PORT SAID ENGINEERING RESEARCH JOURNAL

Faculty of Engineering - Port Said University
Volume 29 No. 3 pp: 102:119

Environmental Impact Assessment of Municipal Solid Waste Management in Port Said: A Sustainable Comprehensive Approach

Shaimaa R. Nosier [1, *]

[1] *Assistant Professor in Architectural Engineering and Urban Planning Department, Faculty of Engineering, Port Said University, Egypt. Port-Fouad, POST NO:42523. E-mail: Shaimaa.Nosier@eng.psu.edu.eg*
ORCID. https://orcid.org/0000-0001-8094-9950
**Corresponding author, Email address, DOI: 10.21608/pserj.2025.351467.1387*

Received 8-1-2025,
Revised 3-2-2025,
Accepted 25-3-2025

© 2025 by Author(s) and PSERJ.

This is an open access article licensed under the terms of the Creative Commons Attribution International License (CC BY 4.0).
http://creativecommons.org/licenses/by/4.0/

ABSTRACT

Environmental Impact Assessment (EIA) plays a vital role in sustainable development by evaluating potential environmental impacts. Municipal solid waste (MSW) constitutes a significant environmental challenge, presenting serious environmental, economic, and social effects that influence global environmental balance. Given the global general agreement on the necessity of EIAs for such projects, as reflected in various legal and regulatory frameworks, this research digs into the EIA of the MSW management system in Port Said Governorate, Egypt. The study proposed a comprehensive approach to sustainable waste management. A sustainable and integrated solid waste management (S-ISWM) system involves three primary stages: First, Quantifying MSW: Analyzing statistical data on population, commercial, industrial, and service establishments. Second, Evaluating MSW Management System Efficiency: Assessing the existing systems environmental, health, social, and economic impacts. Third, Exploring Technical Alternatives: Investigating potential technical for the integrated MSW management system in Port Said. The research concludes by offering recommendations to mitigate environmental impacts, the priority is minimizing consumption and waste, and then recycling (maximizing the use of produced elements), with a focus on sustainable architectural and construction elements in recycling to preserve resources and recover energy., considering advanced alternatives, and promoting public participation. This contributes to an effective EIA system in Egypt, particularly in Port Said, while safeguarding the environment and natural resources for present and future generations.

Keywords: Environmental Impact Assessment (EIA), Pollution abatement, Egyptian Environmental Affairs Agency (EEAA), Management of municipal solid waste (MSW), Sustainable and integrated Solid Waste Management (S-ISWM), Public-Private Partnership (PPP), Civil Society Organization (CSOs).

1 INTRODUCTION

The natural environment, in its normal state without destructive or harmful human intervention, is considered balanced. Each element of the natural environment is created with specific characteristics and a certain amount to ensure its equilibrium [1,2]. This is affirmed by the following verse from the Quran [3]: "And We have created everything in due measure" (Al-Furqan, verse 2) and "And the earth We have spread out (like a carpet); set thereon mountains firm and immovable; and produced therein all kinds of things in due balance" (Al-Hijr, verse 19).

The "Global Waste Management Outlook 2024" report by the United Nations Environment Programme titled "Beyond Waste: Transforming Waste into Resources" provides the latest update on global waste generation, cost, and management since 2018. The analysis utilizes life cycle assessments to explore what the world could gain or lose by continuing with business as usual, adopting halfway measures, or committing to waste-free and circular economy communities.

According to the report, municipal solid waste production is expected to grow from 2.3 billion tons in 2023 to 3.8 billion tons by 2050. In 2020, the global direct cost of waste management was estimated at around 252 billion US dollars. However, when adding the hidden costs of pollution, poor health, and climate change from bad waste disposal practices, the cost rises to 361 billion US dollars. Without urgent action on waste management, by 2050, this global annual cost is projected to almost double to 640.3 billion US dollars [4]. Pollution has become one of the most pressing environmental problems, with serious environmental [5], economic, and social dimensions, especially in recent times [6], which usually leads to the deterioration of the ecosystem and the disruption of global environmental regulation [7].

Hence, Through national, regional, and global action plans, legal, regulatory, and executive frameworks for environmental affairs in all countries have agreed on the necessity of conducting environmental impact assessments for new projects, major expansions, and sensitive renovations, even for existing projects [8,9], in the early stages of the planning process to regulate the relationship between the environment and development to achieve sustainable development and meet current requirements without sacrificing the ability of future generations to meet their needs [10,11]. The choice of applying the scope in Port Said Governorate because it is considered more fortunate than other Egyptian governorates, as it is always a nucleus for successful experiences in all projects and presidential initiatives. significant expansions, and sensitive renovations, even for existing projects, at an early stage of the planning process.

1.1 The Research Problem: The problem of study concentrates on the increasing of waste generation and improper waste disposal which leading to various environmental and health problems [12], economic losses [13], and environmental degradation. Port Said has witnessed development in various sectors and fields, making it imperative to address the issue of the environmental impact of solid waste, as it may negatively impact tourism and the quality of life in general there.

1.2 Research objective: The aim of this study is to assess the environmental impact of the inadequate management of solid waste in Port Said Governorate to protect the environment of the governorate.

2. BASIC CONCEPTS OF ENVIRONMENTAL IMPACT ASSESSMENT

Environment: The all living surroundings as living organisms, materials, air, water, soil and the man-made structures within it [14, 15].

Environmental pollution: Any changes in the environmental properties that may directly or indirectly harm living organisms, infrastructures, or affect human activities in their life [16, 17].

Environmental Preservation: Protection and enhancing environmental components [18], and reducing the severity of pollution [19] to prevent Environmental degradation.

EIA is a vital tool for sustainable development. It assesses a project's environmental impacts, identifies mitigation measures for negative impacts and enhances positive ones, and ensures environmental soundness and human health protection.

3. THE IMPORTANCE OF THE ENVIRONMENTAL IMPACT ASSESSMENT PROCESS (FOR DECISION-MAKERS, INVESTORS, SOCIETY, AND THE ENVIRONMENT)

The environmental impact assessment is an important process in providing decision-makers with comprehensive information to make informed decisions, assisting investors in managing risks and liabilities, facilitating public participation, and ensuring a balance of economic development [20] with environmental sustainability. Below the following highlights the significance of the EIA process for decision-makers, investors, society, and the environment [21, 22,23] as illustrated in Fig. [1].

3.1 Decision-Makers: It provides crucial information to make informed decisions and balance development with environmental protection [24].

3.2 Investors: It helps them to identify risks, ensure regulatory compliance, and enhance project character [25].

3.3 Society: It safeguards public health and empowers public participation [26].

3.4 Environment: It encourages sustainable practices and protects ecosystems, resources, and biodiversity [27].

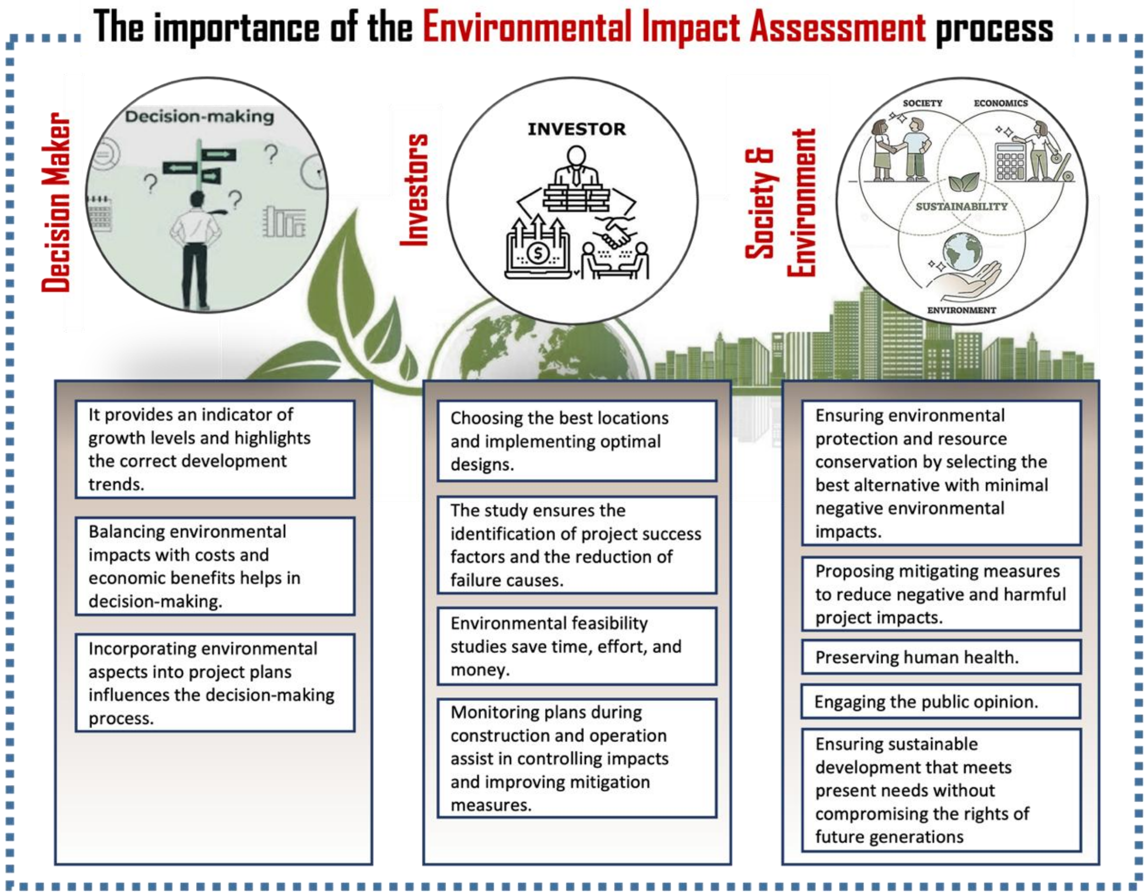

Figure 1: The importance of the environmental impact assessment process (for decision-makers, investors, society, and the environment. Source: Author according to [25,27,28,29]

4- THE EGYPTIAN PROCEDURES FOR CONDUCTING AN ENVIRONMENTAL IMPACT ASSESSMENT (EIA) FOR PROJECTS

The starting point for the Egyptian government's efforts to bridge the gap between projects and the environment is the issuance of Law No. 4 of 1994, by establishing a system for assessing the environmental impacts of projects as illustrated in the Fig. [2]. The law aimed to [28,29]:

- Compel industrial institutions to modify their systems by legal standards and limits.
- Mitigate future environmental problems through environmental impact assessments for new projects or existing expansion works.

EIA is considered a strategic tool relied upon by the Egyptian Environmental Affairs Agency as a preventive activity. It is applied to assess the impacts of projects or development activities and identify the necessary measures to mitigate negative impacts and maximize positive effects.

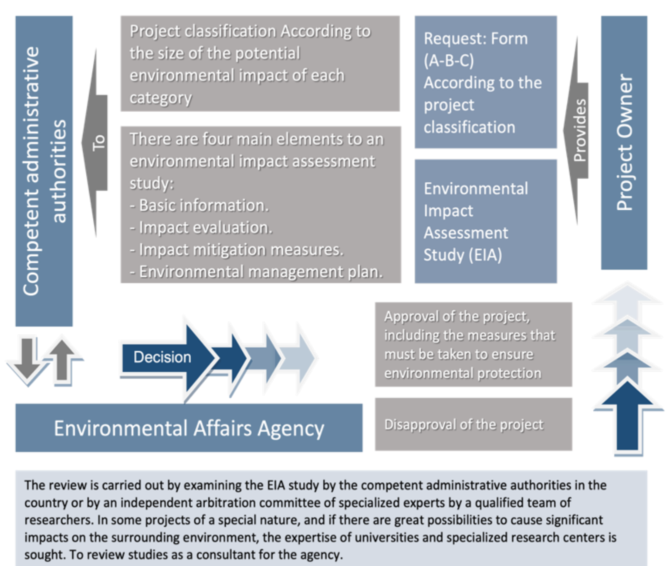

Figure 2: Environmental Impact Assessment (EIA) procedures for projects in Egypt. Source: Author according to [30, 31,32,33].

5. HOW TO CLASSIFY PROJECTS? [34]

projects are classified in (EIA) process based on their potential environmental impacts. The ERs of Law 4/1994 identify projects which should be subjected to an EIA based upon the following main principles:

A. Type of activity undertaken by the establishment.
B. The extent of exploitation of natural resources.
C. The project Location.
D. The type of energy used to operate the project.

The classification adheres to the guidelines and regulations established by (EEAA). The classification involves the following steps:

5.1 Screening: In this step, it is determined whether a project requires a full EIA, by checking if the project falls within specific sectors like industry, energy, infrastructure, agriculture, tourism, or waste management.

5.2 Scoping: The scoping process is identifying the potential environmental impacts associated with the project. With the EEAA and relevant stakeholders, the project proponent assesses the project's activities, location, and possible impacts.

5.3 Categorization: The EEAA has established comprehensive principles for assessment, which include the following pillars:

- Defining the environmental impact assessment system for the project objectives.
- Establishing procedures and regulations for the environmental impact assessment
- Classifying projects based on their environmental impact and the level of assessment. as outlined in Fig. [3].

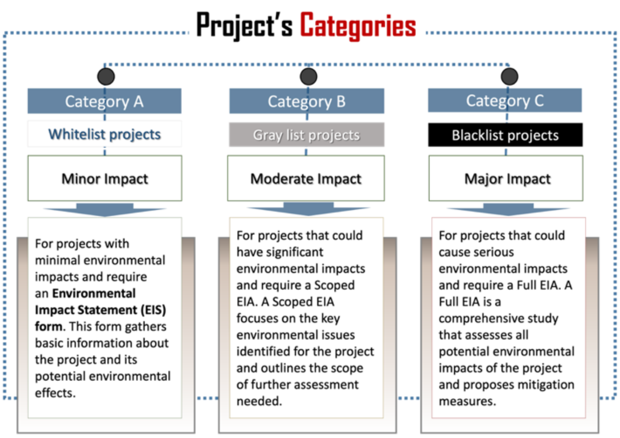

Figure 3: Projects classification. Source: Author according to [34,35].

The EIA system classifies the projects into three categories based on different levels of EIA requirements according to the severity of possible environmental impacts and location of the establishment and its proximity to residential settlements [34]:

5.3.1 Category (A): projects with minimum environmental impacts. These are required to complete an environmental impact assessment form A.

5.3.2 Category (B): projects with potentially adverse environmental impacts yet less adverse than Category C. These are required to fill out the Environmental Impact Assessment Form B completely.

5.3.3 Category (C): projects which have highly adverse impacts. These projects should prepare a comprehensive Environmental Impact Assessment (EIA) study.

The classification of projects is based on specific criteria and Illustrative lists of projects have been provided to guide project proponents.

5.4 Public Consultation: This step is essential. The project proponent is required to engage with the affected communities, stakeholders, and the public to gather their inputs and incorporate them into the process of decision-making.

5.5 Decision-making: After the EIA study and public consultation, the EEAA reviews the study and decides on project approval, which may include conditions, mitigation measures, or rejection.

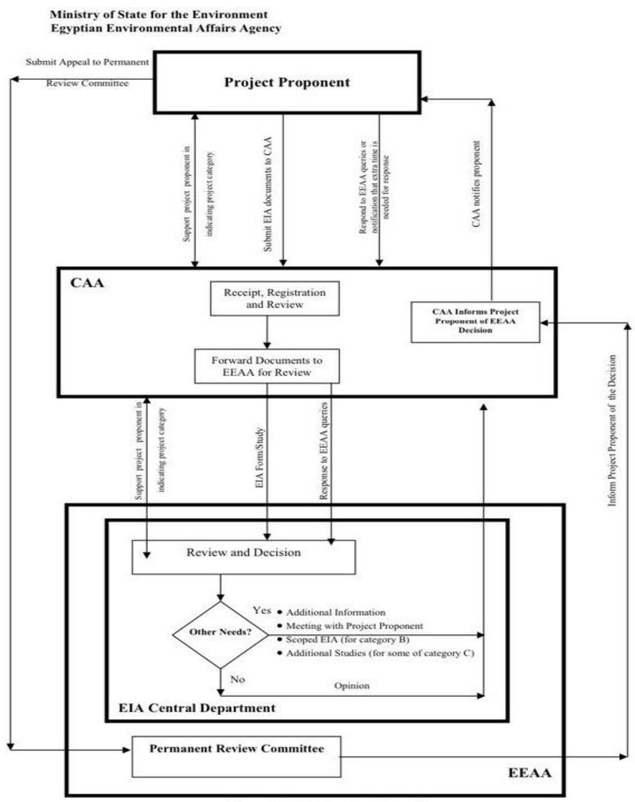

Figure 4: EIA system procedures. Source: [34].

6. SOLID WASTE MANAGEMENT

Solid waste is one of the major challenges that directly impacts the environment and public health. Therefore, assessing the environmental impact of solid waste becomes crucial, as it helps identify potential risks and enhances mitigation strategies. Sustainable waste management and preserving the environment can achieved by following effective steps [35].

6.1 Integrated Solid Waste Management (ISWM):

SWM involves a sustainable safe management of waste from generation to disposal, careful planning and implementation are required for effective waste management, taking into considering factors such as population size, economic conditions, and available technology.

6.2 Municipal Solid Waste (MSW):

Solid or semi-solid materials are refered to MSW. These materials include [36]:

- **Household waste:** Food fragments, paper, plastic, metals, glass, etc.
- **Commercial waste:** Food fragments, packaging, paper, plastic, etc.
- **Institutional waste:** Food fragments, paper, plastic, office furniture, etc.

MSW does not include:

- **Medical waste:** Surgical waste, needles, infectious waste.
- **Dangerous waste:** Chemicals, medical waste, radioactive pollution.
- **Industrial waste:** Factories and agricultural waste.

The percentages of solid waste contents vary significantly between countries as illustrated in Table [1], depending on various factors such as:

- Consumption habits is affected the type and quantity of waste produced.
- Countries economic growth level, countries with high economic growth level produce more waste.
- Waste management infrastructure affects how waste is treated and disposed of.

Table 1. percentages Composition of Municipal Solid Waste for some countries in 2023. Source: [37, 38, 39, 40, 41,42].

Country	Paper	Organic Waste	Ash	Metals	Glass	Other Materials
Egypt	10%	55%	10%	5%	5%	15%
United States	25%	28%	12%	8%	7%	20%
United Kingdom	23%	30%	10%	6%	7%	24%
China	12%	60%	8%	4%	3%	13%
India	6%	50%	15%	4%	2%	23%
Germany	18%	45%	12%	7%	7%	11%
Saudi Arabia	15%	50%	17%	5%	4%	9%

7. EVALUATING THE EFFICIENCY OF MUNICIPAL SOLID WASTE MANAGEMENT SYSTEMS IN PORT SAID (PUBLIC LANDFILL) BY ANALYZING AND ASSESSING THE ENVIRONMENTAL, HEALTH, SOCIAL, AND ECONOMIC IMPACTS RESULTING FROM THEM.

The research examines the environmental impact of inadequate solid waste management. Improper waste disposal can lead to health issues, economic losses, and negative impacts on tourism. Based on all of the above, it was formulated the **Methodology for assessing the efficiency of solid waste management systems in Port Said** is divided into a set of stages, as shown in Fig. [5].

The first stage: Data collection phase. The second stage: Analysis phase, the third stage: Mitigation plan phase, and the final stage: consists of two parts; the first part is a proposal for a comprehensive framework for the waste management system in Port Said, while the second part is a proposal of Utilizing Recycled Materials in Architecture and urban design. The latest reports and periodic statistics provided by the Waste Management Administration in the governorate were relied upon, in addition to the statistics from the company contracted with the governorate for waste collection and disposal in December 2024.

7.1 STAGE 1: Data Collection Phase:

7.1.1 Basic Data for Port Said [43]:

- Area: 1351.14 km²
- Population: 801,436 inhabitants
- Generated Waste Quantity: 730 tons per day as periodic statistics provided by the Waste Management Administration in the governorate.
- Administrative Boundaries for Service Areas: (Port Fuad City, AL Sharq District, West District, South District, Zohour District, Monakh District, Arab District, Dawahi District).

7.1.2 Stakeholders and Responsible Entities for Solid Waste Management [44]:

- Local Government Authorities: Responsible for overall waste management policies, regulations, and oversight.
- Waste Management Administration: Manages and coordinates waste collection, transportation, and disposal activities within the governorate.
- Contracted Waste Management Company [Zero Carbon Company]: Responsible for collecting solid waste and garbage in the governorate under the contract signed between the company and the governorate. A central unit was formed to monitor the implementation of the company's contract, headed by the Secretary-General.
- Districts Administration within the administrative boundaries of each district.
- The Environmental Affairs Department and the Health Affairs Directorate in the governorate are responsible for Ensures compliance with environmental regulations and standards related to waste management and recording violations resulting from deficiencies in waste collection and safe disposal of hazardous medical waste.

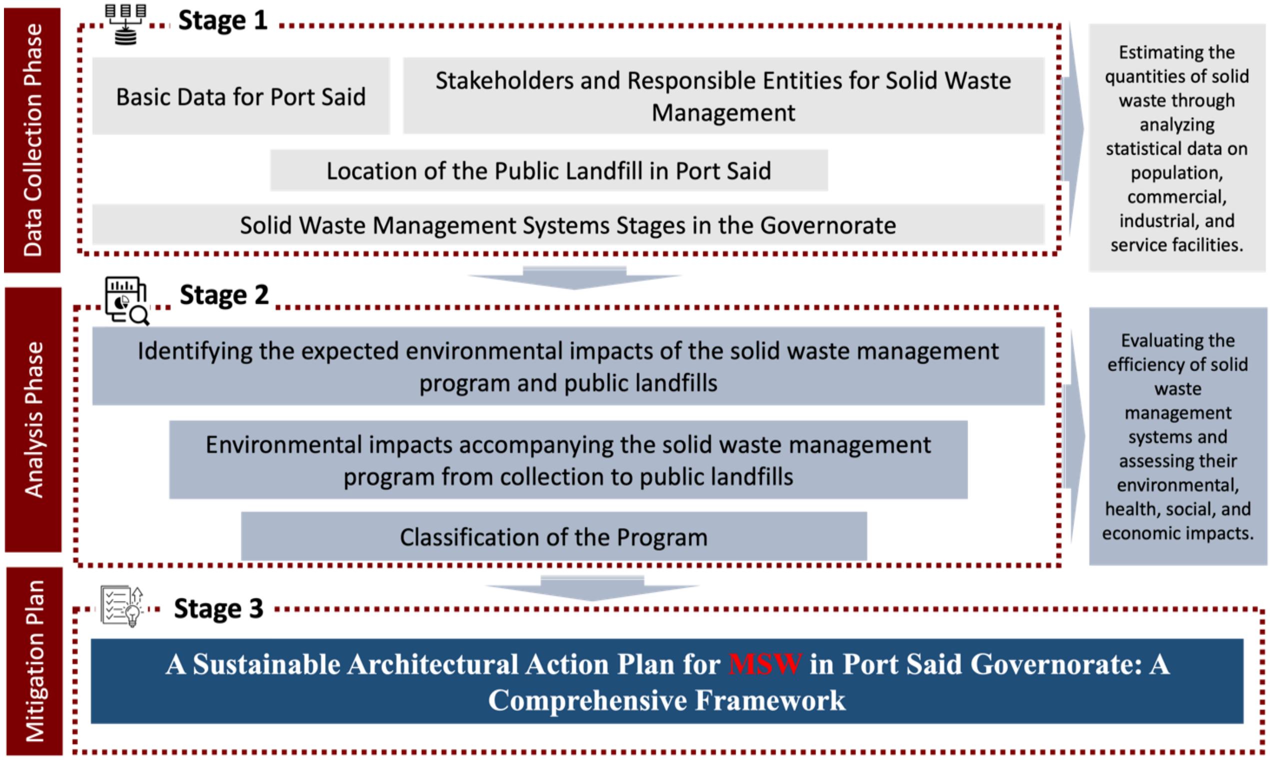

Figure 5: Methodology for assessing the efficiency of solid waste management systems in Port Said. Source: [Author].

7.1.3 Location of the Public Landfill in Port Said: The public landfill and sanitary burial site are a stage in the solid waste management system in Port Said. It is located at kilometer 14. The treatment plant is located in the Abu Auf area, northwest of the governorate, overlooking Lake Manzala from the south. It is also located near the new wholesale market and the new cemeteries.

7.1.4 Solid Waste Management Systems Stages in the Governorate: This system illustrated in Fig. [6] includes:

7.1.4.1 Primary Collection: This phase involves gathering waste from residential areas, public spaces, commercial establishments, government institutions, industries, schools, hospitals, etc. This is done by small trucks or by placing large containers for waste accumulation. Street sweepings and waste from small street baskets are collected using trolleys and transferred to larger vehicles. The collected waste is then transported to a processing plant for sorting, classification, and preparation for reuse or recycling.

7.1.4.2 Collection inside intermediate stations and Transportation: Intermediate containers with a capacity of 1.1 m^3 are used to collect waste then transferred to larger compactors and transported to a fertilizer plant for processing. Some waste may be transported to public landfills for disposal. The organic waste is processed to produce soil fertilizers.

7.1.4.3 Treatment and Recycling facilities: Intermediate containers with a medium capacity of 1.1 m3 are used. The waste from these containers is emptied into Compactors with a capacity of 25 m3, designed to receive garbage from these trucks without human intervention. The waste is then transported to the fertilizer plant.

- Landfill Disposal: The waste is transported to a public landfill for disposal.
- Fertilizer Production: Organic components of the waste are processed to create organic fertilizer.

7.1.4.4 Stages of the sorting process flow: The solid waste is transported to the plant for sorting, classification, and separation for reuse or recycling. In this stage, the following steps are taken:
A. Receiving and unloading the solid waste at the plant.
B. Weighing the waste.
C. Recording the Weight of the Waste.
D. Sorting and classifying the waste according to size and type as follows:

- Large-sized waste: Stored.
- Small-sized waste: Separated using sieves and then transferred to the organic fertilizer area for soil enrichment.

E. Feeding the Waste Recycling Line.
F. Waste Screening.
G. Mechanical/manual sorting of waste (includes plastic, PET, tin, metals, glass, paper, etc).
H. Alternative Fuel (RDF) Production: Transporting Waste to the Cement plant.

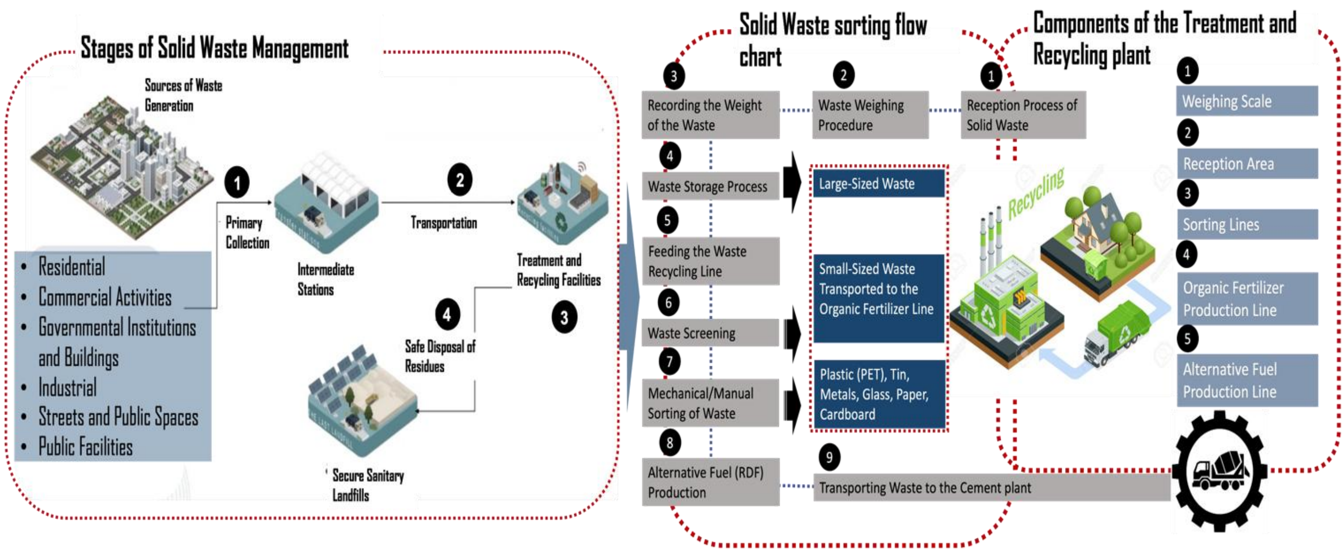

Figure 6: Stages of solid waste management. Source: Author according to [Periodic Report of Solid Waste Management in Port Said Governorate]

7.2 STAGE 2: Analysis Phase:

7.2.1 Identifying the environmental impacts expected of the SWM program and public landfills

Factors affecting the aggravation of the SWM problem in Port Said:

8.2.1.1 Population Growth: Port Said has experienced a massive population boost to 800,000 by this year (2024), According to the statistics issued by the governorate for December 2024, and by comparing the population density and the volume of waste, illustrated in Fig. [7] the volume of solid waste is directly proportional to the population

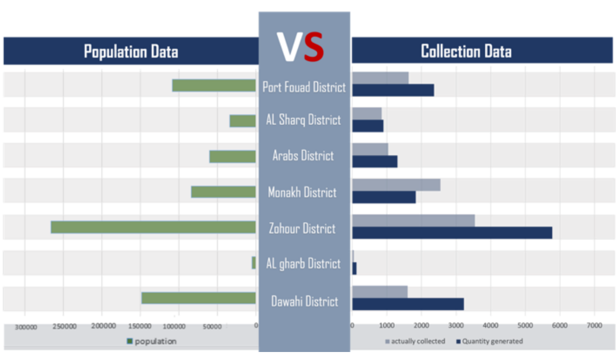

Figure 7: The volume of solid waste in the neighborhoods of Port Said Governorate per ton compared to the number of residents in each neighborhood. Source: Author according to [Periodic Report of Solid Waste Management in Port Said Governorate]

8.2.1.2 Urban Planning and Street Design: The presence of numerous narrow streets and passage obstacles efficient waste collection and transportation.

7.2.1.3 Socio-behavioral Factors: Public awareness about waste management and proper disposal practices is still deficient. By comparing the latest report issued by the Ministry of Environment in 2007, Table [2], and the report issued by the contracting company in December 2024, Table [3], it appears one of the major behavioral problems currently occurring in Port Said that affects the waste quality of the waste is the scavengers who pick out valuable waste, and affect the characteristics and quality of the waste.

Table 2. The solid waste Characteristics [2007]. Source: [45]

Waste Characteristics	Paper	Glass	Metal	Wood	Organic Waste	Plastic	Waste-derived Fuel	Residual Waste
Percentages	12.15 %	12.38 %	19 %	15.8 %	10.04 %	16.25 %	13 %	1.38 %

Table 3. The solid waste Characteristics [December 2024]. Source: Zero Carbon Company for Waste Management [monthly report].

Waste Characteristics	Paper	Glass	Metal	Wood	Organic Waste	Plastic	Waste-derived Fuel	Residual Waste
Percentages	0. 4 %	1 %	1 %	0.3 %	65 %	12 %	12 %	8.3 %

7.2.1.4 Economic Factors: Limited financial resources affect the implementation ability of efficient waste collection, transportation, and processing systems.

7.2.1.5 Technical Factors: Inefficient waste collection, transportation, and treatment methods, coupled with inadequate landfill design, contribute to the challenges in waste management.

7.2.2 Environmental impacts accompanying the solid waste management program from collection to public landfills. The environmental impacts accompanying the solid waste management program and public landfills can be divided into several types as the following Fig. [8] illustrated:

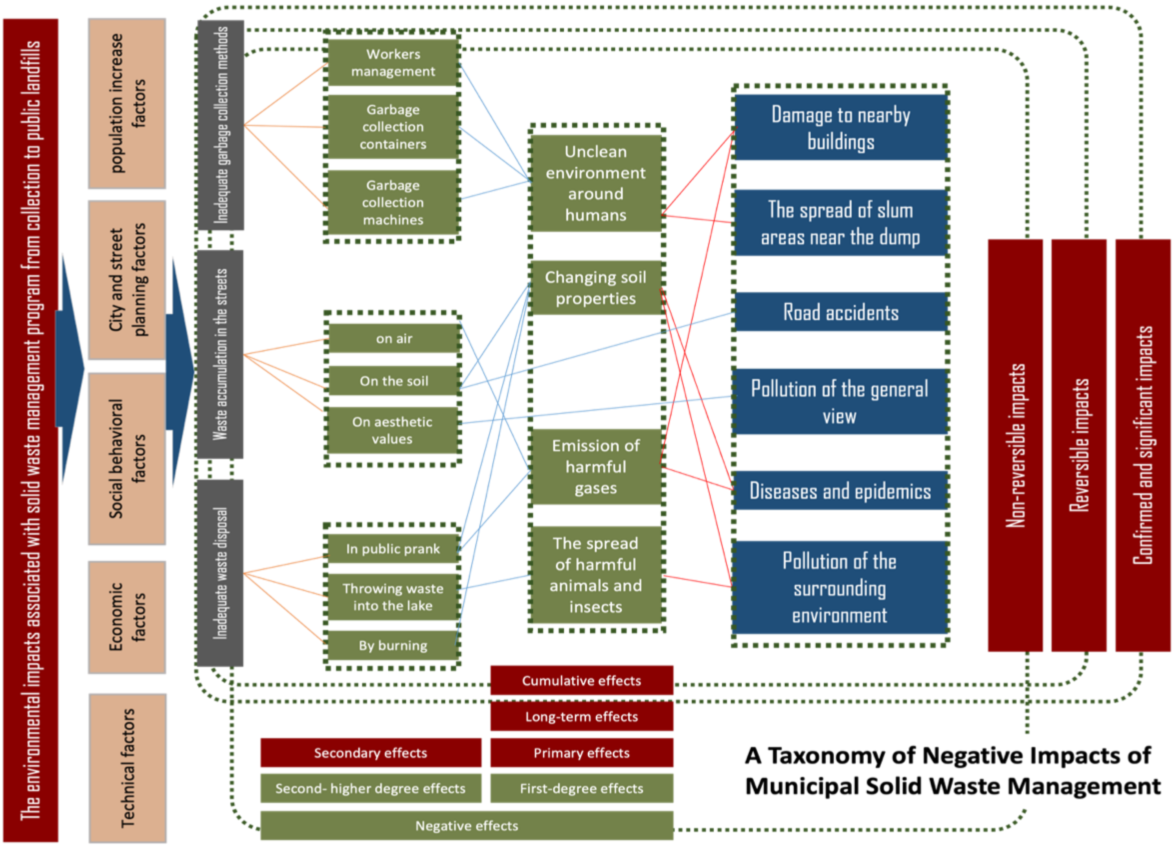

Figure 8: Structure for A Taxonomy of Negative Impacts of Municipal Solid Waste Management in Port-Said. Source: Author according to [Periodic Report of Solid Waste Management in Port Said Governorate]

A: Direct and Indirect Effects: Direct effects stem from the core activities of the SWM program, such as waste collection, transportation, and disposal at the landfill. As for the indirect effects arise from secondary activities, such as the environmental and aesthetic impact of waste collection.

B: Primary, Secondary, and Higher-Order Effects: Primary effects include the impact of inadequate labor, insufficient collection containers, air and soil pollution from accumulated waste, and the effects of dumping waste in Manzala Lake. As for the Secondary effects are the direct consequences of these primary effects (refer to Fig. [8] for a classification structure).

C: Cumulative Impacts: These are effects on air quality and health through burning of wastes and associated diseases, epidemics and road accidents caused by smoke.

D: Impacts on Different Environments: These effects include all surroundings plants, birds, as well as human (economic, health, social, and psychological).

E: Reversible and Irreversible Impacts: However, the majority of the impacts have long-term negative effects; though they can be controlled, they cannot be undone, such as the depletion of the ozone layer by burning and serious health issues.

F: Long and Short-term Impacts: Long-term, means they take a long time to be reversed or undone or to cease having the desired effect.

G: Significant Impacts: Any effects arising from deficiencies in the SWM system are considered significant for the environment.

H: Negative Impacts: System and field study have established that the project is associated with various negative effects.

I: Certain Impacts: All effects of the project are considered certain as they are evident within the Governorate of Port Said.

7.2.3 Classification of the Program:

The public dumps are one of the sub-projects of the SWM program in the Governorate, among the grey list projects because the SWM program has certain effects on the environment in Port Said.

8. STAGE 3: MITIGATION PHASE:

A Sustainable Action Plan for MSW in Port Said Governorate: A Comprehensive Framework

This proposed executive summary is designed in Fig. [9] which aims to enhance environmental sustainability by creating a cleaner, healthier and more resilient city by integrating architectural, engineering and social considerations. The proposal included addressing the current challenges of waste management in Port Said. Below are the proposed Steps in detail:

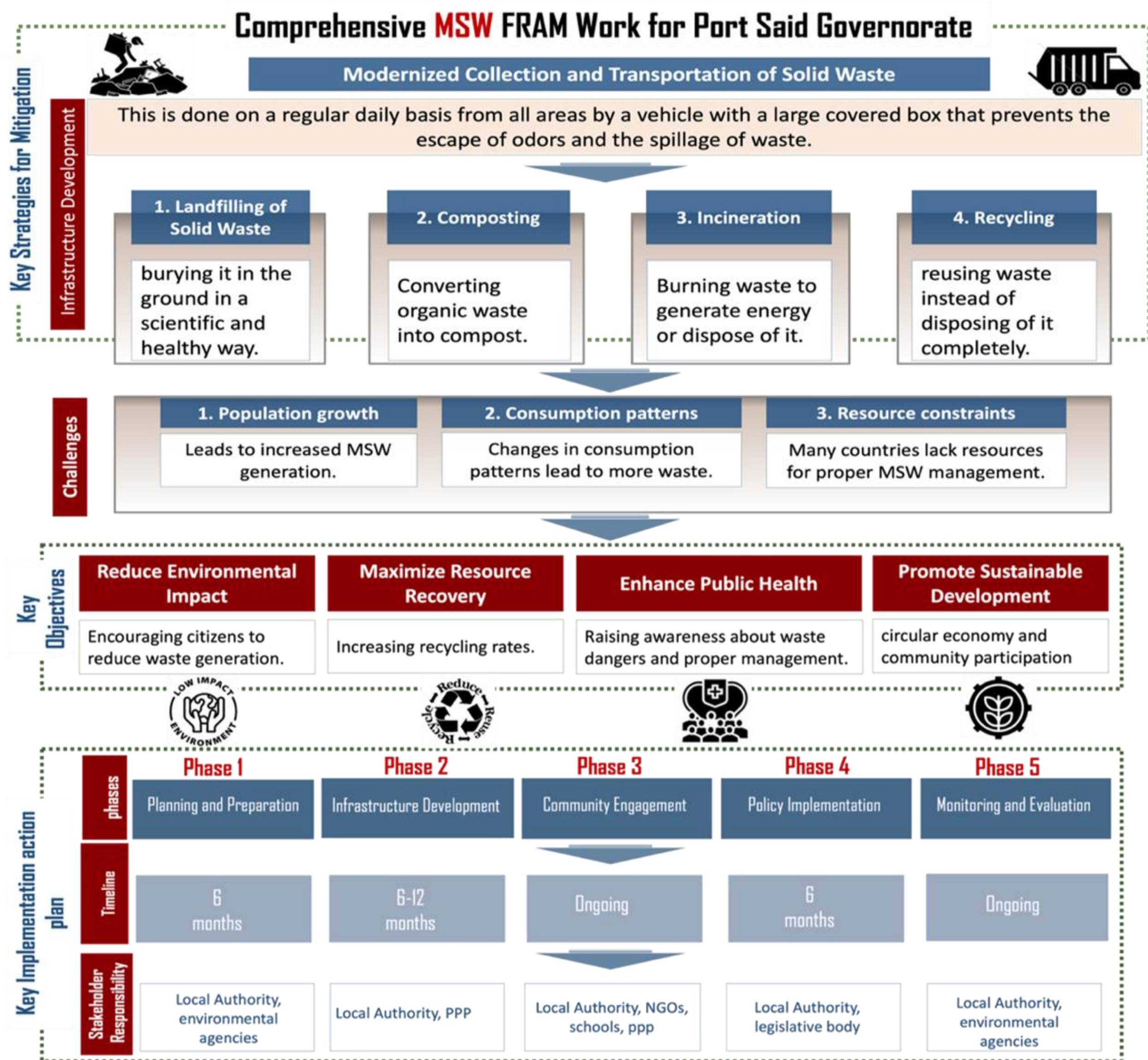

Figure 9: proposal for a comprehensive framework for the waste management system in Port Said. Source: Author according to [46 ,47, 48].

8.1 Key Objectives for MSW framework:

- Reduce Environmental Impact, including contamination of the air and water.
- Maximize recycling, composting, and waste-to-energy recovery to optimize resource recovery.
- Enhance Public Health: Reduce exposure to harmful substances and pests that spread illness.
- Promote Sustainable Development: Encourage community involvement, cultivate a circular economy, and include waste management in urban development.

8.2 Key Strategies for Solid Waste Mitigation and its impacts:

8.2.1 Solid Waste Infrastructure Development.

8.2.1.1 Modern Waste Collection System: Using GPS-tracked vehicles and standard containers, this system is effective for city-wide waste collection.

8.2.1.2 **Advanced Landfill Technologies:** Traditional landfills, while a common waste disposal method, pose significant environmental risks, including.

greenhouse gas emissions and groundwater contamination [49]. To address current problems, advanced landfill technologies offer a more sustainable and environmentally friendly solution [50].

Key Advanced Landfill Techniques:

- **L**eachate Collection and Treatment Systems [51]: Very important for treating the liquid seeping through the waste, and preventing it from polluting groundwater.
- Gas Collection and Utilization Systems [52]: These systems generate energy by capturing methane, a potent greenhouse gas.
- Geosynthetic Liner Systems [53]: These systems create barriers to prevent liquids from leaking into the environment.
- Bioreactor Landfills [54]: These landfills accelerate decomposition by controlling aeration and humidity, reducing waste volume and methane gas release.
- Monitoring and Control Systems [55]: Remotely monitor operations in and key variables.

Impacts of Advanced Landfill Techniques [56]**:**

- Reducing greenhouse gas emissions and runoff water pollution.
- Generating renewable energy from landfill gas.
- Improving the efficiency and sustainability of waste disposal.
- Reducing health risks associated with landfill emissions and runoff water**.**

8.2.1.3 Advanced and Sustainable Composting Solutions **[**57]: Composting is a natural process that converts organic waste into nutrient-rich fertilizer. This fertilizer can improve soil quality and reduce the need for chemical fertilizers [58].

Advanced Composting Techniques:

- Aerobic Composting (accelerates the composting process through controlled aeration).
- Vermicomposting and using them to break down organic waste.
- In-vessel closed composting.
- Automated composting systems using technology.

Impacts of Composting [59]**:**

- Reducing landfill waste by converting organic waste.
- Enhancing soil quality and fertility.
- Sustainable agriculture by relying on organic fertilizers.
- Reducing greenhouse gas emissions.

8.2.1.4 Advanced Incineration Technologies: Incineration is a thermal process that involves burning waste at high temperatures to reduce its volume and generate energy [60]. However, it also has several Negative impacts [61]. Recent technology aims to improve combustion efficiency and environmental impact, including liquid waste incineration, plasma gasification, and advanced air pollution control technologies [62].

Positive Impacts of Incineration [63]**:**

- Reduces the volume of waste.
- Energy recovery by generating electricity or heat.
- Hazardous Waste Treatment.

Negative Impacts of Incineration [64]**:**

- Releases harmful pollutants into the atmosphere.
- Requires significant investment and operational costs.
- Emissions can pose health risks.
- Produces hazardous ash that needs careful disposal.

8.2.1.5 Recycling: [A Sustainable Solution]: Recycling is a crucial process that involves transforming waste materials into new products [65]. Recycling can reduce waste and thus reduce pollution and conserve natural resources. The recycling process usually involves several steps as described below Fig. [10] illustrated:

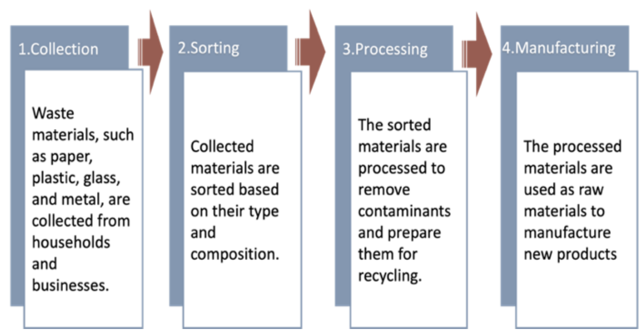

Figure 10: The recycling process Source: Author **according to [66]**

One of the main problems that were previously raised and that the governorate suffers from, which affects the quality of waste and thus the recycling process, is the scavengers who select valuable waste. The solution to this problem can be through community participation and awareness of proper disposal methods and handing over waste to the company or garbage collectors in the neighborhoods in exchange for points or financial rewards, in preparation for reuse. Proposal to utilize more of the collected municipal solid waste materials in Port Said and convert them into sustainable architectural and building elements, As shown in the table [4].

Table 4. sustainable architectural and building elements. according to the previously mentioned proportions outlined in the Source: Author according to periodic waste management report [67,68].

Material		Architectural Elements
Recycling Paper waste	Applications in Architecture	▪ **Architectural Elements** - Partitions and Screens: lightweight, movable partitions that enhance spatial flexibility in interiors. - Ceiling Tiles: These tiles can improve indoor air quality and acoustics. ▪ **Building Materials** - Papercrete: A composite material made from recycled paper and concrete, suitable for constructing low-cost and eco-friendly structures. - Paper Insulation: It can be processed into cellulose insulation, which is effective in reducing energy consumption and providing thermal comfort. ▪ **Interior Finishes** - Decorative wall coverings - Acoustic Panels: Sound-absorbing panels, enhancing acoustics. ▪ **Furniture Design** - Sustainable Furniture: Furniture pieces, such as chairs and tables. - Modular Systems: Paper-based modular furniture can be designed for easy assembly and disassembly, promoting adaptability in spaces. ▪ **Artistic Applications** - Sculptures and Installations: It can be used to create site-specific installations or art pieces that emphasize sustainability. - Textile Applications: Paper can be woven or molded to create textile-like finishes for walls and ceilings. ▪ **Landscaping and Outdoor Structures** - Garden Decor: Outdoor furniture or decorative elements, contributing to sustainable landscape design. - Temporary Structures: As temporary pavilions or exhibition spaces.
Environmental impact		▪ Avoiding the cutting of a portion of forest trees. ▪ Providing 25% of the necessary electrical energy for paper manufacturing from sustainable sources. ▪ Reducing the consumption of non-renewable fuel materials, as conventional paper production consumes a significant amount of coal, diesel, and natural gas.
Recycling glass waste	Applications in Architecture	▪ **Building Materials** - Recycled Glass Tiles: These tiles are used for flooring, backsplashes, and wall coverings, providing durability and aesthetic appeal. ▪ **Glass Aggregate** - Crushed recycled glass can replace traditional aggregates in concrete and enhancing its appearance. ▪ **Insulation Products** - Glass Wool Insulation: Made from recycled glass fibers, this insulation material offers excellent thermal and acoustic properties, contributing to energy efficiency in buildings. ▪ **Facades and Glazing** - Glass Curtain Walls: Incorporating recycled glass in curtain wall systems enhances the sustainability of building envelopes while allowing natural light to penetrate the interior spaces. - Recycled Glass Bricks: These bricks can be used in constructing walls and facades, providing unique design possibilities and energy efficiency. ▪ **Interior Design Elements** - Decorative Features: Recycled glass can be used in countertops, furniture, and decorative art pieces, adding color and texture to interior spaces. - Lighting Fixtures: Fixtures made from recycled glass create stunning visual effects and promote sustainability. ▪ **Paving and Landscaping** - Glass Pavers: Recycled glass can be utilized in paving stones for walkways and patios, offering a stylish and eco-friendly alternative to traditional materials.

Material		Architectural Elements
		- Garden Mulch: Crushed glass serves as a decorative mulch in landscaping, helping to retain moisture and suppress weeds. ▪ **Acoustic Solutions** Sound Barriers: Recycled glass can be used in the fabrication of sound barriers, contributing to noise reduction in urban environments.
Environmental impact		▪ It is worth noting that glass recycling saves 50% of the energy required to produce it from its original materials. ▪ The integration of recycled glass waste in architectural applications enhances the aesthetic, functional aspects of buildings, significantly contributes to environmental sustainability and reduces the ecological footprint of the projects while promoting innovative design solutions.
Plastic waste recycling	Applications in Architecture	▪ **Building Materials** - Plastic Lumber: Recycled plastic processes into durable and weather-resistant lumber, suitable for decking, fencing, and outdoor furniture. - Plastic Bricks: These bricks offer superior strength and durability compared to traditional bricks. - Plastic Concrete: By incorporating recycled plastic into concrete, architects can create stronger, more durable, and lightweight structures. ▪ **Insulation Materials** - Plastic Foam Insulation: Recycled plastic foam can be used as insulation in walls, roofs, and floors, improving energy efficiency and reducing heating and cooling costs. ▪ **Interior Design Elements** - Wall Panels and Flooring: Recycled plastic can be used to create aesthetically pleasing and functional wall panels and flooring. ▪ **Furniture:** Chairs, tables, and other furniture can be made from recycled plastic, offering a sustainable and stylish alternatives. ▪ **Outdoor Structures** - Playgrounds: Recycled plastic can be used to create durable and safe playground equipment, reducing the need for wood and metal. - Park Benches and Shelters: Recycled plastic can be used to construct outdoor seating and shelters, providing a sustainable solution.
Environmental impact		▪ Environmental Impact: Reduces plastic waste in landfills and oceans. ▪ Durability: Recycled plastic products often exhibit superior durability and longevity. ▪ Cost-Effective: Recycled plastic can be more cost-effective than traditional materials. ▪ Aesthetics: Recycled plastic can be used to create visually appealing and innovative designs.
Rubber waste recycling.	Applications in Architecture	▪ **Building Materials** - Rubberized Asphalt: Recycled rubber can be mixed with asphalt to create more durable and flexible road surfaces. - Rubber Tiles: These tiles, made from recycled rubber, are ideal for flooring in gyms, playgrounds, and industrial settings, offering excellent shock absorption and sound insulation properties. - Rubber Concrete: Incorporating rubber into concrete can improve its impact resistance, durability, and sound insulation properties. ▪ **Insulation Materials** - Rubber Insulation: Recycled rubber can be used as insulation material in buildings, providing excellent thermal and acoustic insulation properties. ▪ **Outdoor Applications** - Playgrounds: Rubber mulch and rubber tiles are commonly used in playgrounds, providing a safe and cushioned surface for children. - Athletic Tracks: Recycled rubber is used to create durable and shock-absorbent athletic tracks. - Landscape Architecture: Rubber can be used to create various landscape elements, such as garden borders, mulch, and decorative features.

Material		Architectural Elements
Environmental impact		▪ Environmental Impact: Reduces the amount of rubber waste in landfills ▪ Durability: The new paving mixture is known for its minimal impact on the wear of car tires. ▪ Safety: Rubber surfaces offer excellent shock absorption in playgrounds and recreational areas to provide a safe and resilient playing surface. ▪ Noise Reduction: Rubber materials can help reduce noise pollution in buildings and outdoor spaces . ▪ Aesthetics: Recycled rubber can be used to create innovative designs.
Metal waste recycling	Applications in Architecture	▪ **Structural Components** - Steel Beams and Columns: Recycled steel can be processed into structural components for buildings, bridges, and other infrastructure. - Reinforced Concrete: Recycled steel rebar can be used to reinforce concrete structures, improving their strength and durability. ▪ **Architectural Elements** - Façade Cladding: Recycled metal panels can be used to create visually striking and energy-efficient building facades. - Roofing Materials: Metal roofing, made from recycled materials, offers durability, weather resistance, and aesthetic appeal. - Interior Design: It can be used to create unique and stylish interior design elements, such as wall panels, lighting fixtures, and furniture. ▪ **Urban Design** - Sculptures and Art Installations: Recycled metal can be transformed into captivating sculptures and art installations that enhance public spaces. - Urban Furniture: Benches, bike racks, and other urban furniture can be made from recycled metal.
Environmental impact		▪ Environmental Impact: Reduces the demand for virgin metal resources and minimizes waste. ▪ Durability and Strength: Recycled metal often exhibits high strength and durability, making it ideal for structural applications. ▪ Aesthetics: Recycled metal can be used to create unique and visually appealing designs. ▪ Cost-Effective: Recycled metal can be a more cost-effective option.
Using Solid Waste for Energy Generation	Applications in Architecture	Solid waste, can be transformed into a valuable energy resource. By harnessing the energy potential of waste, we can reduce our reliance on fossil fuels. Here are some architectural applications of Waste-to-Energy Technologies ▪ **Incineration:** - Burning waste at high temperatures generate heat and electricity. This heat is used to power buildings, while the electricity feeds into the grid. - Material Recovery: Incineration plants often incorporate systems to recover valuable materials from the ash, such as metals. ▪ **Anaerobic Digestion:** - Organic waste, such as food scraps and sewage sludge, can be decomposed anaerobically to produce biogas, a mixture of methane and carbon dioxide. - Biogas can be used to generate electricity or heat, or it can be upgraded to biomethane for use in transportation. ▪ **Pyrolysis:** - Pyrolysis involves heating waste in the absence of oxygen to produce a gas mixture called syngas. - Syngas can be used to generate electricity or as a feedstock for the production of fuels and chemicals. **Architectural Applications of Waste-to-Energy:** While waste-to-energy technologies are primarily industrial processes, they can indirectly impact architectural design and urban planning: - District Heating and Cooling: Waste-to-energy plants can provide heat and cooling for buildings in a district heating and cooling system. - Sustainable Urban Development: Integrating waste-to-energy facilities into urban planning can help create more sustainable and resilient cities. - Energy-Positive Buildings: Buildings that generate more energy than they consume can be powered by energy from waste-to-energy plants.

Material		Architectural Elements
		- By embracing waste-to-energy technologies, architects and urban planners can contribute to a circular economy and a more sustainable future.
Environmental	impact	▪ Environmental Benefits: Reduced Landfill Dependence, Reduced Greenhouse Gas Emissions and Resource Conservation. ▪ Economic Benefits: Revenue Generation, Job Creation in various sectors (engineering, operations, and maintenance) and Reduced Waste Disposal Costs. ▪ Social Benefits: Improved Public Health by reducing exposure to pollutants and diseases and stimulate economic growth and improve the quality of life in communities.
Compost (fertilizer manufacturing)	Applications in Architecture	▪ **Green Roofs and Vertical Gardens:** - Soil Enrichment: Compost provides essential nutrients to support plant growth on green roofs and vertical gardens. - Water Retention: Compost helps retain moisture, reducing the need for frequent watering. - Improved Insulation: Compost-based growing media can help regulate building temperatures, reducing energy consumption. ▪ **Landscape Architecture:** - Compost can be added to soil to improve its structure, water retention, and nutrient content. - Compost can be used to stabilize slopes and prevent soil erosion. - Compost can be used to restore degraded ecosystems and create new habitats for wildlife. ▪ **Construction Materials:** - Geotechnical Applications: Compost can be used to improve soil stability and reduce erosion in construction projects. - Building Materials: In some cases, compost can be used as a component in building materials, such as soil-cement blocks.
Environmental	impact	▪ Environmental Impact: Reduces waste, conserves resources, and improves soil health. ▪ Improved Air Quality: Green roofs and vertical gardens can help filter air pollutants. ▪ Reduced Urban Heat Island Effect: Green roofs and landscaping can help mitigate urban heat island effects. ▪ Enhanced Biodiversity: Compost-rich soils support a diverse range of plant and animal life. ▪ Cost-Effective: Compost can be a cost-effective alternative to synthetic fertilizers and soil amendments.

8.2.2 Community Engagement and Education [69,70,71].

- Conduct comprehensive public awareness campaigns to educate citizens on waste reduction and proper disposal practices.
- Establish community recycling programs, and encourage participation through rewards or discounts for individuals.
- Integrate waste management programs into school curricula to develop environmental awareness among the younger generation.

8.2.3 Policy and Regulatory Framework [72].

- Develop and strictly implement waste management regulations and laws, including regulations on waste generation, collection, and disposal methods.
- Establish a robust licensing and permitting system for waste generators and disposal facilities.
- Provide financial incentives and rewards to companies and individuals who adopt sustainable waste management practices.

8.2.4 Research and Development [73].

- Implement pilot projects to test new technologies and methods for waste management.
- Establish a comprehensive data collection system to monitor and dispose of waste production patterns.
- Partnership with local universities to conduct research in waste management and develop innovative strategies and solutions.

8.3 Implementation phases and Timeline.

The action plan involves five phases: depends on the stages which include planning and preparation, infrastructure development, community engagement, policy implementation, and lastly monitoring and evaluation. It's a collaborative effort between various stakeholders to address the sustainable solid waste management problem in Port Said.

Table 5. Implementation action plan phases, stakeholder and timeline. Source: Author according to [74,75].

Phase	Activities	Timeline	Responsible Party
Phase 1: Planning and Preparation	Needs assessment, stakeholder engagement, budget allocation	6 months	Local Authority, environmental agencies
Phase 2: Infrastructure Development	Development of waste sorting facilities, and composting facilities	6-12 months	Local Authority, PPP
Phase 3: Community Engagement	Public awareness campaigns, educational programs	Ongoing	Local Authority, NGOs, schools, ppp
Phase 4: Policy Implementation	Development and enforcement of waste management bylaws	6 months	Local Authority, legislative body
Phase 5: Monitoring and Evaluation	Data collection, performance evaluation, and adjustments	Ongoing	Local Authority, environmental agencies

8.4 Sustainability and Benefits [76].

- Environmental benefits: Conservation of natural resources, improved air and water quality, and reduced greenhouse gas emissions.
- Economic benefits: Reduced waste disposal costs, increased revenue from recycling and composting, and job creation.
- Social benefits: Enhanced quality of life, increased community participation, and improved public health.

8.5 Potential barriers to implementing the proposed strategies include:

- Lack of funding: Adequate financial resources are essential for executing sustainable architectural projects effectively.
- Limited technical expertise: Implementing sustainable architectural practices requires specialized knowledge and skills that may be lacking among stakeholders.
- Resistance to change: Some individuals or organizations may resist adopting new sustainable practices, hindering the implementation of the action plan.
- Regulatory challenges: Existing regulations and policies may not fully support sustainable architectural initiatives, making it difficult to implement the plan effectively. The lack of direct communication between the contracted company and the primary waste collectors .
- Public awareness and engagement: Lack of awareness and involvement from the community can be a significant barrier to the successful implementation of sustainable architectural strategies.
- Infrastructure limitations: Inadequate infrastructure for waste management and recycling facilities may impede the execution of the action plan.

Addressing these obstacles necessitates collaboration and organizing the process among the three main parties (the company, the municipality, and the citizens) to address the issue of recycling waste collection. Education, policy adjustments, and infrastructure development can help overcome challenges and facilitate the successful implementation of a Sustainable Architectural Action Plan for Municipal Solid Waste in Port Said Governorate.

9. CONCLUSIONS

This research focused on solid waste management in Port Said, which has in turn awakened the city's serious environmental challenges, including population growth, deficient infrastructure, and limited public awareness. So, the research proposed guidance for a comprehensive and sustainable waste management strategy for a Sustainable Future:

9.1 Proposed Sustainable Integrated Waste Management System in Port Said:

The proposal was based on studying the available infrastructure and how to develop it, and the local challenges in the governorate and trying to solve them, especially in terms of collection, transportation, safe disposal, utilizing the available material and human elements, stakeholder participation, and community participation. From this, specific steps were followed as follows:

9.1.1 Stage 1: Data Collection Phase to Estimate the quantities of solid waste through analyzing statistical data on population, commercial, industrial, and service facilities.

9.1.2 Stage 2: Analysis Phase to Evaluate the efficiency of solid waste management systems and assess their environmental, health, social, and economic impacts.

9.1.3 Stage 3: Mitigation Plan to Set a Comprehensive Framework to Sustainable Architectural Action Plan for MSW in Port Said Governorate, Its purposes are:

- Minimize environmental impact by optimizing waste collection and transportation systems.
- Spread awareness and encourage public participation through education and campaigns.
- The priority is on reduction (minimizing consumption and waste), reuse, and recycling (maximizing the use of produced elements, with a focus on architectural and construction elements in recycling to preserve resources and recover energy.

9.1.3.1 Advanced Waste Processing Technologies:

- Going to Investment in advanced technologies for efficient waste processing, such as mechanical biological treatment and advanced thermal treatment.
- Reduce landfill dependency by exploring opportunities for waste-to-energy conversion.

9.1.3.2 Strong Policy and Regulatory Framework:

- Generate rigid regulations to govern waste management practices.
- Provide motivations for recycling and waste reduction.
- Establish a strong monitoring and implementation system.

9.1.3.3 Community Engagement and Education:

- Empower communities through awareness campaigns and educational programs for public and private institutions. The contracting company or the governorate can carry out these programs.
- promote a sense of ownership and responsibility among citizens and their participation in waste reduction plans and recycling by encouraging citizens with financial rewards for waste that has value in recycling

9.2 Potential barriers to implementing the proposed strategies include:

Lack of funding, limited technical expertise, resistance to change, regulatory challenge, public awareness and engagement, infrastructure limitations.

Following and implementing these strategies with firm and gradual steps that aim to preserve the environment, increase public health, and move towards a sustainable future, will transform Port Said into a model for successful waste management in Egypt and demonstrate that the situation must change for the better by gradually working on the concept.

10. FUTURE RESEARCH DIRECTIONS:

In this field and to further continue enhancing the effectiveness of SWM in Port Said, directions for future research in four important areas will be outlined:

- Economic Analysis: Assessing the economic feasibility of various recent waste management technologies and strategies.
- Life Cycle Assessment: Studying the entire life cycle of different waste disposal methods and assessing the environmental impact at each stage.
- Social Impact Assessment: Identify and analyze the social and cultural behaviors that influence waste management.
- Emerging Technologies: Explore the potential of innovative technologies applicable to Port Said, such as improving waste management processes with artificial intelligence.

By incorporating these ideas, Port Said can achieve long-term and ongoing sustainability in developing waste management practices.

11. REFERENCES:

[1] Omer, A. M. (2008). Energy, environment and sustainable development. Renewable and sustainable energy reviews, 12(9), 2265-2300.

[2] Kumar, P. (Ed.). (2012). The economics of ecosystems and biodiversity: ecological and economic foundations. Routledge.

[3] The Holy Quran: Original Arabic

[4] https://www.unep.org/news-and-stories/press-release/world-must-move-beyond-waste-era-and-turn-rubbish-resource-un-report

[5] Buttel, F., & Taylor, P. (2013). Environmental sociology and global environmental change: a critical assessment. In Social theory and the global environment (pp. 228-255). Routledge.

[6]Vardhan, K. H., Kumar, P. S., & Panda, R. C. (2019). A review on heavy metal pollution, toxicity and remedial measures: Current trends and future perspectives. Journal of Molecular Liquids, 290, 111197.

[7] Duderstadt, J. J. (2007). Engineering for a changing road, a roadmap to the future of engineering practice, research, and education.

[8] Vanclay, F., Esteves, A. M., Aucamp, I., & Franks, D. (2015). Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.

[9] Getty, R., & Morrison-Saunders, A. (2020). Evaluating the effectiveness of integrating the environmental impact assessment and mine closure planning processes. Environmental impact assessment review, 82, 106366.

[10] Therivel, R. (2012). Strategic environmental assessment in action. Routledge.

[11] Broughton, E. K. (2011). A framework for coherent decision-making in environmental impact assessments in the energy sector of South Africa (Doctoral dissertation, University of Pretoria).

[12] Harper, C., & Snowden, M. (2017). Environment and society: Human perspectives on environmental issues. Routledge.

[13] Singh, J., Laurenti, R., Sinha, R., & Frostell, B. (2014). Progress and challenges to the global waste management system. Waste Management & Research, 32(9), 800-812.

[14] Gavhane, S. K., Sapkale, J. B., Susware, N. K., & Sapkale, S. J. (2021). Impact of heavy metals in riverine and estuarine environment: A review. Res. J. Chem. Environ, 25(5), 226-233.

[15] Jamei, E., & Vrcelj, Z. (2021). Biomimicry and the built environment, learning from nature's solutions. Applied Sciences, 11(16), 7514.

[16] Kolawole, A. S., & Iyiola, A. O. (2023). Environmental Pollution: Threats, Impact on Biodiversity, and Protection Strategies. In Sustainable Utilization and Conservation of Africa's Biological Resources and Environment (pp. 377-409). Singapore: Springer Nature Singapore.

[17] Ajibade, F. O., Adelodun, B., Lasisi, K. H., Fadare, O. O., Ajibade, T. F., Nwogwu, N. A., ... & Wang, A.

(2021). Environmental pollution and their socioeconomic impacts. In Microbe mediated remediation of environmental contaminants (pp. 321-354). Woodhead Publishing.
[18] Al-Dulaimi, W. A. M., & Al-Taai, S. H. H. (2021, June). Pollution and its Impact on Sustainable Development. In IOP Conference Series: Earth and Environmental Science (Vol. 790, No. 1, p. 012025). IOP Publishing.
[19] Glavič, P., & Lukman, R. (2007). Review of sustainability terms and their definitions. Journal of cleaner production, 15(18), 1875-1885.
[20] Wathern, P. (Ed.). (2013). Environmental impact assessment: theory and practice. Routledge.
[21] Wood, C. (2003, November). Environmental impact assessment in developing countries: an overview. In Conference on new directions in impact assessment for development: methods and practice (Vol. 2425). EIA Centre School of Planning and Landscape, University of Manchester Manchester, United Kingdom.
[22] Vanclay, F., Esteves, A. M., Aucamp, I., & Franks, D. (2015). Social Impact Assessment: Guidance for assessing and managing the social impacts of projects.
[23] Ulibarri, N., Scott, T. A., & Perez-Figueroa, O. (2019). How does stakeholder involvement affect environmental impact assessment?. Environmental Impact Assessment Review, 79, 106309.
[24] DiMento, J. F., & Ingram, H. (2005). Science and environmental decision making: the potential role of environmental impact assessment in the pursuit of appropriate information. Natural resources journal, 283-309.
[25] Nicol, S., & Chadès, I. (2017). A preliminary approach to quantifying the overall environmental risks posed by development projects during environmental impact assessment. Plos one, 12(7), e0180982.
[26] Glucker, A. N. (2012). Public participation in Environmental Impact Assessment (EIA)-An investigation into theory and practice in Costa Rica and Nicaragua (Master's thesis).
[27] O'Faircheallaigh, C. (2010). Public participation and environmental impact assessment: Purposes, implications, and lessons for public policy making. Environmental impact assessment review, 30(1), 19-27.
[28] Badr, E. S. A. (2009). Evaluation of the environmental impact assessment system in Egypt. Impact Assessment and Project Appraisal, 27(3), 193-203.
[29] Badr, E. S. A., Laban, A. E., & Zahran, A. A. (2023). Benchmarking Evaluation of Environmental Impact Assessment Studies Case Study: New Burg El Arab City–Alexandria–Egypt. International Journal of Environmental Studies and Researches, 2(2), 99-117.
[30] Egyptian Environmental Affairs Agency (EEAA): https://www.unccd.int/resources/knowledge-sharing-system/ministry-environment-egyptian-environmental-affairs-agency-eeaa
[31]EEAA EIA Guidelines: https://www.eeaa.gov.eg/Uploads/Service/Files/20221214131316215.pdf
[32] Law No. 4/1994 on the Environment: https://www.gafi.gov.eg/English/StartaBusiness/Laws-and-Regulations/PublishingImages/Pages/BusinessLaws/envi romental.pdf
[33] Decision No. 340/2005 on the Executive Regulations of Law No. 4/1994: https://www.unccd.int/resources/knowledge-sharing-system/ministry-environment-egyptian-environmental-affairs-agency-eeaa
[34] Egyptian Ministry of Environment: https://eeaa.gov.eg/
[35] Gupta, P., Sharma, A., & Bhardwaj, L. K. (2023). Solid waste management (SWM) and its effect on environment & human health
[36] United States Environmental Protection Agency (EPA): https://www.epa.gov/report-environment/wastes
[37] United States Environmental Protection Agency: [https www epa gov report environment wastes]
[38] DEFRA: [https www defra gov uk waste evidence and data waste statistics ON Department for Environment Food and Rural Affairs]
[39] National Bureau of Statistics of China: [https data stats gov cn english easyquery htm cn c01
[40] Central Pollution Control Board: [https cpcb online cpcb website ON cpcb.nic.in]
[41] Umweltbundesamt: [https www umweltbundesamt de en themen/waste management/municipal solid waste ON German Environment Agency]
[42] Saudi General Authority for Environment: [https www sge saudi com en ON Saudi General Authority for Environment
[43] https://www.portsaid.gov.eg/
[44] General Administration of Waste. Port Said Governorate, 12,2024.
[45] https://www.eeaa.gov.eg/Reports/215/Details
[46] United States Environmental Protection Agency (EPA): https://www.epa.gov/report-environment/wastes
[47] World Bank: https://www.worldbank.org/en/topic/urbandevelopment/brief/solid-waste-management
[48] World Health Organization (WHO): https://www.who.int/news-room/fact-sheets/detail/health-care-waste
[49] Ozbay, G., Jones, M., Gadde, M., Isah, S., & Attarwala, T. (2021). Design and operation of effective landfills with minimal effects on the environment and human health. Journal of environmental and public health, 2021(1), 6921607.

[50] Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. Environmental chemistry letters, 19(2), 1433-1456.
[51] Lebron, Y. A. R., Moreira, V. R., Brasil, Y. L., Silva, A. F. R., de Souza Santos, L. V., Lange, L. C., & Amaral, M. C. S. (2021). A survey on experiences in leachate treatment: Common practices, differences worldwide and future perspectives. Journal of environmental management, 288, 112475.
[52] Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. Environmental chemistry letters, 19(2), 1433-1456.
[53] Nanda, S., & Berruti, F. (2021). Municipal solid waste management and landfilling technologies: a review. Environmental chemistry letters, 19(2), 1433-1456.
[54] Mohammad, A., Osinski, P., Koda, E., & Singh, D. N. (2021). A case study on establishing the state of decomposition of municipal solid waste in a bioreactor landfill in India. Waste Management & Research, 39(11), 1375-1388.
[55] Ali, T., Irfan, M., Alwadie, A. S., & Glowacz, A. (2020). IoT-based smart waste bin monitoring and municipal solid waste management system for smart cities. Arabian Journal for Science and Engineering, 45, 10185-10198.
[56] Mapunda, A. S., Kimwaga, R. J., & Kassuwi, S. A. (2024). Modeling Solid Waste Minimization Performance at Source in Dar es Salaam City, Tanzania. Journal of Geoscience and Environment Protection, 12(9), 17-32
[57] EPA's Composting Basics: https://www.epa.gov/
[58] Argun, Y. A., Karacali, A., Calisir, U., & Kilinc, N. (2017). Composting as a waste management method. Journal of International Environmental Application and Science, 12(3), 244-255.
[59] Adugna, G. (2016). A review on impact of compost on soil properties, water use and crop productivity. Academic Research Journal of Agricultural Science and Research, 4(3), 93-104.
[60] Environmental Protection Agency: https://www.epa.gov/
[61] Tangri, N. (2023). Waste incinerators undermine clean energy goals. PLOS Climate, 2(6), e0000100.
[62] World Health Organization: https://www.who.int/
Waste Incineration Drives the Triple Planetary Crisis - IPEN.org: https://ipen.org/news/report-waste-incineration-drives-triple-planetary-crisis
[64] Waste Incineration Drives the Triple Planetary Crisis - IPEN.org: https://ipen.org/news/report-waste-incineration-drives-triple-planetary-crisis
[65] Sharma, K. D., & Jain, S. (2019). Overview of municipal solid waste generation, composition, and management in India. Journal of Environmental Engineering, 145(3), 04018143.
[66] Nie, Y., Wu, Y., Zhao, J., Zhao, J., Chen, X., Maraseni, T., & Qian, G. (2018). Is the finer the better for municipal solid waste (MSW) classification in view of recyclable constituents? A comprehensive social, economic and environmental analysis. Waste Management, 79, 472-480.
[67] Troschinetz, A. M., & Mihelcic, J. R. (2009). Sustainable recycling of municipal solid waste in developing countries. Waste management, 29(2), 915-923.
[68] Zhang, J., Qin, Q., Li, G., & Tseng, C. H. (2021). Sustainable municipal waste management strategies through life cycle assessment method: A review. Journal of Environmental Management, 287, 112238
[69 Kala, K., & Bolia, N. B. (2020). Waste management communication policy for effective citizen awareness. Journal of Policy Modeling, 42(3), 661-678
[70] Hasan, M. J. A., Hanafiah, M. M., & Satchet, M. S. (2019, June). Public awareness on solid waste management: A case study in Al-Nassyriah City, Iraq. In AIP Conference Proceedings (Vol. 2111, No. 1). AIP Publishing
[71] Leknoi, U., Painmanakul, P., Chawaloesphonsiya, N., Wimolsakcharoen, W., Samritthinanta, C., & Yiengthaisong, A. (2024). Building Sustainable Community: Insight from successful waste management initiative. Resources, Conservation & Recycling Advances, 200238
[72] Bhatti, L., Talpur, M. A. H., Memon, I. A., Chandio, I. A., & Shaikh, F. A. (2021). The challenges faced in the collection and disposal of municipal solid waste (msw) management: a case study of Sanghar City. Sukkur IBA Journal of Computing and Mathematical Sciences, 5(1), 59-72
[73] seng, M. L., Wong, W. P., & Soh, K. L. (2018). An overview of the substance of resource, conservation and recycling. Resources, Conservation and Recycling, 136, 367-375
[74] Woldesenbet, W. G. (2021). Stakeholder participation and engagement in the governance of waste in Wolkite, Ethiopia. Environmental Challenges, 3, 100034
[75] Ma, W., & Hao, J. L. (2024). Enhancing a circular economy for construction and demolition waste management in China: A stakeholder engagement and key strategy approach. Journal of Cleaner Production, 450, 141763
[76] Calderón, E. J. (2000). An applied method for the assessment of sustainability of urban pilot projects. Environmental Impact Assessment Review, 20(3), 289-298