site or they may be isolated and brought from outside to this contaminated site for bioremediation. Microorganisms degrade and transform these pollutants through their metabolic reactions and use them for their growth. The complete degradation of a pollutant requires the action of several microbes, therefore, sometimes, potential microbes can be added to the contaminated site for the effective degradation process and this process is called bioaugmentation [56].

The biodegradation process depends on favorable environmental conditions, the type and solubility of the pollutant, and the bioavailability of the pollutant to the microbes, therefore, environmental conditions are controlled or manipulated to allow sufficient microbial growth and therefore rapid and effective biodegradation [56].

In bioremediation, microbes inhabit varied environments such as hot springs, deserts, glaciers, saline lakes and oceans. Microbes with degradation potential can be isolated from contaminated environments such as heavy metal polluted sites, landfills, petroleum contaminated sites, pesticide contaminated sites due to agricultural activities and wastewater treatment plant, for the degradation of various pollutants. Microbes use the hazardous pollutant as their energy and carbon source under both aerobic and anaerobic conditions and therefore, through metabolic activity, can degrade or convert the pollutant into less or non-toxic metabolites. Microbes and soil pollutants are not evenly distributed in the soil, so the pollutant must be available or in contact with the microbes for the effective degradation of the pollutant and this can be done by the application of surfactants [57].

Aerobic bacterial species such as Mycobacterium, Alcaligens, Sphingomonas and Pseudomonas are known for their aerobic degradation of hydrocarbons (alkanes and polycyclic aromatic hydrocarbons) and pesticides. Along with this, some of the aerobic methyltrophs are also recognized for degradation of dichloroethane and trichloroethane (chlorinated aliphatics). Some of the anaerobic bacterial species are known to degrade PCBs and trichlorethylene (chlorinated solvent). In addition to bacterial species, some fungal species, such as Phanerochaete chrysosporium, have also been reported to be effective in remediating a variety of toxic and persistent pollutants [57].

From the point of view of future bioremediation prospects, it appears that the development of knowledge of microbial populations, their interactions with the natural environment and contaminants, the enhancement of their genetic capabilities to degrade contaminants, long-term field studies of new economic bioremediations techniques can increase the potential for significant advances. There is no doubt that bioremediation is a necessity in today's world and can lead to the protection and preservation of the natural resources that we navigate for generations to come. Ahead, some of the most used types of bioremediation are highlighted [56].

Most of the time, in situ is applied to eliminate pollutants from contaminated soils and groundwater. It is a superior method for cleaning contaminated environments as it saves transportation costs and uses harmless microorganisms to eliminate chemical contamination. These microorganisms are more likely to have a positive chemotactic affinity for contaminants. This feature increases the likelihood of bioremediation at nearby points where bioremediators have not been distributed. Furthermore, the method is preferred because it causes minimal disturbance to the contaminated area. This would be of great relevance when minimal investment and pollution is preferred (for example, in factories) or in areas contaminated with dangerous contaminants (for example, in areas contaminated with chemical or radioactive materials) [57].

bioremediation in situ is the feasibility of synchronized soil and groundwater treatment. However, this bioremediation has some disadvantages: the method is more time consuming compared to other correction methods and leads to a seasonal variation in microbial activity due to direct exposure to variations in uncontrollable environmental factors, and the use of additives can lead to problems additional. The yield of bioremediation is determined by the type of waste, that is, if the waste could provide the necessary nutrients and energy, then the microorganisms would be able to make the intermediate correction [58].

However, according to Silveira [59], in the absence of favorable residues, the loss of bioactivity can be compensated through the stimulation of native microorganisms. Another less preferred option is the application of genetically modified microorganisms. Two types of in situ are differentiated based on the origin of the microorganisms applied as bioremediators:

I. Intrinsic bioremediation - This type of in situ is performed without direct microbial correction and through intermediation in ecological conditions of the contaminated region and fortification of natural populations and the metabolic activities of native or naturally existing microfauna, improving nutritional and ventilation conditions [59].

II. Bioremediation In Situ - This type of bioremediation is performed by introducing certain microorganisms into a contamination site. As the conditions of the contamination sites are most often unfavorable for the establishment and bioactivity of exogenously altered microorganisms, therefore, here as intrinsic bioremediation, the environment is modified so that improved physicochemical conditions are provided. Oxygen, electron acceptors and nutrients (eg nitrogen and phosphorus) are needed to enhance microbial growth [59].

The bioremediation process here takes place somewhere outside the contamination site and therefore requires transporting contaminated soil or pumping groundwater to the bioremediation site. This technique has more disadvantages than advantages. Depending on the state of the contaminant in the bioremediation step, ex situbioremediation is classified as [60]:

I. Solid phase system (including soil treatment and soil piles) - The system is used for bioremediation of organic waste and problematic domestic and industrial waste, sewage sludge and municipal solid waste. Solid phase soil bioremediation includes three processes including tillage, soil biopilation and composting.

II. Sludge phase systems (including solid-liquid suspensions in bioreactors) - Sludge phase bioremediation is a relatively faster process compared to other treatment processes.

Contaminated soil is mixed with water and other additives in a large tank called an abioreactor and mixed to bring indigenous microorganisms into close contact with soil contaminants. Nutrients and oxygen are corrected, and conditions in the bioreactor are adjusted so that an optimal environment for microbial bioremediation is provided. Upon completion of the process, the water is removed and the solid waste is disposed of or further processed to decontaminate the remaining pollutants.

It is important to point out that different techniques are employed depending on the degree of saturation and aeration of an area.techniques In situ are defined as those that are applied to the soil and groundwater of the site with minimal disturbance.techniques Ex situ are those applied to site soil and groundwater that have been removed from the site through excavation (soil) or pumping (water).bioremediation In situ by the indigenous microbial population is an increasingly popular and environmentally friendly option for cleaning up contaminated sites and currently considerable effort is being spent to design inexpensive and viable strategies using this technology, which shows promise as a relatively good alternative. Mercury-resistant bacteria were considered as a potential approach to biological remediation [61].

Based on the post, bioremediation offers many advantages over the physical and chemical treatments used to treat contaminated water and soil. Bioremediation tends to have lower costs than other treatments, such as incineration, used to remove toxic substances from the soil. Another advantage is that bioremediation aims to degrade and detoxify dangerous pollutants, while other technologies simply transfer the pollutants to a different location. Therefore, it is a simple technology compared to the others [62].

One of the disadvantages of bioremediation is the difficulty in predicting the realization of this treatment. The success of such a project depends on the ability of the process operators to create and maintain the environmental conditions necessary for microbial growth. Microorganisms are sensitive to temperatures, pH, toxicity of the pollutant and its concentration, moisture content, nutrient concentration and oxygen concentration. A decrease in microbial activity will decrease degradation and prolong the period If microbial activity stops, it would be very difficult to restart treatment [63].

Sometimes bioremediation will not be useful when contaminants are not degradable, or partially biodegradable, or because contaminant levels are so high that microbial activity is affected. As pollutant levels decrease, biological degradation decreases and microorganisms need to change energy sources or stop growing together. In this case, bioremediation is not sufficient to treat a site and therefore another treatment will have to be used, therefore it is time consuming, i.e. the time required to remediate a site usually depends on the rate at which the pollutant is degraded [64].

IX. CONCLUSION

Waste management has been a challenge for all nations around the world. The production of garbage has increased in a generalized way, as it was possible to notice in the information pointed out in the Brazilian context. As the production of waste increases, more investments are needed for proper treatment to be carried out, preventing environmental damage from occurring due to incorrect management of different types of waste.

In recent decades, the high production of consumer goods and population growth have had a direct impact on the growing generation of solid waste, many of which lack adequate final disposal to avoid harmful impacts to society and the environment; and this fact is what currently represents one of the greatest challenges. Given this scenario, for some countries such as Brazil, the fourth largest generator of waste in the world per year, with a total of 216,629 tons per day, the scale of this challenge is even greater.

Current public policies require concrete actions in search of higher rates of recycling and reuse of waste, as well as a rearrangement in the planning of public spending and costs related to its management. In fact, Brazilian regions have high levels of solid waste generation, which means that if its management is carried out improperly, the recycling and reuse process is compromised, generating high environmental and social impacts.

As existing alternatives, the Composting and Bioremediation processes are recommended, given their efficiency in the reuse of organic waste. These alternatives contribute to the projection of a circular model of the economy, both in terms of energy and soil fertilization, vital processes for the current reality in Brazil.

In addition, other processes can be adopted in Brazilian policies, such as Incineration, which is efficient in different contexts, promoting the conversion of waste into energy that can be used to supply electricity, or even compose the energy matrix of a city when well designed.

Finally, several alternatives can be taken with regard to solid waste management, but in the Brazilian case, due to the extension of territory and the diversity of types of waste generated in different states and regions, an elaborate study is necessary to point out which alternative best suited to the country's needs.

Another important aspect is the transparency in expenditures and in the numbers raised on the production of waste and its destination. As noted, data and studies are released vaguely and sporadically, emphasizing that the sector needs more rigorous political support, with solid projects, which consider the various forms of management presented in this research, and recycling techniques can be adopted, Incineration, Bioremediation, Composting and Sanitary Landfills, which can be efficient and environmentally friendly when well managed.

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