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Household waste management: Between citizenship and environmental sustainability

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Abstract

Recycling household waste is a significant priority for contemporary civilization, motivated by the need to conserve natural resources and decrease pollution. This strategy is aligned with a sustainable development framework that seeks to minimize the adverse effects of human actions on the environment, while simultaneously encouraging more effective resource use. This study aimed to analyze the issue of waste accumulation, with a special emphasis on household waste, and its substantial impact on the environment and human health. It attempts to explore potential solutions and evaluate the advantages and disadvantages of various waste-treatment methods. Therefore, our secondary aim was to highlight citizens' participation in the sorting and management of waste. Amidst growing worldwide awareness of environmental issues, the issue of waste is considered a significant obstacle to achieving Sustainable Development Goals (SDGs). Waste incineration, a common practice in managing solid waste, results in the production of slag and fly ash, along with the release of harmful combustion gases, such as sulfur oxides, nitrogen oxides, and hydrogen fluoride. This method offers advantages such as significant waste reduction (up to 90%) and weight reduction (60-70%), in addition to generating thermal energy for electricity or heat production. However, it is essential to address the production of hazardous substances and metals during incineration, which necessitates complex and expensive filtration systems. Waste generation is projected to soar to a staggering 3.4 billion tons annually within the next 30 years, from 2.01 billion tons in 2016. High-income nations, comprising only 16% of the global population, contribute astonishingly to over a third (34%) of the world's total waste production. The East Asia-Pacific region currently accounts for 23% of the worldwide waste generation. Alarming projections suggest that by 2050, waste production in South Asia and sub-Saharan Africa will more than double and triple, respectively. In conclusion, coordinated worldwide efforts are necessary to prioritize the implementation of appropriate waste management techniques, measures to reduce waste, and active involvement of the public in order to tackle this increasing environmental crisis.

Keywords: Waste, Household waste, incineration, compost, Sustainable Development Goals

Full length review article **Corresponding Author*, e-mail: rahkel@hotmail.fr

1. Introduction

Environmental pollution resulting from waste disposal is an important issue that must be addressed by the international community. The current predicament arises from a multitude of elements, with human activity being identified as a prominent contributor to this concern [1]. The presence of waste significantly disrupts the equilibrium of the ecosystem and has a profound impact on overall quality of life. This encompasses a wide range of items, such as food waste, plastics, metals, glass, and paper goods, that have reached the end of their useful lives. Furthermore, it is of more relevance that this waste contains a variety of perilous compounds, such as mercury derived from used batteries and dangerous chemicals originating from domestic solvents and paints. Consequently, this situation has detrimental effects on public health and exacerbates environmental contamination [2].

Undoubtedly, the environmental consequences resulting from the diverse array of waste categories have been considerably amplified in tandem with technological progress. Although these technological advancements have provided several advantages to humanity, they have also played a role in increasing the global issue of waste management [3]. Novel materials, such as plastics, have been created with the distinctive characteristic of exhibiting an extended degradation period spanning hundreds of years or even an indefinite resistance to degradation. Consequently, these materials amass inside landfills, emitting a range of hazardous pollutants, such as leachate and other poisonous compounds [4]. The disposal of domestic waste has become a significant and pressing issue in contemporary global landscapes. Undoubtedly, the ongoing expansion of global population has resulted in a commensurate increase in the quantity of trash generated. The uncontrolled buildup of garbage has the potential to result in worldwide disasters [5]. To address this urgent issue, a comprehensive recycling and waste management initiative needs to be implemented. The effective management and proper disposal of household waste in urban areas is a crucial environmental concern that plays a significant role in the attainment of Millennium Development Goals (MDGs), specifically the goal of "Clean Water and Sanitation." The preservation of environmental security in the region as well as the maintenance of public sanitation and hygiene in urban areas are crucial aspects of household waste treatment, recycling, and disposal [6]. These efforts align with Sustainable Development Goal 11, which focuses on creating sustainable cities and communities. Additionally, it is important to ensure that these methods contribute to the preservation of living conditions for the population, as well as the well-being of the fauna and flora. This objective aligns with Sustainable Development Goals 14 and 15, which aim to protect aquatic and terrestrial life, respectively [7].

The objective of this study is to examine the issue of environmental pollution resulting from the increasing accumulation of waste, specifically household waste. It aims to emphasize the substantial influence of human activity as the primary contributor to this worldwide concern, which directly hinders the attainment of various Sustainable Development Goals (SDG), including SDG 3 "Good health and well-being" and SDG 13 "Action on climate change.”

2. Waste definition

Waste, which refers to substances or combinations that are unsuitable for future use and need proper treatment or disposal, has a substantial impact on our environment and society. The categorization of these leftover elements is crucial for the implementation of environmentally-conscious management practices [8].

3. Waste-associated issues

In recent times, there has been an increased focus on global environmental issues, particularly in the field of waste management. It is estimated that each individual on the planet produces around 1 kilogram of household waste each day, resulting in hundreds of millions of tons annually. Consequently, the growing use of plastic items has led to the emergence of hazardous areas in the Earth's seas, sometimes referred to as "waste spots". These are vast aggregations of plastic waste organized in large clusters on the surface of the water. They are created from the deposition of waste originating from coastal regions of continents and maritime vessels. Therefore far, researchers have discovered five large accumulations of waste - two in the Pacific and Atlantic Oceans, and one in the Indian Ocean ([9]; [10]). This waste, regardless of whether it comes from industry, municipalities, or households, poses a significant environmental concern on a worldwide level. Their unregulated buildup detrimentally impacts the environment, modifies individuals' quality of life, and presents substantial health hazards. Comprehending the characteristics of waste and its categorization is crucial for adopting suitable methods for its management [11]. Waste is categorized based on many factors. Firstly, they may be categorized based on their source. Industrial waste originates from manufacturing operations and may be classified into many categories, including harmful, inert, and special waste. Municipal and residential waste is produced as a result of the everyday actions of individuals and communities [12]. The second parameter for categorizing waste is its physical condition, which might manifest as either gaseous, liquid, or solid. This differentiation is crucial, since it primarily establishes the suitable procedures for handling and disposing of the materials. For example, different methods are needed to control gaseous garbage than solid waste [13]. Moreover, waste is categorized based on its degree of detrimental impact or toxicity to both people and the environment. This categorization simplifies the identification of waste materials that need specialized handling owing to their significant contamination propensity. Class 1 waste, which is very detrimental, is often resistant to decomposition and has long-lasting impacts on the ecosystem spanning many centuries. Class 4 waste, which is less dangerous, has a narrower effect on the environment and breaks down more quickly [14]. Effective waste management is vital for the conservation of the environment and the promotion of public health. With the expanding global population, there is a corresponding rise in waste production, leading to a more complex waste management process. Unregulated trash buildup may result in ecological catastrophes, including contamination of water, air, and soil [15]. Given the circumstances, the prioritization of implementing suitable recycling and trash disposal initiatives has become imperative. These initiatives should not only prioritize the collection and processing of current waste materials, but also actively contribute to the development of novel strategies for reducing waste generation from its origin. The adaptability of these programs to technological advancements and changing market demands is of the utmost importance [16]. Conversely, these technology advancements may have a significant impact on enhancing waste management, namely by enhancing the efficiency and sustainability of treatment procedures. Addressing this escalating environmental concern requires both a heightened societal understanding of waste issues and the active engagement of citizens [17].

4. Categorization of waste

4.1 Classification by origin

- **Industrial Waste (IW):** These waste materials originate from industrial manufacturing processes. They may contain chemical materials, manufacturing waste, industrial by-products, etc. Their management often involves tight regulations because to the potential risks to human health, nature, and the environment [18].

- Municipal and Domestic Waste (MADW - Municipal and Assimilated Household Waste): This classification encompasses materials produced by residential dwellings, educational institutions, and professional environments (e.g., hospitals and offices). Typical components consist of food residues, packaging, used furniture, obsolete appliances, and so forth. The maintenance of sanitation in urban areas is contingent upon their effective management [19].

4.2 Physical Condition-Based Classification of Waste

At standard temperature and pressure, these refuse materials exist in gaseous form. They are frequently linked to chemical processes or industrial emissions. This category includes greenhouse gases, including carbon dioxide (CO_2) [20]. Liquid debris refers to refuse that is in a liquid state when it reaches room temperature. These consist of liquid compounds, industrial effluents, and domestic wastewater, among others [21]. Solid wastes consist of substances that are in a solid state when subjected to ambient temperature and pressure. These materials comprise an extensive array, such as construction materials, electronic debris, wood, metals, and plastics [22].

4.3 Categorization of refuse materials based on their level of hazardousness

Generally, the harmfulness of a substance is assessed by its impact on the environment and human health, which is utilized to categorize waste into various groups. The following is a prevalent system of classifying waste based on its level of toxicity [23] :

Class 1 - Highly harmful: This category encompasses very hazardous and non-biodegradable waste. They have a significant influence on the environment and human health. The waste from this class requires special management measures, and the environment may take over 300 years to recover after being affected by this waste.

Class 2 - Harmful: The waste in this category is considered very hazardous, however its decomposition is relatively faster than that of class 1. They may take 75 years or more to decompose, and the restoration of soil structure can take 30 years or more.

Class 3 - Moderately harmful: This class covers waste that has a less serious impact, but is still harmful to the environment and to health. Their decomposition time is around 10 years, and environmental recovery can take up to 20 years.

Class 4 - Slightly harmful: Waste in this category has limited environmental impact. Their decomposition time is generally shorter, up to three years, and the environmental recovery period after damage is no more than five years. It is essential to classify waste according to its harmfulness in order to set up appropriate management procedures, minimize its impact on the environment and protect public health. This classification also makes it possible to determine the most appropriate disposal and treatment methods for each type of waste, thus contributing to more efficient waste management. In addition, industrial waste or MSW (Material-Specific Waste) is divided into two main categories [24]:

Toxic waste: These contain physiologically active substances that can be detrimental to human and animal health. Their handling and disposal require special precautions.

Inert waste: These wastes are considered non-reactive and are often destined for disposal in solid waste landfills. It includes materials such as wood, rubble, slag, textiles and plastics.

IV.4 Waste categorization based on its source

The categorization of waste based on its source is very significant, since it directly impacts the following methods of storage and disposal. The categorization plays a crucial role in facilitating effective and sustainable waste disposal, hence mitigating its detrimental effects on the environment and public health [25].

- **Domestic waste**

This waste is generated as a consequence of human activity in residential and governmental structures, as well as in public areas. Household waste encompasses a variety of materials such as paper, metal, plastic, organic fibers (including food), leather, rubber, cloth, ceramics, glass, wood, and any goods derived from these materials [26].

- **Medical**

Medical institutional waste pertains to the waste produced as a result of operations carried out in medical facilities. The objects included in this category consist of remnants of both human and animal tissue, pharmaceutical substances, medical equipment and supplies, bandages, as well as biological fluids. These waste materials may contain microorganisms such as bacteria, fungus, and viruses. This trash may have infectious microorganisms, poisonous particles, and/or radioactive compounds, making it very dangerous to both people and the environment. Unlike residential garbage, it cannot be disposed of in a straightforward manner. They need a unique method of disposal [27].

- **Biological**

Biological waste includes animal carcasses (including domestic and laboratory animal cadavers, deceased animals), animal products that are unlawfully imported or fail to fulfill sanitary regulations, trash generated from food processing, and non-food animal raw materials. Similar to medical waste, biological waste poses a significant risk to human health. Improper collection and disposal of these items may lead to the spread of illness [28]. Industrial waste is produced as a result of manufacturing processes. This encompasses any and all materials that become obsolete throughout the manufacturing process, such as those found in factories or extracted from minerals. The materials included in this list are dirt, concrete, gravel, scrap metal, masonry, oil, chemicals, solvents, and even plant waste from restaurants [29].

- **Radioactive**

Radioactive waste refers to materials that have accumulated the highest levels of radioactivity. Given the lack of practical utility, secondary intervention is not feasible for this group. Radioactive waste is often mistaken for spent nuclear fuel. The disparity is substantial: with certain processing, the fuel may be recycled. While other forms of waste may be handled by licensed entities, the only provider for this particular kind is the National Radioactive waste Management Operator [30].

5. The current worldwide crisis of excessive waste accumulation

The issue of global waste overflow has been a persistent concern for a considerable period of time. It is crucial to acknowledge that trash generation is inherently connected to both household and economic human behavior. Although the handling of liquid and gaseous waste may be relatively easy, managing solid waste poses considerable challenges primarily because it takes a long time, sometimes decades or even centuries, for it to break down naturally in the environment [31]. An excellent illustration of this issue is the UK, where the massive volume of rubbish deposited in landfills—far more than any other member nation of the European Union—has caused a serious financial crisis. Annually, around 330 million metric tons of waste are accumulated inside the nation, occupying an expanse of approximately 109 square miles. In addition, this waste includes a substantial amount of organic material, which produces undesirable filtrates and disagreeable odors after decomposition [32]. Furthermore, leftover products that undergo incomplete decomposition release dried-out dust containing diverse microorganisms and pollutants. Consequently, air, surface and groundwater, and soil experience significant pollution, while stray animals such as cats, dogs, and birds harbor diverse infections. Waste also contains dangerous bacteria and nematode eggs. These may be transported by dust from landfills and pollute water and soil. The presence of hazardous compounds and microorganisms in trash may serve as carriers for illnesses such as TB, hepatitis, ascariasis, and dysentery, among others [33]. In the United States, a country with a population of over 157 million, an estimated 384,400 kilometers of waste trucks are required each year to handle this waste, underscoring the magnitude of the issue. Nevertheless, the problem of domestic waste management in the USA remains largely unaddressed, as only around 20% of waste is properly addressed, while the other portion is deposited in municipal landfills [34].

Sweden has implemented a selective strategy to address the problem of household trash, focusing specifically on the recycling of juice and beer cans. An implemented return system allows individuals to return 80% of cans to designated businesses and collection stations, so allowing the recycling of more than 600,000 cans annually [35]. Germany is renowned for its exceptional recycling and waste management practices, making it a global leader in this field. German residents actively participate in trash segregation by depositing their waste in distinct trash bags, which are then directed to the right containers based on the relevant waste type [36].

6. Factors contributing to the rise in waste

Due to the fast increase in urbanization and population, the global annual waste production is projected to reach 3.4 billion tons in the next 30 years, compared to 2.01 billion tons in 2016 [37]. According to the documents, while high-income nations only make up 16% of the worldwide population, they produce over a third (34%) of the world's waste. The report offers a comprehensive analysis of the global and regional waste issue. The East Asia-Pacific region is currently responsible for 23% of worldwide waste generation. According to Brack et al. [38], the analysis projects that waste production in South Asia and sub-Saharan Africa would have grown by more than twice and more than thrice, respectively, by 2050. The issue of waste becomes more crucial when it pertains to plastics. The research states that global plastic waste generation in 2016 reached 242 million tons, accounting for 12% of the entire amount of household waste generated. However, in the absence of adequate collection and treatment systems, this waste will pollute and deteriorate rivers and ecosystems for a long period, perhaps spanning hundreds or even thousands of years [39]. What a Waste 2.0 emphasizes the vital significance of household waste management for achieving sustainable, healthy, and equitable urban development. It also brings attention to the fact that this sector is often overlooked, especially in low-income nations. In high-income nations, about 33% of waste is recycled or composted; in low-income nations, waste is recycled to a mere 4% [40]. Furthermore, it is projected that waste treatment and disposal produced 1.6 billion tons of CO_2 equivalent in 2016, or around 5% of global greenhouse gas emissions, taking into consideration the amount, content, and management of waste [41]. The report situates the matter of waste management within the context of a circular economic paradigm, whereby items are intentionally created and optimized for the purposes of reuse and recycling. As the circular economy becomes more widely adopted by national and municipal governments, clever, sustainable waste management strategies will emerge, promoting effective economic growth while reducing negative environmental effects [42]. It is crucial to provide assistance to governments in their decision-making processes on the finance, policy, and planning of household waste management. This support should encompass the following measures [43] :

- Allocating financial resources to countries with the greatest need, especially those undergoing rapid development, to enable them to establish contemporary waste management systems;
- Assisting major waste-generating nations in curbing the use of plastic products and marine litter through comprehensive waste reduction and recycling initiatives;
- Addressing the issue of food waste by implementing consumer education programs, organic waste management strategies, and coordinated efforts to manage food residues.

The surge in waste is attributable to a plethora of issues intrinsic to our modern civilization. Below is a comprehensive examination of the primary factors that are responsible for the ongoing rise in waste:

- **The growth of single-use goods:** Currently, there has been a significant increase in the mass manufacturing of disposable products, including food packaging, plastic utensils, and disposable diapers. These disposable goods create a substantial quantity of waste. The short-term convenience they provide is coupled with a long-term environmental impact [44].
- **The emergence of glossy artificial packaging**: The prevalence of synthetic packing materials, such as plastic, has increased significantly. Despite their lightweight, durability, and cost-effectiveness, these materials provide a significant obstacle in terms of waste disposal. Their gradual deterioration in the environment and their widespread presence in the supply chain contribute to the buildup of waste [45].
- **Improvement in quality of life:** Overconsumption of material items is a result of better living circumstances and rising buying power. Electronics, home appliances, apparel, and several other products are often replaced with newer or more trendy iterations. The perpetual cycle of innovation leads to a steady influx of outdated items, which are often discarded, hence contributing to the escalation of waste [46].
- **Changing consumer habits:** Consumer behaviors are progressively moving away from sustainable approaches. Behaviors such as consuming prepared foods, purchasing takeout meals, often buying prepackaged items, and wasting food contribute to the generation of greater waste [47].
- **Planned obsolescence:** Manufacturers deliberately design items to have a predetermined and restricted lifetime. Planned obsolescence is a strategy that pushes customers to replace their products more often, which produces more waste [48].
- **Urban lifestyles:** The process of urbanization is causing changes in consumer behavior. Urban regions exhibit higher resource use, more waste production, and increasing strain on waste management systems [49].

7. Approaches to waste disposal

An industry devoted to waste recycling and appropriate management has emerged as a consequence of the significant amount of garbage generated by human activities [50]. The consensus is that waste treatment cannot be effectively resolved with a single approach. While incineration may be seen as the most effective approach to waste management by certain individuals, it is crucial to emphasize that promoting the incineration of waste should never be advocated. Incinerating waste results in the emission of hazardous compounds that represent a threat to human health. The emissions produced by incineration consist of hazardous compounds that may infiltrate our households via several methods, settling on food, clothes, and skin, and can even be breathed into our respiratory system. In addition, the toxic residue left behind after waste incineration has the potential to be transported by air currents and pollute underground water sources [51]. Incinerating one metric ton of solid waste produces around 320 kilograms of slag and 30 kilograms of fly ash. Additionally, it releases combustion gases that comprise sulfur oxides, nitrogen oxides, and hydrogen fluoride. Household waste in several developing nations is disposed of by incineration in specifically engineered high-temperature furnaces [52]. This approach has many benefits, including a substantial decrease in the the quantity of waste (up to 90%) and its weight (60-70%). Furthermore, it produces thermal energy that may be used for the purpose of generating electricity or providing heat [53]. Nevertheless, it is important to acknowledge that waste combustion may result in the production of harmful substances and metallic elements, which requires the implementation of intricate and costly filtration systems in furnaces. In addition, these filters progressively lose their functionality and must be discarded, so adding to the waste in landfills [54]. Therefore, it is crucial to closely observe and decrease the release of acid gases, nitrogen oxides, sulfur dioxide, and heavy metals during trash incineration, since these compounds present significant hazards to human health, such as cancer and disturbance of hormonal equilibrium [55].

8. Legislative framework pertaining to domestic waste

8.1 Within the continent of Europe

The objective of the European Union's waste policy is to enhance the effectiveness of waste management throughout the Union, treating waste as a valuable resource and progressing towards a European society that prioritizes recycling. This entails enabling member states to establish independent waste disposal systems [56]. The waste regulation landscape in the European Union (EU) is very complex. The Waste Framework Directive and the Waste Shipment Regulation provide the overall structure. The subsequent tier of law comprises documents that pertain to waste management activities, including the directive on industrial emissions (specifically waste incineration) and the landfill directive. Additionally, there exists a tertiary tier of legislation comprising of seven distinct texts that address various categories of waste: agricultural utilization of sewage sludge; packaging and its waste; PCBs/PCTs; disposal of end-of-life vehicles; batteries and accumulators; and the limitation of certain hazardous substances in electrical and electronic equipment (RoHS 2) [57].

8.1.1 Waste Framework Directive

The Waste Framework Directive serves as the fundamental basis for waste legislation in Europe. The document offers precise explanations of fundamental terms such as waste, end-of-waste, reuse, and recycling. The Waste Framework Directive, implemented in 2008, aims to advance the EU's transition towards a "recycling society" by focusing on waste prevention, utilizing waste as a valuable resource, mitigating the adverse environmental and health effects of waste, and enhancing energy and resource efficiency in line with the concept of a "circular economy". The Framework

Directive incorporates the precautionary principle, which is established in the Treaty on European Union. It is based on three fundamental principles [58]. Prevention encompasses two aspects: the reduction of waste generation and the mitigation of waste-related harm. The directive prioritizes waste prevention as the most important waste management option, based on life-cycle theory. Member states are required to incorporate this approach into their national policies. The directive also emphasizes the importance of preparation for reuse, recycling, other forms of recovery (such as energy), and disposal, in that order [59]. The directive requires that member states must develop preventive plans by December 12, 2013. These programs should outline the current prevention measures, identify suitable benchmarks for waste prevention, and define indicators for measuring the effectiveness of preventative measures. Regular updates on progress must be sent to the Commission, as stated by Zorpas et al. [60]. The polluter pays concept, as stated in the Treaty on the Functioning of the European Union, seeks to both prevent and rectify environmental damages. Based on this approach, the responsibility for covering the expenses of waste management lies with the initial waste producer or with the individuals or entities that now or previously had the waste [61]. Extended producer responsibility (EPR) is a notion that seeks to enhance the practices of reusing, preventing, recycling, and other means of recovering trash. Nevertheless, the execution of it is entrusted to the judgment of individual member states [62].

8.1.2 Pertains to the rules governing the export of waste

The transportation of waste is a significant challenge in global commerce. In 2011, the EU was the top worldwide exporter and importer of non-hazardous waste for recovery, surpassing the USA and China. The EU accounted for 35.5% of global exports (compared to the USA's 4.5% and China's 21.4%) and 44.5% of global imports (compared to the USA's 18% and China's 1%). European paper and plastic recycling is often conducted in Asia [63]. The primary objective of the trash Shipment Regulation is to oversee and regulate the transportation of waste with the goal of safeguarding human health and the environment. This regulation pertains to all cross-border transportation of waste, regardless of its intended use, both inside the European Union and between the EU and other countries [64]. EU law also contains regulations on the shipping of trash between member states, including a system of prior authorisation for the shipment of waste for disposal or recovery, an obligatory notification system and a common tracking record for waste shipments. Member states have a responsibility to undertake the necessary actions to examine, get samples from, and regulate shipments of waste. They are required to conduct inspections, examinations, and other forms of scrutiny. Although this law is legally obligatory, its implementation varies across the different member states, as shown by a recent audit conducted in eight EU nations [65].

8.2 United States of America

The management of domestic waste in the United States is regulated by an intricate system of rules and regulations that originate from many tiers of government, namely the federal, state, and municipal levels. Unlike a centralized legal framework, home waste rules in the USA are dispersed across many legislative and administrative texts that cover different facets of waste management. Below is a concise summary of the main legislation and regulations currently in effect: The Resource Conservation and Recovery Act (RCRA) is a federal law that governs the management and disposal of hazardous waste in the United States. The Resource Conservation and Recovery Act (RCRA) is the primary federal law that regulates the handling of hazardous waste in the United States. Although its main emphasis is on hazardous waste produced by enterprises, it also has ramifications for residential garbage, especially in terms of its disposal in public landfills [66]. The Solid Waste Disposal Act (SWDA) is a legislation that is closely associated with the Resource Conservation and Recovery Act (RCRA). Its primary focus is on the effective handling and control of solid waste, which encompasses many types of trash, including domestic waste. The objective is to promote appropriate management of solid waste by implementing regulations for landfills and advocating for recycling and waste reduction ([67]; [68].).

- The Clean Air Act (CAA) and Clean Water Act (CWA) have an indirect influence on home waste management since they address the quality of air and water, respectively. They oversee the regulation of possible emissions from waste incineration plants and monitor the release of contaminants into wastewater from landfills [69].

- Landfill laws: The regulations governing landfills differ among states, with each state establishing its own set of criteria and rules for public landfills, including those that accept domestic waste [70].

- Local restrictions: Local jurisdictions, such as counties and municipalities, enact precise legislation pertaining to the handling of residential waste. The requirements include a range of areas, including the gathering, reusing, minimizing, and handling of hazardous waste, as well as other essential components of waste management at the municipal level [71].

9. Citizen involvement in waste sorting and management

The recycling of urban waste is a significant issue in contemporary civilization, motivated by the need to conserve natural resources and mitigate pollution. This strategy is aligned with a sustainable development framework that seeks to minimize the adverse effects of human actions on the environment, while concurrently advocating for more effective resource use [72]. Citizen engagement is key to this recycling process. Implementing waste segregation at home is a vital measure to guarantee the effectiveness of recycling on a large scale. The concept revolves on the idea of both individual and community accountability for the management of trash. Below are some crucial factors to contemplate within this particular framework ([73]; [74]):

1. Conservation of ecological assets: Home waste sorting aids in diminishing the need for fresh, unused resources, since recycled materials may be used in the production of novel goods. This approach conserves energy and water, while also mitigating the exploitation of natural resources.

2. Decrease in pollution: Disposing of unsorted waste by landfilling or incineration produces greenhouse gas emissions and dangerous contaminants. Through the act of segregating recyclable waste, individuals contribute to the mitigation of these detrimental emissions and enhancement of air and water purity.

3. Job creation: The recycling business generates employment opportunities at the local level, including various tasks such as collecting, sorting, treating, and processing recyclable materials. Individuals that engage in waste segregation at their residences contribute to the growth of the local economy.

4. Education and awareness: Engaging in rubbish sorting at home enhances people' consciousness of environmental concerns. This motivates individuals to adopt sustainable lifestyles and actively engage in the preservation of the environment.

5. Decreased waste management expenses: A reduction in non-recyclable waste results in a smaller amount of waste that has to be processed, hence potentially lowering the costs linked to its disposal. Conserved resources may be allocated to other initiatives.

6. Waste recovery: Waste sorting differentiates between items that can be recycled and those that cannot be recycled. This process enables the gathering, reprocessing, and reintegration of these materials back into the manufacturing cycle, therefore reducing the need for new, unused resources.

The practice of separate waste collection (SWC) often generates resistance and uncertainty among the general population, mostly owing to the prevailing notion that all waste is ultimately gathered up in the same waste truck and placed in a landfill without discrimination. Nonetheless, it is crucial to correct this misinterpretation and advocate for a more precise understanding of the inherent advantages of segregating trash [75]. SWO acceptance relies on several crucial factors. First and foremost, a suitable infrastructure is crucial for ensuring its efficacy. This entails providing dedicated receptacles for the segregation of recyclable items, ideally furnished with visual infographics and clear instructions to assist residents. The containers should also have obvious marks that identify the operator in charge of managing them. This will make the sorting process easier during the first phase [76].

Simultaneously, environmental education has a pivotal position in the process of acceptance. Disseminating information to the public on the advantages of SWO is an essential component. The process of increasing awareness may be accomplished via a variety of methods, including the display of artistic posters in public areas, the presence of information stands at the doors of buildings, the publication of frequent pieces in local media, and engaging in conversations within the community. Furthermore, organizing conferences, seminars, and courses on waste management and sustainability serves to enlighten individuals on SWO [77]. Community engagement is an additional crucial foundation. It is essential for everyone to recognize their pivotal role in preserving the environment. Local administrations, environmental groups, and educational institutions have the ability to arrange neighborhood meetings, training sessions, and awareness campaigns with the aim of promoting the active involvement of the public [78]. Furthermore, it is crucial to maintain a transparent and ongoing communication with the public, ensuring that they are always updated on advancements pertaining to trash management and recycling. This may be accomplished by regularly publishing information, organizing public meetings, and conducting consultations [79]. Conversely, nations like Sweden have effectively handled their waste management, to the point that they now have a unique issue: a scarcity of waste. The outcome is a consequence of several variables, such as proficient governmental strategies, a firmly established culture of recycling, and cutting-edge waste management technology [80].

10. Recycling for environmental conservation

Recycling is becoming a financially beneficial alternative to expensive waste approaches. The continuous expansion in the quantity of waste recycled globally, together with its growing popularity, provides evidence of the favorable prospects of this technique [81]. The comprehensive trash recycling process involves many crucial stages: collection, sorting, recycling, and reuse. The advancement of waste treatment technology necessitates the incorporation of many key factors. It is essential to not only meet existing market demands, but also to foster the development of new markets for recycled goods. Furthermore, these technologies need to possess agility and flexibility to effectively handle evolving environmental and market situations, while simultaneously considering the factors of economic viability, environmental sustainability, and the broadest possible array of waste categories [82]. Establishing a waste management system relies on existing organizational concepts. Diverse waste management techniques, including biodegradation, composting, and burning, are used to efficiently repurpose waste. Municipal solid waste is often composted, however complicated industrial waste need specialized techniques. The cost of composting varies depending on the kind of equipment used [83]. The selection of composting technique is contingent upon a thorough evaluation of expenses and advantages, as well as the presence of markets for the final outputs. Composting depends on the action of thermophilic microorganisms that produce heat, which eradicates pathogens and facilitates the conversion of waste into a substance resembling humus. The evaluation of waste should be based on its composition of organic matter, ash, total nitrogen, calcium, and carbon. In order to address the increase in trash, researchers are working on developing advanced and automated techniques for waste management. These techniques include many stages such as waste collection and preparation, biothermal composting, and efficient management of the final product [84].

10.1 Utilizing composting as a method to recycle domestic waste

When composting household waste, it is crucial to generate products that are epidemiologically safe. Indeed, the majority of harmful microorganisms perish during the biothermal process. However, compost derived from the biothermal neutralization of solid waste at waste treatment facilities should be avoided for agricultural and forestry purposes due to potential heavy metal contaminants. These contaminants, if absorbed by plants such as herbs, berries, vegetables, or transferred to milk, might pose a risk to human health. Therefore, it is advisable to apply these composts in an unsystematic manner, especially in public areas like squares and parks [85]. One disadvantage of composting is the need to store and properly dispose of the non-compostable fraction of the waste, which makes up a substantial percentage of the overall waste volume. One possible solution to this issue is to use incineration, pyrolysis, or landfill disposal methods [86]. The consensus is that biological approaches for breaking down organic contaminants are highly regarded for their environmental and economic benefits. Waste biodegradation methods differ depending on the kind of waste. For instance, liquid waste is processed in bio-ponds, while liquid, pasty, and solid waste is handled in bioreactors. Waste gases undergo treatment in biofilters, and there are many additional forms of biotechnology available [87]. At now, a considerable variety of diluted industrial wastes are subjected to biological treatment, namely using the oxidation approach. This process takes place in aeration basins, biofilters, and bio-ponds, which are the primary areas where microorganisms are intentionally used in biotechnology. However, a significant disadvantage of this method, especially when dealing with concentrated wastewater, is the high energy consumption needed for aeration. Additionally, there are challenges related to the handling and disposal of the substantial amounts of surplus sludge produced (up to 1 to 1.5 kg of microbial biomass for each kilogram of organic matter eliminated) [88]. Conversely, the process of anaerobic wastewater treatment by methanization provides a remedy for these limitations. This is due to its lack of energy consumption for aeration, which is particularly important in the context of the energy crisis. Additionally, it decreases the amount of sludge and produces methane, a valuable fossil fuel. The microbial conversion of organic compounds via anaerobic processes is characterized by its complexity and diversity, with several essential elements having been recently elucidated. However, throughout the 1980s, industrial anaerobic treatment technology made substantial advancements and were widely used internationally. However, genetic engineering techniques offer the potential to obtain strains that can neutralize environmentally hazardous organic substances and other materials [89]. An extensive categorization of anaerobic reactor designs that are commonly used in different countries. It is crucial to acknowledge that bacteria exhibit diverse reactions to the multiple compounds included in waste. Therefore, it is crucial to evaluate the capacity of anaerobic microorganisms to break down waste naturally, while identifying the most favorable circumstances for the treatment process. The most suitable test for this objective is the Biochemical Methane Potential (BMP) test. This experiment entails combining a waste sample with an anaerobic culture in a designated medium, which is maintained in a closed tank with no oxygen present. The amount of gas generated is measured at regular intervals. The methane production throughout the test period, as determined by the Chemical Oxygen Demand (COD) and relative to the carbon content in the trash, provides insight into the biodegradability of the tested waste sample ([90] ; [91]).

11. Conclusions

Effective management of domestic waste recycling is of utmost importance in modern society. The driving force behind this initiative is the pressing need to preserve natural resources and to counteract the detrimental effects of pollution. This collaborative endeavor is intricately integrated into a sustainable development framework that aims to reduce the negative environmental consequences of human actions while simultaneously encouraging the efficient use of resources. In this study, we conducted research in the field of waste accumulation. The subject has been thoroughly examined through careful analysis of various waste treatment methods, including their advantages and disadvantages. Simultaneously, efforts have been made to emphasize the crucial role that individuals play in the sorting and management of garbage, recognizing the growing worldwide consciousness of environmental challenges. Waste, with its intricacies, has become a significant obstacle to achieving Sustainable Development Goals (SDGs). Therefore, it is crucial that a worldwide coordinated effort be prioritized, focusing on implementing efficient waste management procedures, establishing waste reduction measures, and actively involving the public. Only by making these coordinated endeavors can we fight and triumph over the imminent environmental problems that pose a significant danger to overpower humanity.

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