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Municipal Solid Waste Management Strategies in Egypt

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Abstract

Municipal solid waste is mainly produced from residential and commercial sources, and this waste increases with increasing human consumption. Municipal solid waste causes negative effects on air, water, and soil, especially when disposed of by burying or burning it. Medium and developing countries lack a system that manages these wastes. These countries depend on burial or incineration to dispose of these wastes, and there is a very low percentage of this waste that is sorted or recycled. Egypt is considered one of the middle-income countries that lack a continuous administrative system for solid municipal waste management, and there are also no strict or specific laws regulating the process of waste management with poor awareness among large groups of people. A large part of the municipal solid waste in Egypt is not collected at all and remains for several days until it is burned by the people. Another part remains dumped at the waste collection point for several days in the streets until it is collected by the responsible institutions. The largest part of the collection is not sorted and thrown into open dumps or buried randomly whereas the smallest one is recycled. Despite the weakness in the strategies of municipal solid waste management in Egypt, there are efforts done by the Ministry of Environment and government directions to support this sector like striving to update the laws related to municipal solid waste management.

Keywords: MSW Generation in Egypt; MSW Management in Egypt; MSW Recycling; MSW Landfill

Introduction

Pollution is the addition of any gases, solids, liquids, or any form of energy such as heat, and radiation to the environment at a faster rate than normal that cannot be treated by recycling, dispersion, or dilution processes. The main types of pollution are air pollution, water pollution, and land pollution [47]. The pollution sources are either natural, such as volcanic eruptions, floods, droughts, and forest fires, or human. Either the source of pollution is human or this appears in human consumption, or by over-exploitation of various natural resources, whose excessive use leads to a shortage in the ring of nature. As for the waste resulting from various industries that serve the basics of human life and well-being. Waste generation is increasing worldwide with 4.8 tons of waste generated per EU inhabitant in 2020 [27].

One of the most pressing challenges that always have faced Egyptian's authorities, and will continue for the coming decades is solid waste management. This problem is growing with the rapid population growth [42]. Egypt produces around 100 million tons of waste annually, with agricultural, drainage, canal, and municipal waste making up the majority, as reported by the National Solid Waste Management Program (NSWMP) in 2023. Urban areas see waste collection rates of up to 85%, while rural areas lag behind at 35%. Despite this, a substantial portion of municipal waste, estimated at 80 to 88%, ends up in open dumpsites, with only about 7% directed to landfills [4].

Waste and Its Impact on the Environment

Waste is a material that is no longer useful after it has been used once or several times, or it is materials that resulted during the process of manufacturing a particular product or as a result of consuming a product and can result from a biological process such as feces, urine, etc. If not handled properly, they pose a health hazard and an environmental threat [2]. Waste can be divided into several divisions according to its source, condition, degree of danger, and other divisions. Here it will be divided into two types Solid and liquid, effluent is wastewater such as sewage waste or other effluents, especially toxic waste that flows into water such as a river or lake. Solid waste is a useless and sometimes hazardous substance with a low fluid content. These include municipal waste, waste from agricultural and animal husbandry operations, industrial and commercial waste, demolition waste, mining waste, and others. [59]

Pollution usually increases due to increased production and consumption, but at high income levels pollution may decrease due to investments in pollution reduction technologies [11]. Only about 20% of municipal solid waste is recycled, about 14% is used for energy conversion and the rest is disposed of in open dumps or landfills [8]. In the European Union, 39.2% of the waste generated in a year was recycled.2020 is a good percentage compared to other countries [27]. In most developing countries, waste is disposed of and treated inappropriately, resulting in air pollutants such as greenhouse gases and other hazardous organic compounds [49].

Waste fires and landfills threaten to pollute the environment through toxic pollutants emitted into air, water and soil [22]. Air pollution, which means pollution of the internal or external environment by any chemical, physical or biological agent that alters the natural characteristics of the atmosphere [63]. One of the most important sources of air pollution is methane and carbon dioxide. Landfilling is one of the most important sources of both gasses. In 2020, 32.2% of the total waste generated by the European Union was buried in 2020 [27].

Landfill emissions are the result of the decomposition of organic matter in them, and these landfills include household waste, food and paper waste, and the organization and cleaning of trees and gardens. Due to the nature of landfill construction, this decomposition is anaerobic and results in the production of large quantities of methane and carbon dioxide [22]. Landfills are the largest source of methane emissions in the United States, especially MSW landfills where they generate about 93% of U.S. landfill emissions [6]. Waste incineration results in the release of toxic organic compounds that pollute the atmosphere [54].

Exposure to chemicals and other substances emitted by waste site fires, such as suspended particulate matter, carbon dioxide and carbon monoxide, puts human health at great risk [51]. It is believed that the emission of both solid and gaseous pollutants takes at least three decades or even centuries to finish from the closed landfill site [52]. In the Middle Ages, epidemics associated with water contaminated with pathogens wiped out a large number of Europe's population. As a result, waste has been recognized as an important and emerging new source of air pollutants that pose a threat to ambient air quality and public health [56].

Water pollution is the presence of harmful and unwanted substances in water whose concentration is high enough to render it unusable [58]. Waste is therefore a source of water pollution by inducing undesirable changes in water quality in receiving water bodies [37]. The decomposition of solid waste in open landfills or landfills leads to the production of materials containing heavy metals and organic compounds such as benzene, phenol, toluene and others [62] . In the absence of appropriate drainage systems and the failure to collect and treat the leachate, the discharge of this pollutant-filled leachate into aquifers or runoff water such as rivers or streams near the burial area or landfill leads to pollution of these water bodies and this pollution of groundwater resources poses a great danger to the users of local resources and to the natural environment [44].

Soil pollution is caused by the presence of chemicals that have a significant negative impact on any organisms in it or on soil functions. Soil pollutants include organic and inorganic compounds, and other excess modifications added to soils [28]. Soil contamination has a direct impact on food security, and there is a direct link between the quality and safety of the food we eat and the level of soil contaminants. Because some contaminants are ingested by plants through different pathways, they accumulate in the food chain, compromising the safety of the food that It is consumed by both humans and animals. Waste placed in landfills or open landfills is exposed to either groundwater flow or leakage from rainfall. Since most of the waste is in unprepared landfill sites, there is direct contact between the soil and municipal solid waste that leads to contamination by pathogenic microorganisms and toxic organic matter such as hydrocarbons and PCBs to contaminate the soil. Burning and open burning residues such as slag and fly ash also lead to soil contamination in the area [30].

Municipal Solid Waste

By 2050, the world is expected to generate 3.40 billion tons of waste annually, significantly more than 2.01 billion tons of world production in 2017 [38]. Waste is divided into three types, the first is mineral waste, which is all metal and solid waste, except for combustion waste, metal waste resulting from waste treatment, and stable waste. Mineral waste includes the following mineral waste from construction and demolition, natural mineral waste, synthetic mineral waste, waste of refractory materials and dredging spoils [24]. Second, hazardous waste is a term that applies to those wastes that cause hazard, or are likely to cause hazard, to health or the environment due to their chemical reaction, toxicity, explosion, corrosion, radiation, or other properties [12]. Third, municipal waste consists largely of household waste, but may also include similar waste from small businesses and public institutions collected by the municipality [24].

Municipal solid waste is mainly generated from residential and commercial sources. Municipal solid waste is classified into two types, the first type is biodegradable such as food waste, paper, and other organic waste and other waste, the other type is non-biodegradable, which are man-made materials such as plastic, metal, glass and other inorganic waste, and municipal solid waste includes some hazardous materials, such as batteries, paints, electronic waste, some construction waste and industrial waste. Waste generation Much higher in high- and middle-income countries, the average amount of waste a person produces per day in these countries is about 1.9 kilograms, while in low- and middle-income countries, the average amount of waste a person produces there per day is about 1.5 kilograms. [64]

The amount of municipal waste per person in the EU reached 505 kg in 2020, an increase of about 1 kg per person from 2019. The total EU waste will be 225.7 million tonnes of municipal waste in 2020 [26]. While Africa produced about 174 million

tonnes of municipal solid waste in 2016, about 13% of this waste is plastic, and 57% is organic waste. Waste generation in Africa is expected to reach 244 million tonnes per year by 2025. By 2050, it will produce about 516 million tonnes per year. Egypt and Nigeria produce from 15,000 to 20,000 10^3 tonnes/year and South Africa more than 20,000 10^3 tonnes/year in 2021. [57]

Despite the clear difference in the amount of waste produced by developing countries from developed countries, we find that the negative impact of waste on the environment is evident in developing countries from developed countries due to the way these countries deal with municipal solid waste. Local governments in low- and middle-income countries typically spend between 3% and 15% of their budgets on solid waste management [53]. More than 90% of waste in Africa is disposed of in uncontrolled landfills and landfills, and a large part is burned outdoors, although 70-80% of municipal solid waste generated in Africa is recyclable. The world's 50 largest landfills have 19 in Africa [5].

Municipal Solid Waste Generation in Egypt

The total solid waste in Egypt for the year 2009 is about 75 million tons, distributed between agricultural waste about 24 million tons, municipal waste by 20 million tons by 27%, waste from the purification of canals and drains by about 20 million tons by 27%, industrial waste about 5 million tons by 7% and demolition and construction waste by about 4 million tons by 5% and sewage waste about 2 million tons (2%) [15]. The Egyptian Environmental Affairs Agency estimated the production of Egyptian municipal solid waste at 0.3 to 0.8 kg/day/person, with an annual growth of 3.4% [16]. In 2012, Egypt produced 89.03 million tons of solid waste, of which 21 Million tons of municipal solid waste [31]. The amount of municipal waste generated per person in Egypt from 2010 to 2015 increased by 43.9% [25]. While the municipal solid waste generation rate in 2018 was between 0.6 and 0.8 kg/person/day, which shows an increase from the minimum per capita in 2011 by 0.3 [38].

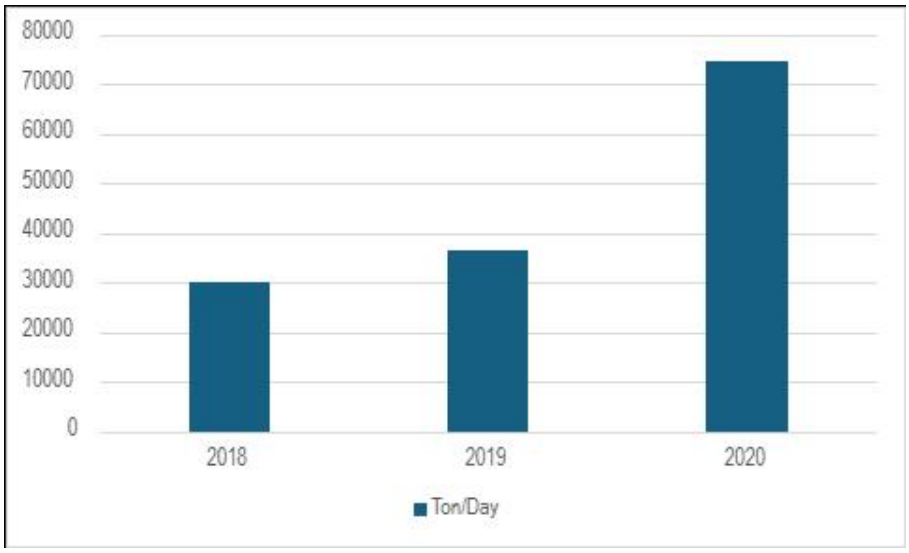

Figure 1: Municipal solid waste production in Egypt 2018-2020 tons/day [8]

According to the annual bulletin of environmental statistics issued by the Central Agency for Public Mobilization and Statistics and as shown in Figure 1, Egypt's daily production of municipal solid waste for 2018 amounted to about 30026.7 tons, for 2019 about 36556 tons and for 2020 about 74569 tons, and it appears that the amount of waste increased about twice from 2019 to 2020. This waste consists mainly of food waste from 41% to 70%, while high-income areas contain a large portion of plastic (12.9%) and paper (5.9%) compared to low-income areas [1]. This is reflected in the estimated distribution of municipal solid waste generation in the governorates of Egypt, where Cairo alone leads the highest percentage, with a volume of waste of about 6 million tons per year, representing 47% of the total municipal solid waste, followed by the Delta 31%, Upper Egypt 10%, Canal and Sinai 5%, Alexandria and Matrouh 7% of waste [19].

Since 1980, the population size of most Egyptian villages has increased significantly and as a result, job opportunities in the agricultural sector have become very limited. This situation led to the migration of some of the workforce from rural areas to major cities, others remaining in their villages and some traveling abroad to work. This situation has led to significant changes in the lifestyle of the rural community and consumption patterns. These changes have led to significant changes in the quality of and The amount and components of solid waste generated. Waste is produced as a result of common practices in rural areas such as direct dumping of solid waste on the banks of canals, drains and other various places and burning solid waste randomly, as the land available for landfill is not sufficient and is not designed to receive waste and there is no system for managing or receiving waste. Although solid waste management is the responsibility of the village's local units by law, it plays a very weak role in this area. Although solid waste generated in rural areas is highly organic, the number of organic fertilizer plants is very small [20]. Some organic parts are generally used to feed household feedstock in rural areas. The unusable part is disposed of on empty land, along roads, irrigation and water streams [14].

Demolition waste is estimated to account for 20% to 30% of total annual solid waste. In Egypt, the daily amount of construction and demolition waste is estimated at 10,000 tons. This is equivalent to one-third of the total daily municipal solid waste generated daily in Egypt, and research has shown that 0.4% of the weight of construction waste disposed of in landfills is hazardous waste such as paints, solvents, adhesives and others [7]. The amount of demolition and construction waste in Egypt for the year 2020 reached 4630279 tons/year [8].

Egypt has become the first country in Africa and the Middle East to consume plastic, due to the daily use of plastic, especially in packaging and packaging, especially foodstuffs, and there are many plastic waste that is difficult to recycle due to mixing many types of plastic, which may cause great difficulty in sorting types. Now about 9% of plastic can be recycled. Therefore, Egypt is one of the most important sources of plastic waste in the Mediterranean region and the Middle East, so Egypt produces more than 22 million tons of municipal solid waste annually, and plastic waste accounts for 13%, meaning that there are approximately one million tons of plastic waste generated in Egypt every year.[34]

Municipal Solid Waste Landfill in Egypt

Municipal solid waste is the most common method of waste disposal that degrades soil quality [28]. About 65% of municipal solid waste is disposed of in open dumps or landfills [10]. There are two main types of landfills First, sanitary landfills Sanitary landfills are usually placed in areas where land characteristics act as natural barriers between landfills and the environment to prevent the negative impact of landfills on The environment while taking other safety measures in its design to prevent its risks. They are those authorized to accept toxic waste, as they have safety precautions. Second, controlled landfills are disposal sites that comply with most sanitary requirements with fewer control measures but are closed or fenced, reducing the risk of environmental pollution. In addition, they are characterized by low initial and operational costs [9]. These two types, if well exploited, can be used using biochemical systems, such as anaerobic digestion and fermentation, biological processes to convert organic waste into energy in the form of liquid or gaseous fuels [48]. Closing landfills In some developing countries, the matter is not to close landfills and continue to put waste until it becomes a mountain of waste, especially in desert places or far from human activities.

Landfills are a major cause of water, soil and air pollution, resulting from landfills that are not designed according to specifications, strong pollutants that seep into the soil, pollute it, and can mix with groundwater and reach surface water and pollute it. Landfills have been identified as one of the main threats to groundwater resources [61]. Landfills also produce methane, which contributes 3-4 percent.% in anthropogenic annual greenhouse gas emissions globally. The waste sector contributes significantly to the emission of greenhouse gases into the atmosphere, which greatly affects the Earth's climate change and global warming .[52]

Despite the significant negative effects of landfills on the environment, municipal solid waste in Egypt is managed by landfilling, which poses multiple environmental and health risks [39]. About 81% of municipal solid waste in Egypt is disposed of in public and random landfills, while 7% is disposed of in safe landfills, causing more greenhouse gas emissions that affect climate change [45]. The number of sanitary cemeteries in Egypt in 2018 reached 40 cemeteries, while it reached 21 cemeteries in 2019 [8]. meaning less about the text due to the state's trends to close many burials that have been filled and to establish new burials designed according to international specifications to preserve the environment and benefit from these burials. The Ministry of State for Environmental Affairs has developed a plan to remove the historical accumulations and transfer them to controlled cemeteries within the boundaries of each governorate, which were estimated at about 15 million cubic meters, in addition to providing financial support to close some dumps, including the Zagazig and Minya al-Qamh dumps in Sharkia Governorate, and the Dalgamoun dump in Gharbia Governorate [17].

The state seeks to develop the landfill sector to benefit from it and reduce its negative effects on the environment. According to the law regulating waste management, which requires the safe closure of landfills within a specified period of time, the procedures for the safe closure of random dumps of waste continue. The leachate liquid generated from the sanitary landfill with loyalty and hope was transferred sustainably to the sewage treatment plant, and the preparation of the conditions and specifications booklet for the speed of development of the dump area, and the closure and rehabilitation work of the peace dump due to its proximity to the residential block, where the work of Coverage as a first phase, and the Urban Communities Authority will launch the second phase of the construction of a public park [55]. A number of 18 sanitary landfills have been delivered, including the cemeteries of Sannur and Somasta in Beni Suef, Kom Oshim and Youssef Al-Siddiq in Fayoum, and the burials in Farafra, Kharga and Dakhla in the New Valley, Kafr Daoud in Menoufia, Badr in Beheira, Dar es Salaam in Sohag, Al-Madamud in Luxor, Sharm El-Sheikh in South Sinai, Belbeis in Sharqia, Suez and Matrouh in Marsa Matrouh, Shubramant in Giza, Edfu in Aswan, Marsa Alam in the Red Sea, and the implementation of (4) sanitary landfills is underway.[18]

Municipal Solid Waste Recycling in Egypt

It is a bitter fact that only about 20% of municipal solid waste is recycled [10]. Local governments in low- and middle-income countries typically spend 3% to 15% of their budgets on solid waste management, of which 80% to 90% are spent on waste collection [53]. Waste can be recycled at less than 20% in these countries because it is sometimes collected, buried or incinerated randomly without sorting the materials apart to determine what can be recycled and utilized. Approximately 70-80% of municipal solid waste generated in Africa is recyclable, however, only 4% of municipal solid waste is currently recycled [5]. Less than 65% of that waste is managed through some form of collection, disposal or recycling, and the rest accumulates on city streets and in illegal landfills [15]. This is due to the lack of sufficient storage containers and the insufficiency of public waste dumps, which often leads to the burning of waste from the people for disposal. In addition to limited funds and the inability of municipal authorities to provide reliable and affordable services. In addition to the lack of interest in educating citizens towards solid waste management, recycling and other policies and laws that are not implemented in this sector [42].

Recycling is defined as any recovery process through which waste materials are reprocessed into products or materials whether for original or other purposes [23]. Solid waste management has been given low priority in Egypt so far, and this is reflected in the limited funds allocated to solid waste management by the government [37]. Municipal solid waste management includes different types of waste, including recyclables such as paper and cardboard boxes [46]. MSW in Egypt is divided into two types: economically valuable recyclables such as paper and cardboard bins sold to merchants and organic waste that is left piled up on the streets or burned openly causing pollution and methane emissions [17].

Recycling activities in Egypt have only taken place in some cities under unsafe and unsanitary conditions, exposing workers involved in these operations to many risks [13]. The treatment and recycling of municipal solid waste in Egypt in 2012 is estimat-

ed by 12% of the total waste [45]. According to the latest statistics of municipal solid waste collected in 2015, 10-15% was recycled, 7% was composted, and 7% was disposed of in sanitary landfills [35]. More than 80% of the municipal solid waste generated in Egypt is simply disposed of, with a total recovery rate of only 11.5% [29]. These percentages are due to the lack of garbage sorting in general, as the percentage of government institutions that sort is very few, as well as private institutions are also few compared to the volume of waste produced. Separation and recycling centers should be deployed across the country to fully exploit the waste through appropriate recycling and reuse activities and the use of non-recyclable waste to enhance the raw materials available for waste-to-energy projects [46].

Recently the government keen to develop recycling institutions like Adwa garbage recycling factory in the village of Adwa in Fayoum governorate. This factory occupies 35 thousand square meters, the factory works with a recycling capacity of 8 tons / hour, equivalent to recycling 192 tons daily. The factory recycles garbage by converting it into organic fertilizer, and alternative fuel, as well as sorting and sparing metal ores in addition to cardboard, paper, glass and plastic, pointing out that the garbage goes through three stages within the factory, which are collection, recycling and sanitary burial of raw materials Mission [21].

Also many private institutions that work on sorting and recycling municipal solid waste have been developed recently such as the Ikaru Foundation, which operates 5 open dumps in Dakahlia Governorate are Mit Ghamr, Aja, Dikirnis, Matareya and Qalabsho through mobile sorting units. And Green Tech Egypt, which established the first solid waste sorting station in Hurghada with a capacity of up to 400 Tons per day, which uses new technologies conforming to European specifications and standards, and all machinery and equipment have been imported from the Netherlands and Germany and work on the latest recycling technologies, the plant is currently managed by the Environmental Conservation Association HEPCA, and other institutions.

The country's GDP loses about $5.7 billion annually due to the lack of recycling and utilization of waste, in addition to the cost of waste treatment and its negative impact on the environment [33]. A government program has been developed to improve the solid waste management system to raise the efficiency of waste collection, management and transportation by 80% and increase the percentage of recycling to 25% by 2030 [17]. According to the Central Bureau of Statistics, the number of recycling factories distributed over the different governorates of Egypt reached 20 factories in 2018 and 52 in 2019, including 27 factories operating and 18 factories not working, and the number of factories in 2020 reached 51 factories, and the implementation of 3 recycling plants has been completed, namely Tuna Al-Jabal in Minya, Dar Al-Salam in Sohag, and Al-Mahalla Al-Kubra factory in Gharbia [18].

Waste Management Strategies in Egypt

The main problem facing Egypt is the lack of an integrated and consistent solid waste management system due to the lack of an institutional infrastructure capable of carrying out the necessary processes to plan, organize, and implement an ongoing solid waste management system [42]. Solid waste management has become a major public health and environmental concern in Egypt as current regulations remain very limited, while illegal disposal of domestic and industrial waste remains a common practice. Solid waste management has been given low priority in Egypt [35]. Policies on waste management have been reformed with the issuance of the Waste Management Regulation Law No. 202/2020 and its executive regulations, and the Prime Minister's Decision No. 41/2019 on the waste-to-energy feed tariff [60].

The lack of a sustainable waste management system is due to deficiencies in the environmental policy-making process, deficiencies in the Egyptian legal framework; and deficiencies in Egyptian societal practices and culture. First, in terms of public policy--making, environmental public policies lack comprehensive data and this results from deficiencies in the monitoring process and this negatively affects the formation and implementation of policymaking, making the assessment process almost impossible on which policies are based [39].

Second, with regard to the shortcomings of Egyptian societal practices and culture, the lack of effective human resources with environmental expertise as well as the lack of public awareness of knowledge regarding environmental issues and solid waste management in particular. A large part of the Egyptian people throw waste in the street, especially the waste of fast food and others that are eaten in the street, plastic water bottles, soft drink bottles and others, certainly due to the lack of awareness to maintain cleanliness and streets and also because of the failure of the bodies responsible for collecting waste, psychologically when the citizen finds that the garbage dumped in the street without boxes, it is natural that he will throw garbage anywhere, so it is a common default.

Third, concerning the shortcomings of the Egyptian legal framework, the problem does not lie in the issuance of laws, but in the need for uniform environmental regulations and the ability to ensure compliance with these laws and their implementation on all institutions and individuals with the presence of regulatory bodies to follow up the implementation of these regulations. Law No. 4 of 1994 and Law No. 38 of 1967, on environmental protection and their legislative amendments, regulate the solid waste management sector in Egypt for a long time. Further updates to the legislation were made during the period 2005-2010 with the promulgation of Law No. 10/2005, which established the system of solid waste collection fees. Law No. 4 of 1994 regulating the disposal of hazardous waste was amended by Presidential Decree No. 86 of 2010 [35]. Article No. 18 is included in the Waste Management Regulation Law No. 202 of 2020, which prohibits the free distribution of single-use plastic bags [18].

To achieve these goals, the Egyptian Environmental Affairs Agency was established in 1994, and the Ministry of State for Environmental Affairs was established in 1997. Then the Egyptian integrated sector for solid waste management was established under the supervision of the Ministry of Environment as a first step towards the establishment of the Egyptian Solid Waste Management Authority. Egypt's National Waste Management Policy will be developed through NSWMP This policy will be based on several principles, the first of which is self-sufficiency in services and facilities to ensure the management of all waste produced. Second, the principle of proximity, by establishing intermediate stations, but first the waste must be managed as close as possible to its source of production. Third, the waste management hierarchy where some waste management practices should be prioritized over others, and fourth, the principle of recognition includes the recognition of waste management and recycling as an important professional sector. Fifth, the polluter pays principle includes those who manufacture products that lead to waste, and those who generate waste must be responsible for paying for its management costs appropriately.[31]

The authorities responsible in Egypt for waste management seek to develop the sector, even if it is slow and unnoticed, within the planning of the subject Collecting new contracts with the private sector, especially with international companies. Construction of five sanitary landfills outside Cairo, two transmission stations with a capacity of 2,000 tons/day, increase the number of inspectors and add 30 new monitoring and control units, and establish composting plants at new landfill sites for the recycling of organic waste [18]. The Ministry of Environment started the first phase of the National Solid Waste Management Program project in 2015 to achieve an effective and sustainable system for integrated solid waste management based on the development of policies, legislation, institutions, financing, human and technological resources, public awareness to contribute to the sustainable protection of the environment and climate, reducing environmental risks that threaten the population in Egypt and protecting natural resources.

Among the programs that the Ministry of Environment is working on to support waste management is the National Program for Solid Waste Management and the partners for this development are Germany, Switzerland, the European Union with an amount of 55.750 [43]. The state seeks to rehabilitate and establish new treatment plants to use at least 60% of the collected waste, and to close uncontrolled landfills and replace them with sanitary landfills, provided that they do not exceed 20%. Percentage of waste collected by 20%2025, and increase the contribution of waste to energy in solid waste management by up to 20% of waste collected by 2026 [60]. The World Bank Foundation provides a $9.13 million grant from the Global Environment Facility to scale up the Cairo Climate Change in Governance project. One of the benefits of this project is to facilitate waste and

sanitary waste management, with a focus on carbon emissions elimination and solid waste purification [65].

The first phase of the National Waste Information System (WIMS), which is being implemented with GIZ, has also been completed to establish an integrated institutional system for collecting, storing and analyzing data related to waste management at the state level, and includes a central database for waste management, data analysis, decision-making, the possibility of live control and increasing business efficiency. The Ministry of Environment has also prepared a draft of the work names in the field of waste management, and they are collecting, Sorting, recycling and final disposal of the waste management system. [18]

Implementation of the first waste-to-energy projects in Abu Rawash area in Giza Governorate at an investment cost of $ 120 million, to produce 30 MWh of electrical power in 2023, and the Ministry of Environment continued efforts to integrate the informal sector in the field of waste, which led to the registration of 4,200 individuals nationwide so far, their data on the website for the registration of workers in the field of waste recycling, within the cooperation protocol between the Ministries of Environment and Social Solidarity. To officially register irregular workers in the system, and a decision was issued for job titles and accordingly, the Civil Status Department will add these titles so that anyone can obtain the job title, to legalize the conditions of workers in the informal sector socially to encourage cooperation between them and the ministry.[55]

Evaluation of the Egyptian Municipal Solid Waste Management Strategies Considering the Experiences of Some Other Countries

Egypt's municipal solid waste management (MSWM) strategies reveal a complex interplay of traditional practices and modern approaches, often characterized by a dependence on informal waste collectors and limited recycling initiatives. About 60% of waste in Egyptian cities is managed by informal sectors, which, while effective in collecting, lack the infrastructure for sustainable waste treatment [32]. In contrast, many developed and developing countries, such as Germany, Brazil, Jordan, and Morocco, have developed and implemented more robust waste management frameworks. For example, Jordan has established a comprehensive framework that includes public-private partnerships to develop waste management practices, resulting in better service delivery and community engagement [3]. Also, Brazil has created a National Policy on Solid Waste, which stresses the importance of waste segregation at the source and encourages recycling initiatives, leading to a recycling rate of around 4% in 2018 [50]. These approaches contrast sharply with Egypt's current management practices, revealing significant gaps and the need for more structured policies and public engagement to boost recycling rates and reduce landfill dependence.

To outline potential improvements in Egypt's MSWM strategies, it is crucial to study successful international models. Countries like Japan have adopted advanced waste management practices, including community engagement and education into their systems, that leading to makeable reductions in waste generation and increased recycling rates [41]. Moreover, integrating technology, such as smart waste bins and data analytics, has proven beneficial in optimizing collection routes and improving efficiency in countries like South Korea [40]. In Morocco, the government has initiated programs to formalize the informal waste sector, herewith improving waste collection efficiency and increasing recycling rates [36]. By studying these international best practices, Egypt could develop intended policies that not only improve waste management efficiency but also adopt a culture of sustainability. Investing in technological advancements and implementing community education programs could significantly bridge the existing gaps in Egypt’s municipal solid waste management system.

Conclusion and Recommendations

It can be concluded that challenges in Egypt's municipal solid waste management (MSWM) system include inadequate collection services, improperly designed landfills, and low public awareness. Approximately 60% of municipal waste is managed offhandedly, resulting in significant environmental health issues, such as pollution from open landfills and poor recycling tech-

niques. Despite efforts that have been made by the Egyptian government recently to update waste management regulations and build new treatment facilities, the current system is underfunded and incoherent so far. The comparison with stronger waste management frameworks in countries such as Germany, Brazil, Jordan, and Morocco, shows the urgent need for wide reforms in Egypt's approach to garbage management.

Finally, some suggestion for the policymaker and the stakeholders can be formed as follow.

- Invest in Infrastructure and Technology: Determine a definite percentage of the national income for promoting waste management infrastructure, including the construction of proper sanitary landfills and recycling amenities. Operational efficiency can be enhanced by implementing smart technologies, like waste monitoring systems and automated sorting technologies.

- Developing an Integrated Waste Management System: to be an umbrella that joins different stakeholders, including government authorities, private companies, and civil community organizations, to ease garbage collection, sorting, recycling, and disposal processes.

- Track and Evaluate Progress: Create metrics to evaluate the efficacy of put strategies, permitting for continuous improvement and reworking of policies of the changed waste management needs.

- Enhance Public Awareness Campaigns: Put in place educational programs for increasing public knowledge about proper waste disposal practices, recycling benefits, and the environmental impacts of waste. Involving communities can help promote a waste management culture of accountability.

- Formalize the Informal Sector: Create channels for integrating informal waste collectors into the formal waste management system, offering them training, resources, and incentives to improve overall waste management outcomes.

- Strengthen Regulatory Frameworks: Enforce existing laws and develop new regulations that ensure compliance with waste management standards. Developing clear punishments for infractions to encourage accountability among waste management institutions.

By implementing these suggestions, Egyptian stakeholders can reduce the negative impacts on the environment, encourage sustainability in the community, and greatly raise the efficiency of municipal solid waste management.

Ethical Approval

This article agrees with the general ethical framework.

Consent to Participate

The authors have no objection to Participate this article.

Consent to Publish

The authors have no objection to publishing the article

Data Availability Statement

All article data are available in the references.

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There is no conflict of interest

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