Journal of Engineering Science and Technology
Special Issue on AIEC2024 Vol. 20, No. 1 (2025) 133 - 151

REDUCING LANDFILL SOLID WASTE TO MITIGATE THE GREENHOUSE GASES EMISSIONS TOWARDS ENVIRONMENTAL SUSTAINABILITY: A CASE STUDY FROM AJMAN - UAE

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Abstract

Landfills have significant environmental and social impacts due to their associated greenhouse gases (GHGs) emissions. This paper examines solid waste management using Ajman – United Arab Emirates as a case study. It emphasises the necessity of having waste assessment integrated with air quality assessment to monitor and regulate waste disposal procedures The paper examines waste accumulation, previous treatments & services provided at the Ajman landfill. Forecasts of waste accumulated at the landfill indicate a serious issue that needs immediate action from Ajman Municipality despite the low percentage of treatments currently performed. It was found that GHGs increased between 2017 and 2023, with a decrease in 2020 due to COVID-19. Additionally, the paper proposes an integrated waste management model that can reduce landfill-associated GHG emissions and their negative impact on the environment. Moreover, the research predicted that by 2035, Ajman will be able to handle 250,000 tons of waste per year. Moreover, it was indicated that Ajman's environmental trajectory can be improved significantly by capping the landfill.

Keywords: COVID-19, Environment sustainability, Greenhouse gases, Landfill, Municipal waste.

1. Introduction

Urbanisation and industrialisation have increased the amount of waste generated and the number of waste management facilities required to manage the generated waste. Municipal and industrial waste is commonly disposed of in landfills around the globe. Besides the threat landfill sites pose to soil and groundwater, they also emit gases and odours [1, 2].

Landfills are filled with a mixture of gases and odours produced by the anaerobic decomposition of solid waste [3]. Gases and odours are mainly generated from the biodegradation of organic matter in the waste [2, 4]. Globally, solid waste (SW) generation has continued to increase exponentially, with its statistic that stood at ~2 billion metric tons in 2016 and has been predicted to reach between ~3 and ~3.5 tons from 2030 to 2050, respectively [5], and 33% of that waste is not disposed of in an environmentally safe manner.

A significant impact could be caused by uncontrolled waste deposition since the formation of gas and leachate could pose a significant challenge to the waste management process in the future [6]. These activities may also pose considerable health hazards, as well as damage to vegetation, unpleasant odours, landfill settlements, pollution of groundwater, air pollution, and global warming [7-10]. According to the World Bank's new report, global waste will increase by 70% by 2050 [11]. Inadequate and improper Municipal Solid Waste (MSW) activities can damage the air, soil, and groundwater.

A circular economy is an economic system that aims to eliminate waste and continues to use available resources over a long period of time. In addition to building economic, natural, and social capital, the circular model is underpinned by a shift to renewable energy sources [12, 13]. Managing waste in an environmentally sustainable manner requires more than ensuring that waste is disposed of safely or recovered [14].

To achieve sustainable development, a hierarchy of objectives should be used; the waste management hierarchy puts a high priority on preventing waste. The hierarchy of waste application requires consideration of several factors: first, it must be prepared for reuse. Then, it must be recycled; then, it must be recovered; and finally, it must be disposed of [15].

2. Landfill and Associated GHG

Undoubtedly, health and well-being are closely related to economic growth and living standards in every community. It has been shown that poor SWM has a big impact on the health of an entire community, as well as on the economy of that community by extension. In addition, it has an impact on the local and global environment. There is evidence that SWM issues have much more significant effects on the economy than was previously thought. There are an increasing number of environmental problems, such as flooding, air pollution, contamination of groundwater, and the emission of unusually high amounts of greenhouse gases (GHGs) [16, 17]. Waste management is one of those sectors that has seen an increase in the amount of solid waste generated in almost direct proportion to the growth of the global population and the growth of the global economy. MSW management and the resulting emissions of greenhouse gases (GHGs) are responsible for an increasing number of gas emissions worldwide. In the coming decades, emissions of GHG resulting from solid waste management are expected to increase steadily.

Approximately 5% of the GHGs released by the MSW are attributed to this sector. It is now mainstream knowledge that anthropogenic emissions of GHGs are one of the key drivers of global warming. This has resulted in climate change with its attendant effects on the environment, biodiversity, lifestyle and livelihoods of humans. A key ingredient in this planning is the ability to accurately project waste generation rates [18]. GHGs are an important part of the Earth's climate system and help keep it a place where people can live. It's important to remember that GGs are not very opaque to the sun's rays. In addition to radiating into space, some of the radiation is absorbed by molecules of GHGs and sent back out. Two primary factors cause the greenhouse effect: carbon dioxide (CO_2) and water vapour (H_2O) [19].

There are three types of effects that can be identified: human health, environmental and socio-economic [20, 21]. Regarding human health, improper waste management can negatively influence human health (for example, decaying organic waste attracts mice, insects, and stray animals). Inadequate solid waste management (SWM) can be costly in terms of direct and indirect costs. Mismanaged solid waste systems are a missed opportunity for economic growth, including increased property values and tourism benefits from having clean streets and beaches. If implemented correctly, programs reducing waste can lead to cost savings in transportation, fuel costs, and cost recovery.

Additionally, due to the high organic content in the MSW, trash workers, rag pickers, and residents in the area are at risk of contracting infectious and chronic diseases [22, 23]. The uncontrolled mixing of hazardous and electronic wastes with solid trash is one of the most serious environmental problems that can cause chemical poisoning, low birth rates, cancer, congenital abnormalities, nausea, vomiting, and neurological illness [23], see Fig. 1.

Identifying potential emission points for a contaminant is the first step in an exposure evaluation. After identifying and locating the sources, the next step is to calculate how much of the harmful air pollutant was released during the study period and its distance from the source. Monitoring equipment or computer models are used to determine the amount of pollution discharged from a source and the amount of pollution at different distances from the source. Monitoring devices are used to determine the concentration of the pollutant in samples of air.

A landfill gas is produced due to the natural decomposition processes within a landfill [21]. Landfill gases are usually composed of 50-60% methane (CH_4), 40-50% carbon dioxide (CO_2), and 1% of other compounds to which the gas is a source of other odorous chemicals, including esters and hydrogen sulphide, may also be present in this gas [24].The presence of CH_4 in the atmosphere has an adverse effect on the climate of the planet. The release of CH4 can be attributed to a variety of anthropogenic (human-influenced) and natural sources. The sources of anthropogenic emissions include landfills, oil and gas infrastructure, agricultural practices, coal mining, stationary and mobile combustion, wastewater treatment, and certain industrial operations. The development of an efficient waste-air quality management system requires a thorough examination of several crucial components, as highlighted by recent studies [25, 26]. These components include socio-economic drivers, country-specific per capita waste generation, estimation of emissions, implementation of the latest sustainable waste management legislation, and adoption of circular waste management systems.

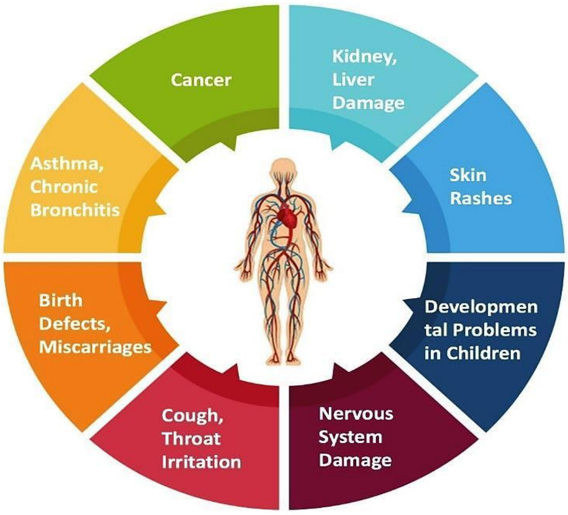

Fig. 1. The uncontrolled mixture of different types of waste associated with health impacts.

It is well-established that socio-economic factors significantly impact the generation of GHGs, and the amount released into the atmosphere. Previous research has shown that seasons also considerably influence the amount and composition of waste generated, with the summer season having a pronounced effect compared to spring and the rainy season having a less significant impact compared to winter [27] . Investigation has further revealed that middle- and low-income groups generate the most waste during winter, while high-income areas produce the most waste during spring, primarily due to increased food and yard waste generation during this time.

Effective SWM requires a comprehensive approach that considers various key aspects. However, the current literature still lacks a policy-focused analysis of SWM [28]. A comprehensive and specific legislative framework is needed to cover all elements of the waste management system, including generation, storage, collection, transport, processing, and disposal [29].

The legislation must consider all interrelated components of the waste management system, rather than just one particular element, to achieve its desired outcomes. For instance, recycling legislation should consider not just recycling but also other elements, such as waste segregation and collection, that may impact the success of the recycling policy. To ensure the effective implementation of such legislation, a specific law related to waste separation should be established to clearly define the responsibilities of the public in this regard [30].

If the ISWM method is implemented, a sustainable solution could be achieved. Depending on the nature of the selected site, the approach to IMSWM will be determined at this stage by considering the ecological and socio-economic factors that are in play at that particular site and the context in which the site will be positioned. Healthy cities can be built considering the IMSWM framework, which is essential to achieving sustainable cities [14]. The lack of available land and the growing public concern regarding landfill dumping further contribute to the problem [31]. Waste reuse and reduction must be included in the IWM. Emerging and industrialised nations need an IWM strategy to address the associated waste accumulation problem [32].

Due to the inclusive character of the IWM strategy, its application to waste management in developing nations is difficult, primarily due to the lack of appropriate data on trash generation and the need for financial resources [33]. If the IWM method is implemented, a sustainable solution could very well be achieved. Depending on the nature of the selected site, the approach to IWM will be determined at this stage by considering the ecological and socio-economic factors that are in play at that particular location and the context in which the site will be positioned [34].

This research aims to evaluate the waste accumulated in a selected landfill and its management practices. The goals are to evaluate the waste accumulated in a selected landfill with the historical position of waste management; to determine the quantity and types of emitted gases from the landfill, provide a schematic picture of the contamination levels with the most affected surrounding areas, and furthermore to develop an integrated waste management model to reduce the carbon footprint from the landfill.

The research methodology involves several key steps. First, collecting quantitative primary and secondary data for analysis on a specific landfill in Ajman, including information on the waste being landfilled, the age, condition of the landfill, local climate and weather conditions at each selected air-quality station. The second step is performing statistical analyses (including forecasting of future quantity of gases) to present GHG emissions from the landfill and identify areas with the most significant potential for their reductions.

3. Some good landfilling practices worldwide

Many countries use the landfilling method to dispose of waste. This involves burying the waste in a landfill, which can lead to environmental pollution. To reduce the environmental impact of landfills, countries should adopt more sustainable waste management practices such as recycling and composting. Landfills produce large amounts of Methane, a greenhouse gas that contributes to global warming and can have a negative impact on air quality. Additionally, leachate, a toxic liquid, can seep from landfills into groundwater and contaminate drinking supplies. By reducing waste and reusing materials through more sustainable practices, countries can help prevent these negative environmental impacts. For instance, there are initiatives such as the EU's Resource Efficiency Programme, which promotes sustainable resource management and encourages the use of resources such as energy, water, and materials in an efficient and cost-effective way.

3.1. The world cup park at Nanjido, South Korea

During 1990-2015, the number of landfills in South Korea was decreased from 623 to 287 with the implementation of several waste reduction measures, such as the volume-based waste charging in 1995. The Nanjido landfill was closed and restored to be a large open park hosting the 2002 World Cup [35]. Table 1 illustrates the main data of this park.

Table 1. Data on Nanjido landfill.

Parameter	value
Size	180 ha
Period of landfill operation	1978-1993
Restoration period after closure	1996-2002
Aftercare period	30 years
Usage	Park
Cost	187 million USD
Managing party	Government
Gas Collected	For district heating

3.2. The Fudekeng environmental restoration park in Taiwan

The number of landfills in Taiwan has also sharply fallen over the past two decades upon the implementation of several waste reduction initiatives and increasing waste incineration as a waste disposal measure. Fudekeng Environmental Restoration Park is particularly noteworthy because of its additional usage for the generation of renewable energy [36]. Landfill data are summarised in Table 2.

Table 2. Data on Fudekeng Environmental Restoration Park landfill.

Parameter	Value
Size	37 ha
Period of landfill operation	1985-1994
Restoration period after closure	1996-2003
Usage	2GWh Solar farm
Cost	14.76 million USD
Managing party	Government
Gas Collected	Electricity generation

3.3. Background on Ajman's landfill waste and air pollution data

Ajman is located within the UAE, covering an area of approximately 260 km2. The Emirate is situated within the northern part of the UAE and is surrounded by three other emirates, which comprise the Northern Emirates region. Ajman has limited land for development due to having the largest population in the Northern Emirates.

Landfill waste assessment is the process of assessing the amount of GHG emissions that are generated from a landfill site. It involves collecting data from the landfill site, analysing the data to determine the amount of GHGs emitted, evaluating the potential for GHG mitigation strategies, developing a landfill waste management plan, and implementing the plan to reduce the amount of GHGs emitted from the landfill. Landfill waste assessment is an important part of waste management that helps to ensure that landfills are operated in an environmentally responsible manner. Ajman produces various types of solid waste, and the current disposal, diversion, and recycling rates of this waste can help us better understand the waste management system of the Emirate.

The Ajman landfill has been the Emirate's main waste disposal facility since 2006, disposing approximately 1,200 tons of waste per day. Approximately

650,000 tons of waste are expected to be disposed of at this landfill by 2022, making it one of the UAE's most important waste disposal sites. Electronics and medical waste were classified as hazardous waste, along with domestic, commercial, and industrial waste. In addition to its use for waste disposal, the landfill also plays an important role in environmental protection due to its location in the desert.

To make the Ajman landfill as safe and efficient as possible, the Government has put several measures in place. This includes emergency measures to prevent fires and explosions and protective measures such as leachate and gas collection systems. The landfill is also regularly monitored to ensure that it is operating at optimal capacity and efficiency. In addition to the safety measures, the Ajman landfill also has an efficient waste collection system, which is designed to maximise waste diversion and reduce the amount of waste sent to the landfill. This includes initiatives such as recycling, composting and waste-to-energy programs. These initiatives not only help to reduce the amount of waste sent to the landfill but also help to promote sustainability and create a cleaner environment.

In addition, Ajman has introduced waste management laws and legislation to regulate the work of cleaning and waste management companies as well as the separation of demolition and construction wastes from their source. Contracting companies are required to provide adequate waste containers before starting any construction project under this local order. The digging or extraction of waste from the ground after it has been disposed of is prohibited. In addition, similar rules and decrees are applicable to hotels, commercial centres, hypermarkets, supermarkets, industrial establishments, etc. The authors' investigation further reveals that middle- and low-income groups generate the most waste during the winter season, while high-income areas produce the most waste during spring, primarily due to increased food and yard waste generation during this time.

Several countries have proven and are now employing landfill gas recovery systems, and these technologies have significant development potential in both developed and developing nations [32, 37]. As a future strategy for utilising existing landfills, this concept was considered as one of the strategies to be implemented within the model described in this paper. The authors have conducted a thorough survey of the landfill to comprehensively understand its history and status. As part of the historical review, initial data were obtained from local authorities and private companies to enhance the collected information with evidence and verification. Data were analysed to characterise the landfill's full description regarding dimensions and quantities of waste.

4. Research Methodology

4.1. Data acquisition

An aerial imagery survey carried out by authors using the latest technology supported by drones with a schematic layout shown in Fig. 2.

The drone was equipped with an HD camera to capture images of the landfill from the sky. The images were then stitched together to form a mosaicked composited map of the landfill. The survey revealed several features indicating the landfill's age and condition. The size of the landfill was determined to be approximately 6 hectares, with a depth of approximately 8 meters. The survey also revealed that the landfill was divided into three sections, each with a different level of activity. The northern section was identified as the most active, while the southern section was the least active.

Fig. 2. Technology supported by drones with a schematic layout.

The survey also revealed that the landfill had some areas that were heavily contaminated with materials. These areas were identified as the sections with the highest levels of contamination. The authors recommended that these areas be covered with an impermeable liner and sealed off to limit the spread of contamination. In addition, the survey revealed several other hazards and risks. The presence of plastic and other non-biodegradable materials in the landfill was identified as a potential source of contamination. In addition, the presence of hazardous substances, particularly heavy metals, was also detected.

4.2. Assessing waste-associated air quality

This study has collected data from seven locations spread across the city of Ajman where the quality of the air can constantly be monitored to enable a continuous monitoring of ambient air quality throughout the city. Five stations are in Ajman town centre, and two are located outside, as shown in Fig. 3.

Fig. 3. Air quality monitoring seven stations [38].

The authors have helped to set up and utilise an artificial intelligence vehicle at Ajman authority, shown in Fig. 4. It is an environmentally intelligent vehicle capable of transporting many innovative pieces of equipment and operating without human intervention. It represents a mobile laboratory. A smell identification device has also been added to measure odour data as well as other air quality elements.

Fig. 4. Ajman municipality and planning department mobile artificial intelligence laboratory [39].

5. Results and Analysis

5.1. Ajman's landfill topography, location and categories

Figure 5 shows a view of the landfill's available topography with layers. At its highest point, the site representative discovered 56.52 m of waste high at the site. The surrounding topography is approximately 20m above the datum (ground level).

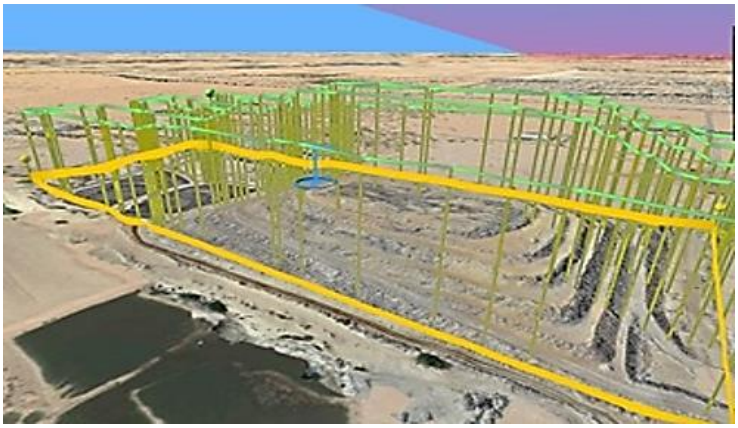

Fig. 5. Aerial view of the landfill available topography with layers.

Figure 6 shows the site location and the landfill waste categories, old and in-operation areas, with the estimated waste volume [38]. The main site is approximately 600 m by 300 m, along with a further area of approximately 400 m by 300 m to the west.

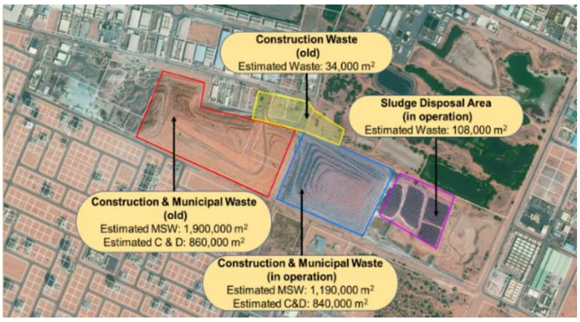

Fig. 6. Aerial imagery for the landfill's site location with estimated waste volume [38].

5.2. Ajman landfill waste quantities and analyses

The authors conducted a full survey of the landfill to get a complete description of its history and current situation obtained from the local authority and private sectors. The survey consisted of collecting live data for the existing amounts, measuring the areas for each category, recording the daily income of the waste for three months distributed over a year to calculate the waste input rate and estimating the volumes from the site measurements. These collected values were verified by comparing them with existing data from the Ajman Municipality. These data were analysed to characterise the landfill's full description about dimensions and quantities of waste. Table 3 shows quantities of disposed waste in Ajman collected by the authors.

Table 3. Calculated quantities of disposed waste in Ajman.

Items	Construction and Municipal Waste (In Operation)	Construction and Municipal Waste (Old)	Construction Waste (Old)	Sludge Disposal Area (In Operation)
Total area	119,000 m^2	172,000 m^2	34,000 m^2	27,000 m^2
Waste thickness	15-20 m	15-20 m	1 m	4 m
Total volume of construction and demolished waste	1,190,000 m3	860,000 m3	34,000 m^3	-
Total volume of municipal solid waste	840,000 m3	1,900,000 m3	-	-
Total volume of sludge	-	-	-	108,000 m^3
Estimated density of waste	0.6 tons/m3	0.7 tons/m3	0.5 tons/m3	0.18 tons/m3
waste quantity	1,218,000 tons	1,932,000 tons	3,400 tons	19,440 tons
Accumulative Total	**3,172,840 tons**			

The Ajman landfill is responsible for disposing of various types of waste. The quantities of disposed waste were determined by measuring the area in square meters, multiplied by the height to get the volume in m3. This volume was then converted to tons by multiplying it by the density. Table 3 presents the quantities of disposed waste at the Ajman landfill.

The total volume of refuse disposed of at the landfill was 3,172,840 tons, which has important implications for waste management in the Ajman area. Proper management of waste is essential to ensure a clean and healthy environment. By accurately determining the amount of disposed waste, decision-makers can use this data to plan and implement more effective waste management policies.

5.3. Types, quantities and analyses of Ajman's solid waste data

This type of waste is believed to include items that can be reused and recycled, such as glass and metal containers, plastic bottles, and paper (see Fig. 7).

The authors verified the quality of the collected data and found that a Weighbridge recording system was implemented at every point of disposal, treatment, or transfer. A Weighbridge records the weight of different types of waste and recyclable materials entering the facility. A central database was integrated with each weighbridge. The registration plates of each vehicle were scanned as it passed over the weighbridge to determine if the company has permission to bring waste types (identified by classification system numbers) to specific disposal or treatment facilities. According to Fig. 4, the most important waste categories are MSW, IW, and other waste, depending on the quantity of waste.

In 2022, the volume of MSW waste makes up 42.9% of the total, while other waste makes up 29.6% and industrial waste 12.8%. The results also indicate that the amount of disposed waste has been increasing between 2017-2019. During the period 2019-2020, COVID-19 led to a decrease in waste generated. The Ajman authority has determined that medical waste will be treated as hazardous waste and will be sent to an incinerator for medical waste in 2019-2021.

In 2017, the total amount of disposed waste was 435,000 tons; in 2022 it increased to 650,000 tons. This increase is likely due to population growth, urbanisation, and increased industrialisation in the area. The results of this study have important implications for waste management.

The Ajman Municipality has implemented several initiatives to reduce waste generation, including waste collection and segregation, waste reduction and recycling, and reusing waste. Based on the Materials Recovery Facility data, recycling rates have increased from 2.9% in 2019 to 3.0% in 2020, 4% in 2021, 5% in 2022 and 11% in 2023. Ajman hopes to increase its recycling rate and reduce the amount of waste sent to landfills. Figure 7 portrays the major types of waste, i.e. MSW, IW, AG, IHW and other waste.

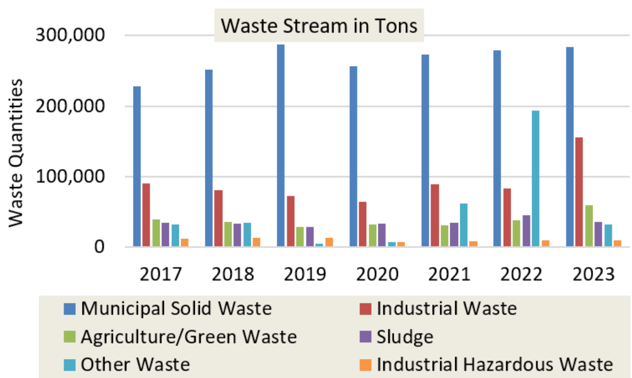

Fig. 7. Type of waste and quantities at the Ajman landfill from 2017-2023.

Figure 7 shows that all types of waste delivered to landfills decreased in 2020. Tourism activities decreased in 2020 because of the Covid-19 pandemic, resulting in a decline in tourism-related municipal waste. In addition, building construction activities were restricted during that period. The following two years were evidently marked by an increase in these amounts as such restrictions were lifted.

5.4. Forecasted waste

The forecasting procedure looks at long-term accumulations of waste. To calculate the impact of waste reduction efforts in tons of carbon dioxide avoided, the Stop Waste Partnership GHG calculator can be used [40]. Figure 8 exhibits the forecasts for up to 2035 (based on the available data for the period (2017-2022).

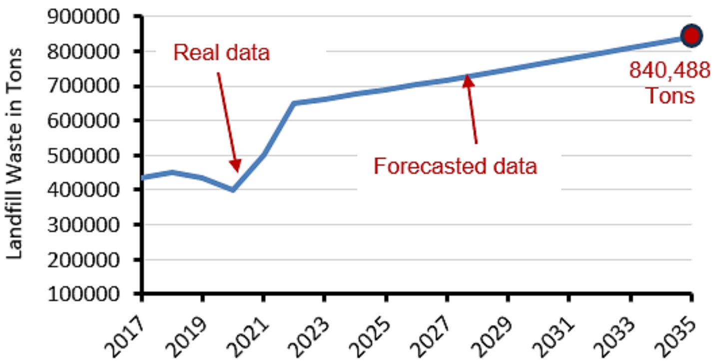

Fig. 8. Forecasted waste in Ajman landfill from 2022 to 2035 (in tons).

According to these forecasted data, Ajman Municipality should consider mitigation and waste treatment strategies to prevent future waste accumulation. To maintain sustainable waste management over the long term, these strategies must be based on concrete policies and future innovative solutions, which specialists review annually for continuous improvement. Consequently, reducing the waste could substantially impact achieving the desired level of sustainability.

5.5. Quantitative analysis for Ajman's landfill emitted gases

Figure 9 shows the GHG emission from the total waste quantities (in tons), along with their quantities avoided by treatment and % treated for 2017-2023. It is clear from Fig. 9 why the treated waste is fluctuating. However, the percentage of treatment is low, indicating a need for an efficient treatment strategy to be introduced for the waste management system in Ajman. Gaps and issues are uncovered and require proper strategic plans to be addressed. The above figures demonstrate three categories of gas-associated waste types. GHG gases are the leading essential gases to be considered. The low percentage of GHG indicates that Ajman's waste management system is not sufficiently equipped to process the amount of GHG waste it produces. This could lead to elevated levels of GHG emissions and have a negative impact on the environment.

Looking at the results shown in Fig. 9, GHG has been at a high level for the period 2017-2022 but decreased in 2023. However, the increase in the level of gases between 2017 and 2019 was followed by a considerable reduction in 2020 as the amount of

MSW was less over the COVID-19 period, indicating evidence that possible reduction can be achieved if the right mitigation policies for MSW are adopted.

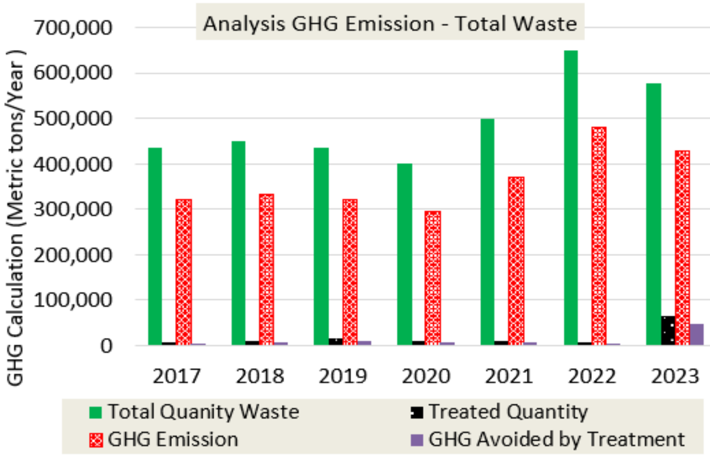

Fig. 9. GHG emissions corresponding to the total waste.

5.6. Integrated waste management in Ajman (IWM)

5.6.1. First stage towards a zero landfill

The Integrated Waste Management framework (IWM) is an approach to managing waste that minimises its environmental impact and maximises resource recovery and sustainability. It involves a systematic and coordinated approach that considers all aspects of waste management, from generation to disposal. As part of the IWM, various strategies and practices are incorporated to ensure efficient and effective waste management.

Ajman Municipality has been the main driver for implementing the IWM framework. Through implementing various waste management strategies, such as waste segregation, reduction of waste generation, and efficient waste disposal, the Municipality has achieved its goal of reducing waste and improving sustainability [38]. Table 4 shows the total waste quantity in tons for 2022, as well as the percentage of treated waste.

Table 4. Total amount of waste in tons for 2022 and the percentage of waste treated.

Waste Stream in Tons	Max Capacity	2022	%	2035
Reduce, Reuse & Recycle (3R)	400,000	245,180	37.72	317,166
Organic Waste	250,000	240,500	37	311,112
Non-Recyclable Material (Incineration)	200,000	164,320	25.28	212,565
Total Waste		650,000	100	840,844

Additionally, it involves using technologies for waste reduction, reuse, resource recovery, and disposal. IWM aims to encourage using clean, green, and safe waste management practices throughout the entire life cycle of waste. While achieving its intended objectives, it seeks to minimise the environmental impacts of waste management. Figure 10 portrays integrated waste management.

Figure 10 shows that it is predicted that a waste to energy facility with 250,000 tons/year capacity in Ajman can withstand all expected waste until year 2035. To reach zero landfills, we must stop to prevent the supply of 650,000 tons of waste from going to the landfill and then dispose it in the following ways. For the waste collection station, where 650,000 tons of waste are collected and recycled, about 37.72% of the total waste received is sorted at the station. After sorting, the remaining waste is divided into two sections; the first (Organic Waste) contains 37% heat treated to produce organic fertilizer. The second section (Non-Recyclable Material) is estimated at 25.28% and burned in waste-to-energy incinerators, resulting in ash waste.

To achieve zero-waste going to the landfill, the ash waste is to be used in construction for building and paving materials. The amount of waste generated by 2035 is expected to reach 840,844 tons. The material recovery facility (MRF) capacity for 2035 is expected to be 840,844 tons, which means that it will be unable to handle the increased amount of waste generated.

Meanwhile, the Ajman municipality should be able to allocate funds to expand the MRF facility to receive all this amount of waste to reach the net-zero landfill

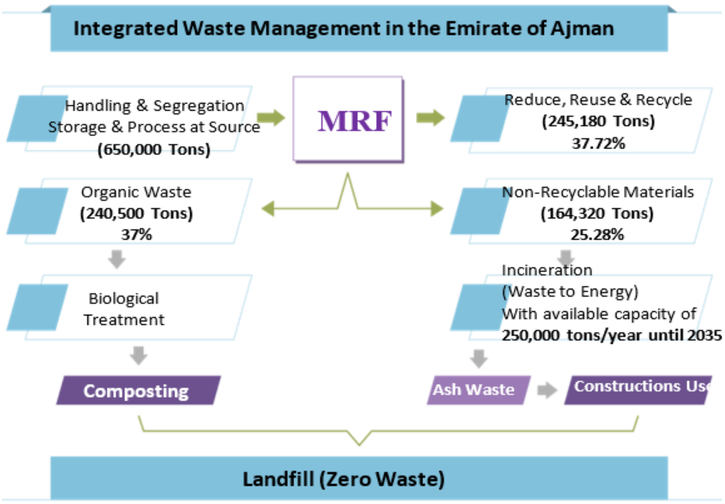

Fig. 10. Integrated waste management (IWM).

5.6.2. Second stage towards a zero landfill: Capping the Ajman landfill

Ajman's environmental trajectory can be improved significantly by capping the landfill. It offers a range of critical benefits through a multifaceted approach backed by research. The first big advantage is the reduction of greenhouse gas emissions because proper capping methods can effectively mitigate Methane release by 90%, significantly reducing its warming potential on leachate management [41].

Secondly, this initiative contributes to public health by decreasing contaminant exposures, such as dust, volatile organic compounds (VOCs), and Methane, improving air quality and minimising health risks. Additionally, capping helps prevent the spread of vector-borne diseases by eliminating breeding grounds for insects and vermin. Stabilised landfills post-capping can be utilised for various purposes, including green spaces, recreational facilities, or even renewable energy projects. Examples include New York City's Fresh Kills Park and Barcelona's La Trinitat Park, which demonstrate the potential for Land Reclamation and Reuse.

Finally, Biodiversity Enhancement emerges as a key outcome, as capping not only creates new habitats for diverse flora and fauna, [42] but also amplifies ecosystem services by improving air and water quality, reducing noise pollution, and counteracting urban heat islands, resulting in a healthier environment.

6. Conclusions

Landfills are a primary method of waste disposal in Ajman and across the UAE, but they could have adverse effects on human health and the environment, particularly on-air quality. This paper aimed at exploring this issue with a practical case on Ajman landfill by reviewing the amount of waste accumulated at that location with the historical recorded services and treatments done at that site. Statistical results showed that decreasing the amount of waste directed to the landfill can have a positive impact in decreasing the GHG gases generated from the landfill. Two scenarios were suggested as an alternative solution; the first was initiating an integrated waste management (IWM) which has been proved to achieve zero waste to landfill. The second was capping the Ajman landfill and utilising the capped area will be utilised for a future solar farm. The authority is advised to follow the right procedures that assure the treatment, starting from the source of the waste to the end of the process, should be effective to empower the treatment procedure. This includes assuring proper waste collection, management and effective treatment, using state-of-the-art treatment plants, segregation from source initiative, customer enterprise resource planning services, and providing waste-type bins according to the area residential, industrial, construction, hotel and restaurant areas, etc. The paper showed the necessity of having waste assessment integrated with air quality assessment to monitor and regulate waste disposal procedures. A landfill cap provides wildlife habitat and promotes erosion control by applying impermeable covers and native plant layers.

It is recommended that to develop an effective waste-air quality management system, the municipality of Ajman should consider socio-economic drivers, waste generation patterns, emissions estimation, and comprehensive legislative frameworks. Future research studies in this field can include, but is not restricted to the following projects

- Waste management strategies implementation effectiveness
- Smart GHG gas calculation on the landfills
- Waste management towards zero landfill

Acknowledgement

The authors would like to express their utmost gratitude to Ajman Municipality and Planning Department for their continuous support, the resourcing of data and for granting access to some of their facility.

Abbreviations

AW	Agriculture/Green Waste
C&D	Construction and Demolished Waste
C&I	Commercial and Industrial
CH4	Methane Gases
GHG	Greenhouse Gases
IWM	Integrated Waste Management
IW	Industrial Waste
MRF	Materials Recovery Facility
MSW	Municipal Solid Waste
SW	Solid waste

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