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Dedications

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الملخص

تم في هذه الدراسة تقييم مكب نفايات حميسي التقني في الجزائر العاصمة، الجزائر، والذي يضم مكب نفايات من الدرجة الثانية والثالثة، ومنشأة فرز، ومصنع للتسميد، ومصنع لمعالجة المادة المرتشحة لتحديد فعاليته من حيث التكلفة. الهدف الرئيسي هو تحديد ما إذا كان الأداء المالي لهذه المرافق يستدعي استثمارًا أوليًا كبيرًا ونفقات تشغيلية مستمرة. وتستند الدراسة الفنية إلى البيانات المالية والتشغيلية الفعلية لعام 2024 المقدمة من مكب نفايات حميسي. بالنسبة لكل مكون، تم فحص مقاييس مهمة مثل التكلفة لكل طن، والإيرادات، والاستثمار، والعائد على الاستثمار وتشير النتائج إلى وجود اختلافات كبيرة في الكفاءة الاقتصادية. بفضل تكلفته المعتدلة وعائده الكبير على الاستثمار، يعد مركز الفرز هو الأكثر فعالية من حيث التكلفة. على الرغم من أهميته، فإن التفريغ من الدرجة الثانية له عوائد معتدلة ونفقات عالية. تمت مناقشة الجدوى الاقتصادية لمصنع التسميد بسبب حجمه المنخفض وتكلفة الوحدة المرتفعة. على الرغم من تكلفته المنخفضة، فإن مكب النفايات من الدرجة الثالثة يولد إيرادات منخفضة. توفر هذه الأطروحة للجزائر خيارات استراتيجية لتحسين كفاءة إدارة النفايات وتخصيص الموارد.

الكلمات المفتاحية: مكب نفايات حميسي، فعالية التكلفة، عائد الاستثمار، التكاليف التشغيلية، تحليل الاستثمار، الجزائر.

Abstract

Hamici technical landfill in Algiers, Algeria, which consists of a Class II and III cells, sorting facility, composting station, and leachate treatment plant, is evaluated in this study for cost-effectiveness. The primary goal is to ascertain whether these facilities' financial performance justifies significant initial investment and ongoing operational expenses. The technical study is based on actual financial and operational data from 2024 that Hamici landfill provided. For every component, important metrics like cost per ton, revenue, investment, and return on investment (ROI) were examined. The findings indicate notable variations in economic effectiveness. With a moderate cost and a substantial return on investment, the sorting center is the most economical. Despite being essential, Class II landfill has moderate returns and high expenses. The economic feasibility of the composting plant is discussed due to its low volume and high unit cost. Despite its low costs, the Class III landfill generates low incomes. This thesis provides Algeria with strategic options for enhancing the effectiveness of waste management and resource allocation.

Key words: Hamici Landfill, Cost-effectiveness, ROI, Operational costs, Investment analysis, Algeria.

Résumé

Le centre d'enfouissement technique de Hamici à Alger, en Algérie, qui comprend une décharge de classe II et III, une installation de tri, une station de compostage et station de traitement des lixiviats, est évaluée dans cette étude pour en déterminer le rapport de rentabilité. L'objectif principal est de déterminer si le rendement financier de ces installations justifie un investissement initial important et des dépenses opérationnelles courantes. L'étude technique est basée sur les données financières et opérationnelles réelles de 2024 fournies par le site d'enfouissement Hamici. Pour chaque composante, des mesures importantes comme le coût par tonne, les revenus, l'investissement et le rendement du capital investi (RCI) ont été examinées. Les résultats indiquent des variations notables de l'efficacité économique. Avec un coût modéré et un retour sur investissement substantiel, le centre de tri est le plus rentable. Bien qu'elle soit essentielle, la décharge de classe II a des rendements modérés et des dépenses élevées. La faisabilité économique de la station de compostage est discutée en raison de son faible volume et de son coût unitaire élevé. Malgré ses faibles coûts, la décharge de classe III génère de faibles revenus. Cette thèse fournit à l'Algérie des options stratégiques pour améliorer l'efficacité de la gestion des déchets et de l'allocation des ressources.

Mots-clés : CET Hamici, Rentabilité, RCI, Coûts d'exploitation, Analyse des investissements, Algérie.

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Table of abbreviations

Abbreviation	Signification
MSW	Municipal Solid Waste
CTC	Controlled Treatment Centers
WSF	Waste Storage Facility
TL	Technical Landfill
TLC	Technical Landfill Center
HDPE	High-Density Polyethylene
EPR	Extended Producer Responsibility
MBR	Membrane Bioreactor
RO	Reverse Osmosis
ROI	Return on Investment

Introduction

Introduction

The control of municipal solid waste (MSW) has developed into one of the greatest environmental and policy challenges of this era. As cities grow and our habits shift, we're creating waste in greater quantity and diversity than ever. While there is an increasing focus on environmentally friendly alternatives such as recycling and composting or using waste to produce energy, disposal in landfills remains the dominant waste treatment method for developing countries with limited access to state-of-the-art techniques or funds. Unfortunately, many of these landfills — especially the older ones — cause a lot of trouble by polluting water sources, releasing methane into the atmosphere, and harming the well-being of nearby communities [1].

For this to change, many countries are beginning to create what are termed technical landfills. These are more sophisticated sites which employ stringent environmental and safety protocols and look to use engineering to lessen the harm associated with simply dumping and covering as in a traditional landfill. Algeria, like many other developing countries, is headed in that direction. In recent years, the government has constructed several modern landfill sites designed to dispose of waste more responsibly. But for all the clarity of the environmental advantages, there's a lot we don't yet know about how expensive these systems are and whether the investments being put into them make financial sense [2].

One of these sites, the Hamici Landfill in Algiers' Mhelma commune, is examined in detail in this study. It is managed by a publicly traded corporation called GECETAL and consists of a leachate treatment unit, a composting station, a sorting center, and a Class II and Class III landfill. This study's primary goal is to determine the technical landfill's economic viability. In other words, what is the true cost of treating one ton of waste, and does the money made from various processes, such as composting, sorting, and landfilling, cover those expenses or even make a profit [3]?

Waste management is a significant public duty that requires significant public expenditure in Algeria, as it does in many other nations, hence, this question is important. Determining the cost-effectiveness of these facilities can assist local authorities in making better, more informed decisions on future investments, service enhancements, and the transition to more sustainable systems [4].

The study uses actual financial and operational data from 2024, supplied by Hamici landfill personnel, to investigate this. It compares the performance of each landfill section using fundamental financial analysis methodologies, such as cost per ton and return on investment

(ROI). The thesis is divided into three chapters: the first provides a general overview of Algerian and international waste management techniques; the second describes the data and methodology employed; and the third provides a detailed presentation and discussion of the results.

This study aims to provide useful insights for enhancing waste management in Algeria from both an environmental and an economic standpoint by examining the Hamici Landfill as a real-world case study.

Chapter I:

Literature Review

Chapter I: Literature Review

Introduction

Waste management is a planned system to effectively control generation, storage, collection, transportation, treatment, and disposal of waste. It is an important element of environmental protection. Its purpose is to provide hygienic, economical, and efficient solid waste storage, collection, transportation, and treatment or disposal without polluting the atmosphere, soil, or water. The various stages of solid waste management, from generation to sanitary disposal, are considered a solid waste chain [6].

In this chapter, we will attempt to define the minimum criteria for future waste disposal sites so that the technical landfill has the least impact on its environment when it is operated and will provide the basic knowledge to ensure the protection of the subsoil and the treatment of biogas and leachate.

I.1 General Concepts of Landfills and Waste Management

I.1.1 Waste Management Methods Worldwide

Globally, waste management is a systematic process that includes waste generation, storage, collection, transportation, and ultimate disposal. Households, businesses, and institutions produce waste, which is then temporarily stored in different containers to reduce environmental risks and protect public health. Following collection by public or private agencies, it is driven to treatment or disposal facilities in specialized vehicles. Environmentally friendly techniques are used, depending on the infrastructure and laws of the nation [7]. Solid waste management can be divided into five key components:

- Generation
- Storage
- Collection
- Transportation
- Disposal

I.1.1.1 Generation

When an item is no longer useful to its owner, it is thrown, creating solid trash, the first step in the waste management process. Waste from homes, companies, industries, and institutions is included in this. Economic activity, population size, and consumption patterns all affect the quantity and kind of garbage produced. Designing effective downstream waste handling systems requires careful management of this stage [8].

I.1.1.2 Storage

Containers of various sizes are used to temporarily store waste near homes or businesses. Because garbage can be collected from a single location, this well-organized structure guarantees hygienic processing and streamlines the collection procedure [8].

I.1.1.3 Collection

Gathering waste from storage locations and getting it ready for transportation to facilities for treatment or disposal is known as collection. For disposal sites to avoid accumulation and overloading, a well-designed collection system is necessary [8].

I.1.1.4 Transportation

Transportation is the process of conveying collected garbage via trucks, trains, or barges to facilities for treatment or disposal. The amount and kind of garbage, distance, and local infrastructure all influence the mode of transportation [8].

I.1.1.5 Disposal

The goal of disposal, the last stage of solid waste management, is to securely get rid of garbage while lowering threats to the environment and human health. Landfilling, incineration, composting, and recycling are the four primary disposal techniques that are most frequently employed worldwide [9]:

- Composting.
- Incineration.
- Recycling.
- Landfill.

I.1.1.5.1 Composting

Composting is a natural process in which microorganisms decompose organic matter under well-defined conditions. Once the composting process is completed, organic raw materials such as crop residues, animal waste, food scraps, some urban waste, and suitable industrial waste can be applied to soils as fertilizer [10].

Figure I.1: Collection point for organic waste at industrial compost plant [11]

Figure I.1 presents the area where organic waste is gathered and prepared before being treated in the composting station is shown in this figure. To enhance the quality and effectiveness of the composting process, the waste is sorted at this point to eliminate any non-organic or inappropriate items.

I.1.1.5.2 Incineration

Waste incineration is a fire transformation technique. Incinerate means “reduce to ashes” or, in other words, burn the material to be incinerated completely. It is one of the waste management techniques that can be used to generate electricity and/or heat (urban heating) [12].

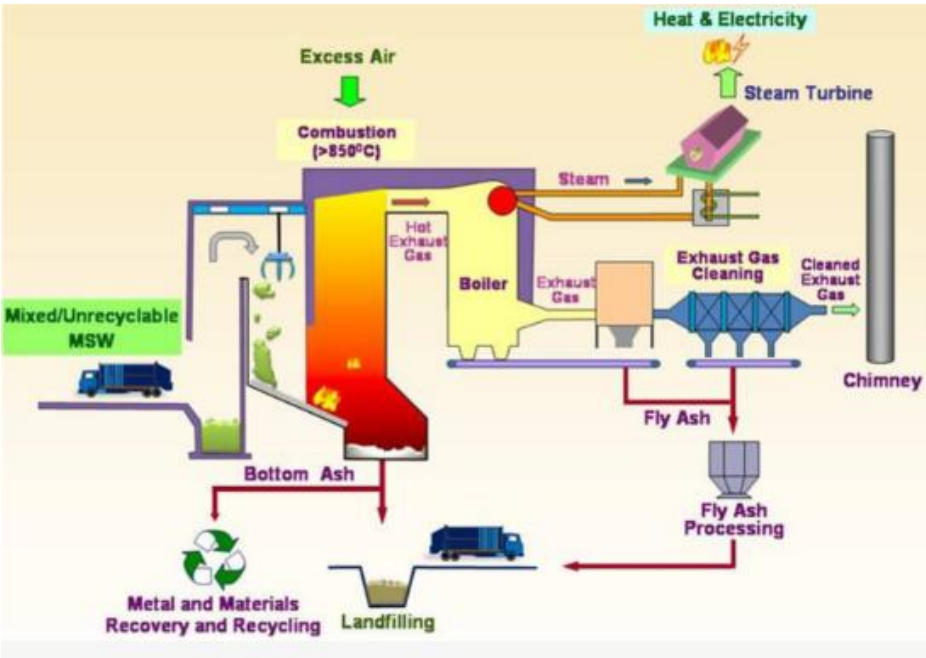

Figure I.2: Schematic Diagram of the MSW incineration process [13].

Figure I.2 illustrates how MSW incineration converts waste into energy: High temperatures are used to burn waste once it is fed into a combustion chamber. A steam turbine produces energy using the steam created by the heat.

An exhaust gas cleaning system filters contaminants out of emissions before release. When metals and other materials are recovered for recycling, bottom ash and fly ash are gathered for additional processing or disposal in landfills.

I.1.1.5.3 Recycling

Plastic bags, containers, tins, and glass will often be automatically recycled since they are likely to be scarce commodities in many situations. In most developing country contexts, there exists a strong tradition of recycling, leading to lower volumes of waste than in many more developed societies [9].

I.1.1.5.4 Landfilling

A landfill is a designated site for waste disposal, categorized into open dumps, sanitary landfills, and controlled treatment centers (CTCs). Sanitary landfills use engineered barriers to prevent contamination, while open dumps pose significant environmental hazards. Modern landfill designs focus on minimizing pollution through advanced waste treatment techniques, including geosynthetics [7].

I.1.2 Technical Landfill Facility Overview

I.1.2.1 Definition

A technical landfill is a site for the storage of household waste, developed according to well-designed modern techniques, to avoid or minimize conflicts between the effects of a landfill on the environment [14], while considering the reintegration of the site in its natural environment after closure.

The method consists of:

- To dig cells with appropriate dimensions for the land.
- Install a landfill site sealing system if necessary.
- To implement a collection and treatment system for percolation water.
- To implement a system for collecting, treating, and recovering landfill gas.
- Deposit organic waste and pack it up to a certain height.
- To make a multi-layer protective cover, the last of which is a layer of topsoil to create a green space.

Figure I.3: Technical landfill in Mostaganem [15]

A contemporary landfill site in Mostaganem is depicted in this graphic, complete with gas control and leachate collecting as environmental protection features. It draws attention to Algeria’s transition to safer, more sophisticated waste disposal methods.

I.1.2.2 Classification of Landfill Sites

Landfills can be classified based on the type of waste they accept, including municipal solid waste (MSW), hazardous waste, industrial waste, and construction debris (inert waste).

From a technical point of view, the regulations recommend three classes of waste storage facilities (WSF) according to the type of waste received, which differs by the degree of permeability of the subsoil of the developed site:

Class I landfills

Hazardous landfills are excavated or engineered sites where non-liquid hazardous waste is deposited for final disposal and covered. These units are selected and designed to minimize the chances of the release of hazardous waste into the environment.

According to the design standards of this type of landfills, their cells are prepared with a substrate having a minimum thickness of 5m with a permeability of 10^{-9} m/s, double liner, double leachate collection and removal systems, leak detection system, run on, run off and wind dispersal controls, and a construction quality assurance program[16].

Figure I.4: Hazardous Landfill [17]

This figure shows a Class I landfill used to dispose of hazardous material. It has several safety features to avoid contaminating the environment, including leachate collection systems and double liners. Toxic contaminants must be properly isolated from soil and groundwater using these constructed safeguards.

Class II landfills

A municipal solid waste landfill is a discrete area of land or excavation that receives household waste. MSWL may also receive other types of non-hazardous waste, such as commercial solid waste, non-hazardous sludge, conditionally exempt small quantity generator waste, and industrial non-hazardous solid waste.

According to standards, Household and similar waste landfill cells are made with a substrate having a minimum thickness of 1m with a permeability of 10^{-9} m/s, then a layer of 5m minimum thickness with a permeability of 10^{-6} m/s [18].

Class III landfills

A Class III landfill is a unit for the treatment and recovery of inert waste. This waste may include materials such as rubble, concrete rocks, earth, bricks, etc., from earthworks, demolition, or other construction activities.

Receiving inert waste is not subject to the special permeability requirement due to the physical and chemical stability of this type of waste.

Figure I.5: Kuang inert waste landfill [19]

The Kuang inert waste landfill, a Class III facility designed to handle stable, non-reactive trash like building and demolition debris, is shown in this figure. Because the garbage in these dumps causes no damage to the environment, sophisticated containment mechanisms are not necessary. The location offers a regulated area for the effective and secure disposal of inert materials.

I.1.2.3 Purpose of a technical landfill

The technical landfill center is intended to receive household and similar waste for disposal in:

- Eradicate wild drop-off sites.
- Reduce the environmental impact of waste.
- Recover and evaluate recyclable materials while reducing raw material losses.
- Reduce the volume and quantity of waste.
- Provide new industrial opportunities and jobs [20].

I.1.2.4 General criteria for the selection of a site for technical landfills

The location of a technical landfill cannot be chosen by accident. Various parameters must be considered to ensure that, once in operation and after closure, the landfill will have as little impact on the environment as possible. It is often important to consider several potential sites from the outset [21].

I.1.2.4.1 Cut-off criteria

In such areas, the location of landfills would cause significant nuisances that cannot be excluded or effectively limited.

Generally, these are the following areas:

- Military zones.
- National Parks.
- Protected natural areas.
- Areas within a distance to an airport of less than 5 km.
- Areas with underground mines.
- Swamps.

I.1.2.4.2 Restriction criteria

Also referred to as weighting criteria, they are given where environmental nuisances cannot be excluded. But it is possible to prevent long-range escape of pollutants by appropriate measures.

As for the following criteria:

- Topographical relief.
- Morphological situation.
- Preliminary nuisances.
- Forests and nature reserves [21].
- Distance to urbanization.
- Regional plan.
- Public opposition.
- Effect of emissions (smell, noise, vermin, dust).

I.1.2.4.3 Consideration criteria

Site search should consider aspects that may influence the decision, such as:

- Metrological.
- Distance to main waste site.
- Transportation network.
- Owner of the land.
- Use of the site.
- General nuisance of the visibility panorama.
- Protection of species.
- Presence of electricity and other infrastructure.
- Distance to a wastewater treatment plant.
- Presence of clay.

I.1.2.4.4 Geological and geotechnical criteria

I.1.2.4.4.1 Exclusion criteria

From the perspective of geotechnical geology and hydrogeology, the following criteria should be applied as exclusion criteria:

- Priority and areas of reserves of raw materials (if applicable, also only as a restriction criterion).
- Earthquake risk area.
- Risk of slippage, collapse, and underground cavities that cannot be eliminated.
- Extreme morphological situation (steep, high mountain).
- Geological natural monument.

I.1.2.4.4.2 Restriction criteria:

- Missing or insufficient geological barrier.
- Uneven land (sloping surface, valley incision).
- An aquifer surface layer above a geological barrier.
- Spring stratified and slope water emerging in the landfill area.
- Area with slippage risk and high lowering sensitivity.
- Quarry in operation or decommissioned with significant flaws that cannot be tamed.
- It is too small a distance compared to quarries in operation (or possibly to be commissioned) where the exploitation is done by explosion.
- Low knowledge and basic data on geology and hydrogeology.
- Area of failure.

I.1.2.5 Basic design principles for the technical landfill

It is the obligation of all those responsible and involved in the design of a technical landfill center to meet basic hygiene and environmental protection requirements [22].

The cost of digging up the traps is extremely high, especially in cases where the subsoil is rocky [21]. To do this, it is recommended to avoid or minimize excavation work for the construction of landfill sites and instead take advantage of site morphology and natural land formations. The topographical conditions of the site must determine the configuration and schedule of the landfill center. In addition, consideration should be given to the reintegration of the site into its natural environment after closure.

Other key elements of a technical landfill design:

- Collection area.
- Types and quantities of waste.
- Waste properties.
- Appropriate technical level.
- Waste pretreatment.

I.1.2.5.1 Site selection

First, a catalogue of exclusion and restriction criteria relating to competing interests and consideration criteria should be drawn up.

In addition to the general and specific environmental protection provisions of existing laws and regulations, any choice of site for waste treatment and storage is subject to authorization by Wali.

Inappropriate site selection may result in excessive expenses, additional environmental risks, and socio-cultural issues. The choice of site for a technical landfill is one of the most important decisions in implementing the waste management master plan.

In addition, the determination of a technical landfill site must consider the requirements for:

- The possibility of operating TL for a minimum period of fifteen (15) years.
- Urban sites.
- Distance to main waste site.
- Protection of nature and landscape.
- Rivers and lakes.
- The existence of groundwater, coastal waters.
- Geology and hydrogeology.
- Position in the geological relief (morphological situation).
- Risk of landslides or avalanches on site.
- Area available for extension.

The TLC can only be authorized if, given the site's characteristics concerning the requirements mentioned above, or the corrective measures considered, the landfill does not pose a serious risk to the environment [22].

The technical landfill may never be authorized in a groundwater protection area used for a drinking water supply.

I.1.2.5.2 Minimal infrastructure

Regardless of its type and capacity, each TLC requires the following minimum infrastructure:

- External and internal routes are always stabilized and accessible.
- Entrance with a gate.
- Control post.
- Full Fence: To prevent unauthorized entry into the landfill, it would be advisable to fence off the land [23].
- Parking deposit.
- Sanitary facilities.
- Lighting and telecommunications.

I.1.2.5.3 Water control

Considering the characteristics of the TLC and weather conditions, appropriate measures shall be taken to:

- To limit the amount of water from precipitation seeping into the mass of landfill waste.
- Prevent surface and/or groundwater from seeping into landfill waste.
- Collect contaminated water and leachate.
- Treat contaminated water and leachate collected at the TLC to achieve the quality required for discharge.

TL sites located on water tables shall have piezometers for monitoring.

Figure I.6: Different types of piezometers [24].

The several kinds of piezometers used to track groundwater levels and identify potential pollution close to technical landfill sites are depicted in this picture. By offering information on water table variations and leachate migration hazards, these tools are crucial for safeguarding water resources.

I.1.2.5.4 Soil and water protection

Any TL facility shall be located and designed to meet the requirements to prevent pollution of soil, groundwater, or surface water and to ensure that leachate is collected effectively [22].

The protection of soil, groundwater, and surface water must be ensured during the operating phase by a geological barrier with a watertight base coating and during phases of inactivity or after decommissioning by a barrier with a waterproof surface coating.

There is a geological barrier when the geological and hydrogeological conditions of the technical landfill site provide sufficient mitigation capacity to avoid any risk to soil and groundwater.

The base and dimensions of TL shall be made up of a mineral layer that meets permeability and thickness requirements, which combined effect in terms of soil protection, of groundwater and surface water is at least equivalent to that resulting from the following requirements:

- $K \leq 1.0\times10^{-9}$ m/s
- Thickness $\geq$ 1 m.

In cases where the geological barrier does not naturally meet the above conditions, it may be artificially supplemented and reinforced by other means offering equivalent protection.

The surface of the sealing system shall be profiled by a longitudinal and transverse slope to allow for free sloping leachate discharge. The thickness of each drainage layer must be at least 50 cm[25], but preferably not more than 30 cm. This is a limit value to obtain good compaction performance and ensure the movement of the machines.

In addition to the geological barrier described above, a leachate sealing and recovery system shall be added following the following principles to ensure the lowest possible accumulation of leachate at the base of the technical landfill.

The following basic sealing types can be used:

- ❖ **Mineral layer composed of clay with the following properties:**
    - $K \leq 1.0\times10^{-9}$m/s.
    - 2 layers, each 25 cm thick.

  Compaction at a minimum of 95% of the normal Proctor value.

- ❖ **Asphalt layer composed of 2 layers of asphalt with the following properties:**
    - ➢ **1 layer of support:**
        - 8 cm thick.

- Granulometry 0-16 mm.
- It contains 5.5-6.5% of bitumen.
- Pore volume ≤ 5%.

➢ **1 sealing layer of a:**

- 6 cm thick.
- Granulometry 0-11 mm
- It contains 6.5-7.5% by mass of bitumen.
- Pore volume ≤ 3%.

❖ Bentonitic recomposite, which is generally composed of:

- Geotextile.
- Polyethylene geo-filter.
- Bentonite (minimum 4 kg/m^2).

Bentonite is only effective if it is moistened and constantly wet. Therefore, in arid areas, the lack of water can be a restrictive problem for the use of bentonite recomposites.

Geosynthetics (geomembranes and composites) must be applied by qualified personnel according to an application plan developed in advance. The geosynthetics must be protected either by:

- 15 cm layer of sand with 0-8 mm grain size.
- Geotextile with a surface weight of ≥1200g/m^2.
- Combination of the two.

The protective layer must not be compacted.

I.1.2.6 Leachate management:

Drainage systems for leachate recovery consist of:

➢ **A drainage layer is laid on the base and support slopes**

- Thickness between 30 and 50 cm.
- Draining gravel with $K \geq 1{,}0 \times 10^{-3}$ m/s, gravel with a grain size of 16/32 mm.
- Non-calcareous gravel or has a low percentage of limestone (max 20%).
- Round gravel.
- Cross tilt ≥ 3%.
- Longitudinal tilt ≥1%.

➢ **Drainage tubes**

- Maximum distance between tubes: 30m.
- Positioned in a straight line.
- End up in a sieve well outside the TL
- Diameter ≥ 250 mm.
- Tilt ≥11 %
- HDPE equipment.
- Minimum pressure resistance PN16.

The corrosivity of leachate attacks concrete under certain conditions. It is recommended to use HDPE tubes for this purpose, also outside the drainage layer for leachate discharge.

Leachate must flow through free-sloping pipes to the sieve wells installed outside of the TL. The construction of burrows inside the technical landfill is prohibited. Leachate is transferred to the collecting pipes outside the discharge body through the sieve wells. Lookouts are also used to maintain and control drainage lines.

For this purpose, the outside sieve wells must provide sufficient space to adequately inspect and clean the hose. The end of the drainpipe in the control hatches must be below the liquid level to prevent air from entering the drainage system.

The leachates are led to the storage tanks through collection pipes. The functions of the storage tanks are:

- Equalization of quantity fluctuations, implementation of drainage.
- Capture of flow peaks.
- Concentration equalization.
- Ensures constant flow to the processing facility.

When calculating the volume of the basins, three essential aspects must be considered:

- The amount of leachate from the landfill.
- The time of residence of leachate in the storage tank.
- The capacity of the processing facility that follows.

Before commissioning, the leachate storage and treatment system must be defined after a preliminary study that considers the quantity and quality of the leachate.

I.1.2.7 BIOGAS Control

Appropriate measures must be taken to limit the accumulation and migration of biogas; the construction of rigid fume hoods for biogas capture should be avoided.

Flexible degassing wells are recommended to be made after the start or completion of case filling [26].

BIOGAS is collected in all technical landfills receiving biodegradable waste and must be treated. If the gases cannot be used to produce energy, they must be burned in torches.

The collection, treatment, and use of biogas are carried out in such a way as to minimize damage or degradation caused to the environment and risks to human health.

I.1.2.7.1 Nuisance and danger

Measures shall be taken to reduce the nuisances and hazards that may result from the operation of technical landfills:

- Odor and dust emissions.
- Wind-blown materials.
- Noise and vehicle movement.
- Birds, pests, and insects.
- Aerosol formation.

The magnitude of these nuisances is determined by the value of the component of the receiving environment, the intensity of the impact, the extent of the impact, and the duration of the impact [27].

I.1.2.8 Stability

Waste shall be deposited on site in such a way as to ensure the stability of the mass of waste and associated structures, and to prevent slippage.

If an artificial barrier is established, it must be ensured that the geological substrate, given the morphology of the technical landfill, is stable enough to prevent settlement, which could damage the barrier.

Maximum slopes of 2V/3H for the support slopes and slope of the landfill center surface are to be respected.

A storage plan is a key element in the design of a technical landfill. Appropriate waste storage sequences should be identified to avoid operational risks and complete the final design.

I.1.2.9 Fencing

- The technical landfill must be protected to prevent open access to the site.
- The gates must be locked after hours.
- The control and access system at each technical landfill should include measures to detect and deter illegal dumping on site.

I.1.2.10 Closure and Rehabilitation

The final contour of the technical landfill site and the reintegration of the site into its natural environment after completion of operation must be planned and approved from the outset.

The objective of a final coverage system for a closed technical landfill is to:

- Isolate environmental waste from the surface.
- Provide long-term minimization of precipitation water filtration within the landfill.
- Plan and authorize the reintegration and replanting of the surface of the completed technical landfill.

I.1.3 Operation of a Technical Landfill Center

I.1.3.1 Accepted types of waste

The waste control is carried out at the checkpoint, at the entrance of the establishment.

The accepted waste reaches the technical landfill after the information of the delivery machine (weight, registration) is recorded in the admission register. The waste must be covered with protective nets against flying when it is delivered by uncovered gear. Trucks are not allowed.

Types of waste accepted in the Landfill:

- Household and similar waste.
- Road waste.
- Industrial and commercial waste is similar to household waste.
- Waste from Green spaces.
- Sweeping waste.
- Bulky waste.
- Small-scale waste.

Prohibited waste is rejected because it is unfit for landfill; another method of treatment is recommended. The reason for the refusal of the waste and its origins are recorded in the refusal register.

Types of waste refused in the Landfill:

- Inert waste (rubble, construction debris, demolition rubble…).
- Contaminated waste from health facilities.
- Vehicle carcasses and heavy scrap.
- Slaughterhouse waste.
- Liquid waste.
- Metal cans and containers of more than 50L capacity.
- Large animal carcasses.

The technical landfill is not authorized to receive, process, or bury hazardous waste, but it may be temporarily stored (for 1-2 years) on site before being disposed of to an appropriate treatment unit [28].

I.1.3.2 Movement of waste:

The admitted waste, after its consignment, is directed either to the weighbridge for new vehicles whose empty and laden weights are not known or directly to the sorting center. In both cases, they use marked paths.

I.1.3.3 Sorting center

The purpose of the sorting center is to sort multi-material waste from raw collection as well as ordinary waste from commercial and industrial activities.

The center helps to meet recycling targets and reduces the use of raw materials. It is also a source of direct or indirect economic activity and employment.

The manual sorting is positive, but its mechanization remains a project of installation. The choice of size and degree of mechanization will be defined in consultation with the partners taking over the sorted materials and according to economic profitability criteria.

I.1.3.4 Sanitary landfill

The cell may be operated in increments or by cells. Only one cell should be operated at a time. The waste is deposited in successive layers and compacted on site. The compacted waste layer shall not exceed 80 cm in thickness. It shall be covered with material 10 cm in thickness. Covering materials shall not be clayed to allow leachate to percolate.

Principles set out in clauses in the specifications governing the design and operation of technical landfills condition the implementation of technical landfilling. These general principles are as follows:

- The minimum amount of overlay material available must be at least equal to that used for 15 days of operation.
- The compaction of waste is carried out with chain-operated machines (chain loader, chain tractor, chain wheel loader, metal-wheel chain compactor).
- Every six months, a waste compaction assessment is conducted.
- The waste is levelled as soon as it is dumped into the cell or immediately after the waste pickers are involved.

Too much compaction of waste at the outset is detrimental to degassing when the waste contains more than 50% organic matter. It is recommended that the levelling be carried out using large track pushers (350g/cm²). The levelling will respect, as soon as the cell is put into operation, the operating plan and will allow to reach the final height of the waste, increased by 20% to integrate the secondary settlement, as quickly as possible, at least on one side of the cell, to initiate its rehabilitation (laying of the anti-contaminant geotextile, degassing wells and final cover and plantations) as quickly as possible[29].

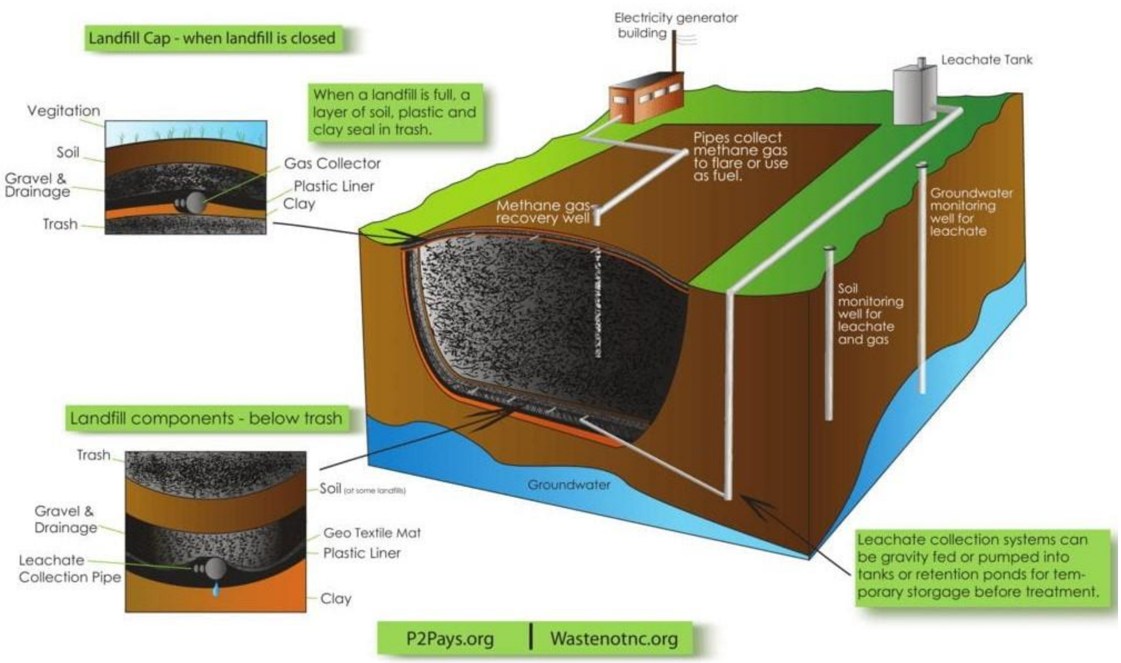

Figure I.7: Municipal solid waste landfill structure [30]

The layout of a contemporary sanitary landfill is shown in this diagram, which includes Closed landfills are sealed with surface cap layers (soil, gravel, and plants). systems for collecting gas to extract methane for flaring or energy. Drainage layers and pipes to send liquid waste to treatment are part of the base leachate collection systems. tracking groundwater contamination through monitoring. By regulating gas emissions and leachate leakage, this engineering design reduces its negative effects on the environment.

I.1.3.5 Leachate treatment

Water and leachate management systems will be maintained in the settling and treatment basins. The leachates, after being purified by natural lagging, are collected by a water curler truck to transfer them to a treatment plant.

Figure I.8: Leachate treatment station [31].

The leachate treatment station at the Hamici landfill, where contaminated liquid is handled via multiple stages, is seen in this figure. After biological treatment breaks down organic waste, the system uses activated carbon filtration and ultrafiltration to get rid of any remaining contaminants and fine particles. The treatment of water satisfies environmental discharge criteria thanks to this multi-step procedure.

Leachate is pumped into the storage tank by an immersed pump.

The biological phase consists of the degradation of leachate pollution by bacteria. The leachate, thus freed of some pollution, is then filtered by an ultrafiltration mechanism.

Ultrafiltration is the filtration of a semi-permeable membrane through a pressure difference. High molecular weight particles in solution or suspension are retained while water and low molecular weight particles pass through the membrane.

The final treatment is done by filtration with activated carbon. Activated charcoal is a very porous material that will fix pollution. It is a true "pollution sponge". Its action is complementary to ultrafiltration.

Finally, the treated effluent can be returned to the natural environment after monitoring.

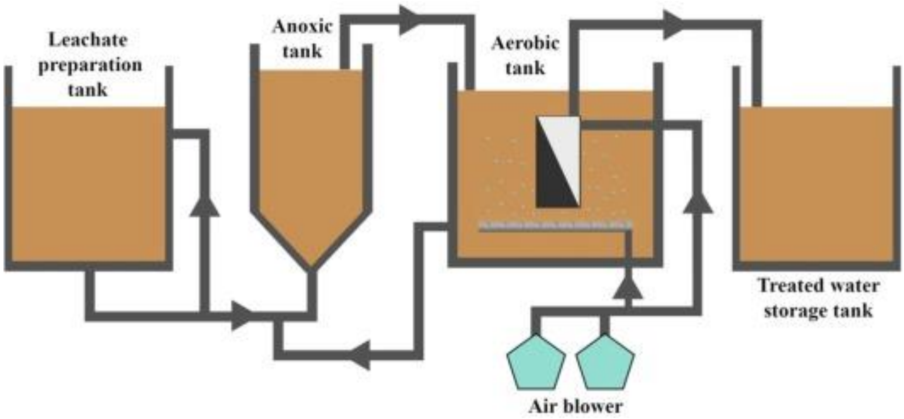

Figure I.9: Leachate Treatment process [32].

A system of consecutive treatment tanks for biological leachate treatment is depicted in this figure: Leachate is delivered raw to the leachate preparation tank. Anaerobic bacteria aid in the breakdown of organic matter in an anoxic tank during processing. To help aerobic bacteria further reduce contaminants, it then passes through an aerobic tank where air blowers add oxygen. In order to monitor the treated effluent before it is released into the environment, it is lastly collected in a treated water holding tank.

I.1.3.6 BIOGAS extraction and destruction technique

The BIOGAS is first extracted employing an extraction system whose flow rate is regulated, which determines the rate of capture and gas quality. The gases are then injected into an incineration unit.

The function of this incineration unit is to convert flammable or toxic compounds in the gas into inert compounds. It is mainly a system consisting of a flare whose performance is related to the flame's temperature and the combustion quality [33].

I.1.3.6.1 BIOGAS Recovery

Given the energy properties of biogas, it may be more interesting to recover it than to dispose of it [33]. The main ways of upgrading biogas are:

- **The production of electrical energy**

One option for reusing gas may be to generate electricity. In this case, the gases are used as fuel for the generator. The electricity produced is either used locally or sold to the local or regional energy distribution system. Biogas is converted into energy with an efficiency of 35%.

- **The production of steam or hot water**

Biogas can be burned in a steam boiler; this technique has higher efficiency, up to 85%. Moreover, biogas can be used for hot water production (efficiency up to 90%).

- **Cleaning and converting biogas into natural gas**

Another option may be to clean and compress natural gas as a fuel supply source for on-site or off-site use. Due to the high investment cost, this approach is only useful for large-scale biogas production.

I.2 Waste Management in Algeria

I.2.1 Waste Definition according to the Algerian regulations

Waste consists of three main categories: Household and similar waste, special waste (industrial, agricultural, care services, etc.), and inert waste. The definition of the different types of waste and treatment methods may vary from one country to another. According to the regulations in force, household waste is defined by Article 2 of Decree No.84-378 of December 15, 1984, setting the conditions for Cleaning and removing household waste, which includes domestic waste and assimilable by nature volume. It is in particular [6]:

- Industrial or collective household waste.
- Products resulting from cleaning, such as sweeping and sewer cleaning.
- Bulky waste, bulky objects, scrap metal, rubble, etc.
- Anatomical and infectious waste from hospitals, chemical or other care facilities
- Slaughterhouse waste and offal.
- Commercial waste, packaging, and other residues are generated by commercial activities.

I.2.2 Situation of waste management in Algeria

In Algeria, waste management is carried out by the public service, the National Program for the Integrated Management of Household Waste (PROGDEM), and by the National Waste Agency created by Executive Decree No. 02-175 of May 20, 2002. Since the Johannesburg Summit in 2002, Algeria has intensified its environmental protection and sustainable development actions, thus giving a prominent place to social and ecological aspects in its choice of societal model. The

Algerian Government has implemented a National Strategy for the Environment and a National Action Plan for the Environment and Sustainable Development (PNAE-DD), which:

- Involves all the ministries and decentralized services, local authorities, and civil society, whose role is to be a force for proposals.
- Aims to integrate environmental sustainability into the country's development strategy (to induce sustainable growth and reduce poverty);
- Puts in place effective public policies to address the environmental externalities of growth connected to activities increasingly initiated by the private sector. This strategy, whose main objectives are: improving health and quality of life, conserving and improving the productivity of natural capital, reducing economic losses and improving competitiveness, and protecting the regional and global environment, has resulted in: the development of the legislative and regulatory framework, institutional capacity building, and the introduction of economic and financial instruments, and the mobilization of significant investments, through the start-up of the first environmental projects, to halt the degradation of the environment and even reverse certain negative trends observed.

Law 01-19 of December 12, 2001, relating to the management, control, and elimination of waste constitutes in this respect the starting point and the reference of this new strategy. Thus, two programs that constitute the continuation of this law have been carried out and have obtained encouraging results:

- PROGDEM (National Program of Municipal Waste Management).
- PNAGDES (National Plan for Special Waste Management).

These programs are characterized by the elaboration, in collaboration with the authorities and local communities, of master plans of integrated management and treatment of waste, and the realization of concrete projects adapted to the local specificities, like the realization of the Technical Landfill Centers [6].

According to the Ministry of Environment and Quality of Life, 412 structures were built until 2023 to preserve the cleanliness of public spaces and improve citizens' living environments.

These achievements are reflected in the establishment of 117 technical landfills for household and similar waste, 52 solid waste Technical Landfills, 156 remediated landfills, 16 recycling centers, and 10 transfer centers. This includes the construction of 15 sorting centers, 31 waste leachate treatment units, and 15 composting units, she added, recalling that the national strategy for household waste management adopted until 2035 is based on the recovery and recycling of waste, which constitutes a promising area of economic investment in Algeria [35].

I.2.3 Waste Quantities and Ratios in Algeria

Between 13 and 13.5 million tons of waste is produced in Algeria each year, which is a substantial quantity. This includes waste from households and other comparable sources, with a significant proportion of organic matter (more than 50%). According to the National Waste Agency, just 6 million of the 13.5 million tons of household and similar waste generated in 2020 was treated, meaning that the treatment rate was only 45%. An average of 1,841 tons per day, or 672,000 tons per year, are processed by waste collection services [36].

I.2.4 Regulations and legislation in Algeria

The legislation currently applicable to waste management and technical landfill is constituted by the following legal provisions:

- ✓ Law no. 03-10 of 19 Jumada El Oula 1424, corresponding to July 19th, 2003, on the protection of the environment in the context of sustainable development.
- ✓ Law no. 01-19 of December 12th, 2001, relating to the management, control, and disposal of waste.

In January 2025, the members of the Council of Nation adopted a bill amending and supplementing Law 01-19 on waste management, control, and disposal, which aims to establish a green economy and lay the foundations for a circular economy.

Law no. 02-25 includes several measures, including:

- ❖ The development of a national strategy for integrated waste management and the implementation of a digital system for its management, in addition to the introduction of new definitions inspired by the United Nations' core circular economy principles.
- ❖ Establishing planning tools, such as the development of the national plan for integrated management of household and similar waste and inert waste, including hazardous waste.
- ❖ The fundamental principles of the circular economy were introduced into this law, including the principle of extended producer responsibility (EPR), which obliges each producer or holder of waste to recover such waste.
- ❖ This new law also introduces eco-design, an approach that aims to reduce the negative impacts of products on the environment over their entire life cycle, while maintaining their qualities of use.

- The law also includes a pyramid classification of waste treatment methods, the gradual replacement of single-use plastic products, and the establishment of a suitable system by producers and distributors to encourage consumers to contribute to the selective collection of waste [35].

Conclusion

The rules that are in existence, which vary from one nation to another, have a significant influence on how waste storage facilities are designed. Local waste management procedures, political decisions, and occasionally pressure from environmental organizations all have an impact on these variances.

Establishing such a facility calls for a dependable system that can reduce its negative effects on the environment. Furthermore, to avoid mishaps like fires, explosions, dangerous chemical reactions, infections, and other forms of contamination, landfill operations necessitate rigorous planning and ongoing oversight.

Chapter II:

Materials and Methods

Chapter II: Materials and Methods

Study Area: Hamici Landfill

II.1 Company overview:

Hamici Landfill is a public institution for managing technical landfills in Algiers, established on July 7th, 2013. As a key player in the region's waste management, Gecetal is responsible for receiving, processing, and recovering household, green, and inert waste while complying with international environmental standards.

The property is located on Hamissi Ramadan's farm, in the municipality of Mhalma in Algiers, covering an area of 103 hectares. It has modern facilities for the efficient management of waste. These infrastructures include a dedicated leachate treatment center, devices for the safe landfill of inert and final waste, as well as advanced systems for biogas management and technical closing of bins. These facilities ensure sustainable and environmentally friendly management that is aligned with the conservation objectives of Algiers city.

The EPIC GECETAL management is committed to meeting international environmental standards while promoting a circular economy. It values the recovered materials, which are resold to the industrial, public works, and agricultural sectors. Thanks to qualified human resources and efficient processes, it embodies excellence in sustainable waste management, thus contributing to a cleaner and more environmentally friendly future for Algiers [37].

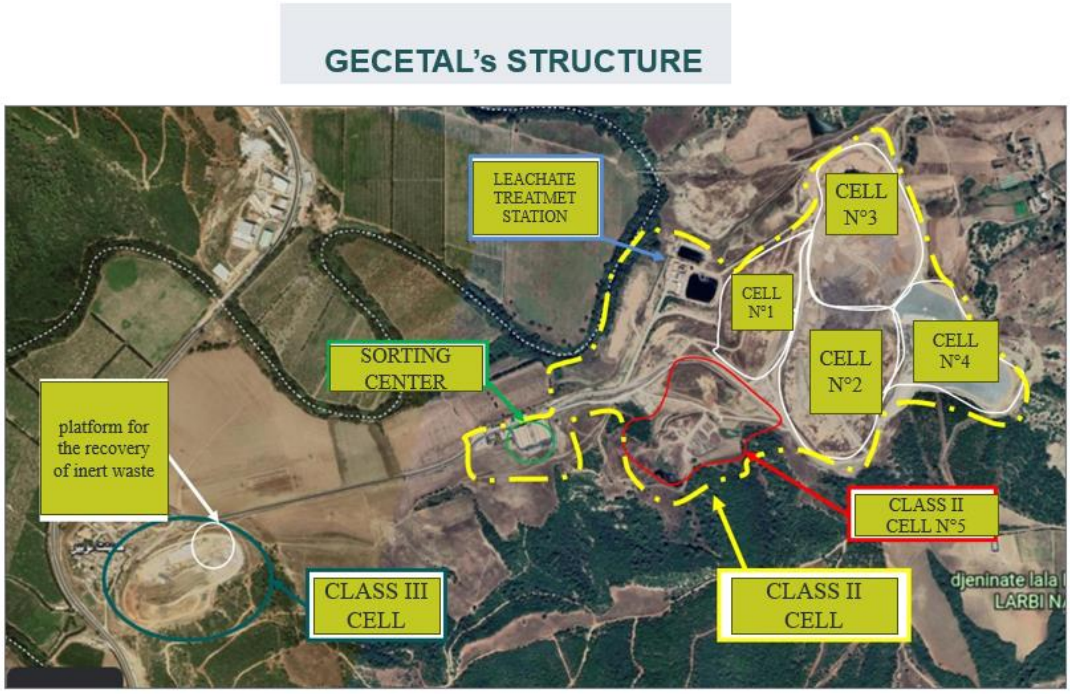

Figure II.10: Hamici Landfill [38]

A panoramic view of the Hamici landfill site is depicted in this figure. The primary operational zones—landfill cells, access roads, trash reception sites, and maybe leachate treatment or sorting structures—are visible in the picture. By showing how different waste management system components are positioned within the facility, the layout draws attention to the site's size and organization.

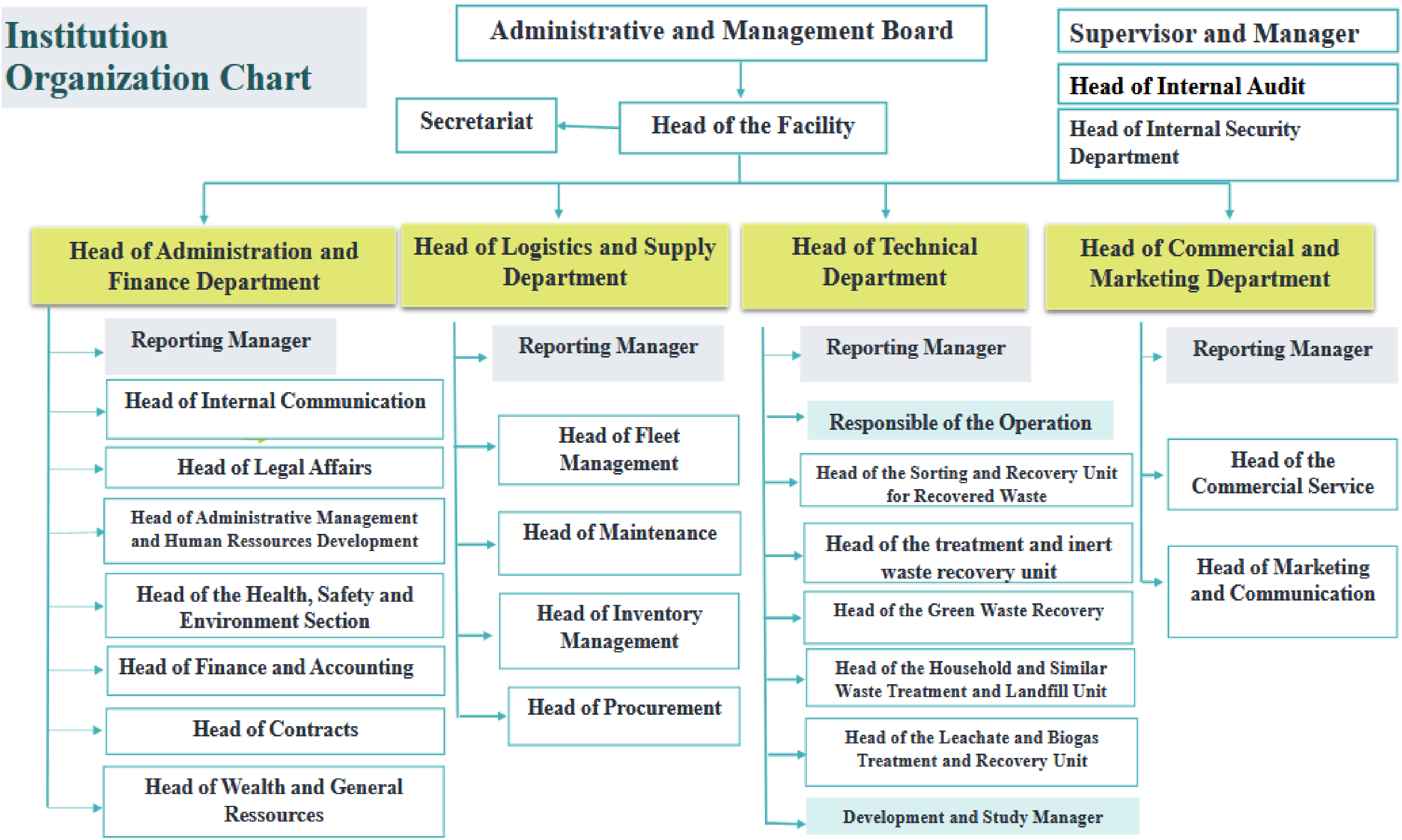

Figure II.2: Hamici Landfill Organization Chart [38]

An obvious and useful framework for running a waste treatment plant is depicted in this graphic. It has distinct leaders in charge of each of its major divisions, which include technical services, logistics, marketing, and administration. This ensures that all aspects of the operation function properly and that duties are assigned appropriately. Additionally, there are specialist sections that deal with maintenance, weighing, lab analysis, and environmental monitoring, demonstrating that the plant prioritizes sustainability and safety in addition to efficiency. Communication and oversight are made easy by clear reporting lines. All things considered, the chart shows a carefully considered system that strikes a balance between everyday operations, long-term objectives, and decision-making.

II.2 EPIC GECETAL's Activities

GECETAL's main activities are:

- GECETAL's first mission is to receive, treat, and dispose of household and similar waste. With local expertise and commitment to environmental protection, GECETAL actively contributes to efficient and sustainable waste management.

Presentation of Landfill cells:

- Landfill Cell No.01 has a total storage capacity of two million five hundred thousand cubic meters (2500000m^3) and began operating in January 2013.
- Landfill Cell No.02 has a total storage capacity of two million five hundred thousand cubic meters, 2500000m^3. It began operating in January 2017.
- Landfill Cell No.03 has a total storage capacity of three million five hundred thousand cubic meters, 3500000m^3. It began operating in January 2020.

Landfill Cell No.04 has a total storage capacity of two million five hundred

- thousand cubic meters, 2500000m^3. It began operating in January 2020[38].

This table represents quantities of waste received in the class 2 landfill of Hamici and it also shows that the amount of household waste decreased from 881,043.28 tons in 2020 to 749,715.86 tons in 2023, indicating a general downward trend in the data. This decrease can be the result of better trash sorting, more recycling, or adjustments to consumption habits. The little increase in 2024 to 808,197.79 tons, however, points to a potential recovery in waste production that would merit more research.

Table II.1: Household waste received for 5 years in the Hamici landfill

Year	Household Waste Quantity (Ton)
2020	881 043,28
2021	861 569,67
2022	764 893,07
2023	749 715,86
2024	808 197,79

Figure II.3: Landfill Cell[38]

At the Hamici site, this figure shows a typical landfill cell. Compacted waste layers, daily soil coverings, and access roads are shown. Waste is delivered and deposited by trucks, then leveled and compacted. The arrangement demonstrates the systematic layering technique used for environmentally compliant garbage disposal.

GECETAL's way of handling this type of waste:

1. Acceptance and Control: Each truck is subject to strict controls to ensure the nature of the waste transported.

2. Waste weighing: Each truck is weighed at the entrance and exit to accurately record the amounts of waste handled.

3. Treatment and landfill: The compliant waste is then sent to designated areas for landfill by applicable environmental standards.

- Secondly, the institution offers services dedicated to the reception and landfill of inert waste.

  GECETAL's way of handling Inert Waste:

  1. Receipt and Control: Each load is checked at the center's entrance to ensure that the waste complies with the admission criteria.

  2. Calculation and Recording: Trucks are assessed based on their size and capacity. A standardized method is applied to estimate the quantities processed, thus facilitating the recording process.

  3. Landfill: Waste is disposed of in designated areas within the Class III technical landfill by defined procedures [38].

Table II.2 represents detailed quantities of inert waste received in Hamici landfill. Significant annual variations in the amount of inert waste received are displayed in the table. In comparison to 2020, there was a notable increase in 2021 (+55.70%) and a slight increase in 2022 (+9.04%). But in 2023, there was a significant drop (-37.76%), suggesting potential geographical or operational adjustments. With a +24.30% increase in 2024, the rising trend resumed, perhaps as a result of better garbage collection or more urban activity.

Table II.2: Inert Waste received for 5 years in the Hamici landfill (Tons)

Month/Year	2020	2021	2022	2023	2024
January	52786	15489	54503	36825,5	63913,5
February	57040	52533	73293	23927,5	74061,74
March	17598	52768	74527,5	16251	37532,5
April	3909	49747	46009,5	12267,5	20432,5
May	12538	36592	52973	11040,5	32426,5
June	26341	42790	56145,5	27682	15007
July	32591	32729	40009	32965,5	33129,50
August	30940	67263	44689,5	39982	30565
September	39404	54236	11290,5	29839,5	26405
October	26026	66751,5	51378,5	46538	18601,50
November	19286	12406	39078	29067	28685,50
December	13250	33161,5	19248,5	44110	54904
Total	331709	516466	563146	350496	435664
Evaluation%	/	55,70	9,04	-37,76	24,30

Figure II.4: Inert waste Cell [38]

A Class III landfill cell, intended especially for inert waste like building and demolition debris, the image shows the deposition of stable, non-reactive materials inside a precisely defined cell.

- Thirdly Waste Valorization: Implementing a sorting center and recycling chains for materials such as plastic (PET, HDPE), glass, Aluminum, paper, cardboard, and Iron (Cans and Solid Iron)

Figure II.5: Recovered products from the sorting center [38]

This figure shows the different types of recyclable materials recovered at the Hamici sorting center, including aluminum, PET, HDPE, cardboard, paper, and others.

Table II.3 represents quantities of waste that entered the sorting centers over the years. Over the five years, the amount of waste that entered the sorting center varied. The quantities were largely constant in 2022 and 2023 after rising from 64,576.36 tons in 2020 to a peak of 84,847.02 tons in 2021. The notable drop to 63,120.94 tons in 2024, however, might be the result of altered upstream waste management procedures or decreased collection effectiveness.

Table II.3: Quantities of waste that entered the sorting center in 5 years

Year	Quantity (T)
2020	64 576,36
2021	84 847,02
2022	81 399,14
2023	80 517,852
2024	63 120,94

Table II.4 represents quantities of detailed sorted materials. The data shows a general decrease in the quantities of sorted materials, with PET and carton showing the most apparent fall. This could be a result of decreased trash intake, inefficient sorting, or changes in the composition of waste. Particularly noteworthy is the decline in PET from 1,762.8 tons in 2021 to 865.6 tons in 2024, which may indicate a decline in market demand or performance for this stream. After 2022, paper recovery stopped, indicating a shift in sorting procedures

Table II.4: Quantities of sorted materials generated from the sorting center over 5 years (Tons)

Year	Alu	Carton	Bread	PET	HDPT	Iron	Paper	Film
2020	14.82	209.75	100.97	1211.8	100.98	139.6	2.19	2.34
2021	20.86	143.46	101.517	1762.8	132.18	168.67	18.719	5.23
2022	15.77	115.15	110.2	1594.4	106.98	177.4	16.49	0.16
2023	13.19	116.8	138.56	1375.6	98.4	156.76	/	1.2
2024	11.405	90.38	120.42	865.6	70.66	109.42	/	0.8

Composting Plant: Its main task is to reduce the volume of green waste in Algiers and turn it into quality compost. Its objectives are multiple:

- ✓ Green waste recovery: Turn leaves, branches, grass clippings, and other plant waste into a useful resource.
- ✓ Reduce landfill: Reduce the amount of waste sent to landfills, thus limiting environmental impact.
- ✓ Compost production: Obtain a rich organic amendment for agriculture and green spaces.
- ✓ Environmental preservation: Contributing to reducing greenhouse gas emissions and soil protection.

Figure II.6: Compost station[38]

The composting station at the Hamici landfill, where green waste such as leaves, branches, and plant materials is turned into compost, is seen in this figure.

Table II.5 introduces quantities of compost generated in hamici landfill over almost 3 years. According to the data, methods for producing compost evolved between 2023 and 2025. No compost bags were utilized in the bulk production of 31.98 tons of compost in 2023. In contrast, only 1.04 tons of bulk and 69 bags totaling 25 kg were produced in 2024, a much smaller total. By 2025, production had increased to 12 packaged units and 12.41 tons in bulk. These discrepancies may arise from changes in the demand for compost, the accessibility of equipment, or operating capability.

Table II.5: Quantities of Compost generated over 3 years

Year	In bags (25 kg)	In bulk (T)
2023	/	31.98
2024	69	1.04
2025	12	12.41

- Leachate Treatment: The two treatment processes of the HAMICI leachate treatment plant, which are affiliated with EPIC GECETAL's leachate and biogas processing unit, are the MBR (Membrane Bioreactor) and the RO (Reverse Osmosis).

1. Membrane Bioreactor is the coupling of a biological basin and a nano- and ultrafiltration membrane. The interest is to retain, thanks to the membrane, all the microorganisms in the biological basin, including those that develop slowly

Technical sheet:

Area: 200m^2
Treatment Capacity: 80m^3/day
Processing efficiency: 80-85%

Figure II.7: MBR[38]

2. Reverse Osmosis: solutes are retained, except a few organic molecules of low molar mass. A high concentration retentate is recovered in salts and organic molecules. On the other hand, unlike ultra- and nano-filtration membranes, reverse osmosis membranes are not microporous but dense.

Technical Sheet:

Area: $100m^2$
Treatment Capacity: $120m^3$/day
Processing Efficiency: 50-60%

Figure II.8: Reverse Osmosis[38]

II.3 Costs

The financial evaluation of a landfill facility requires a comprehensive approach that considers initial investment costs, recurring operational expenses, revenue generation (turnover), and overall return on investment (ROI). These elements are essential for determining the waste management infrastructure's economic viability and sustainability. Accurate financial modeling supports informed decision-making and helps prioritize resources for optimal performance.

II.3.1 Investment costs

Investment cost, or cost basis, refers to the amount initially paid to acquire an investment, such as stocks or mutual funds. It is usually divided into several components: purchase price, brokerage fees, commissions, taxes, and other expenses. This initial investment cost is the basis for calculating capital gains or losses when the asset is sold [41].

II.3.2 Operational costs

Operating costs are the daily expenses necessary to maintain, operate, and administer a business. These include direct costs and indirect costs [42].

II.3.3 Cost-effectiveness

Cost effectiveness refers to the ability of a data team to deliver value and drive business outcomes while being mindful of the costs involved. This includes optimizing resource utilization, making smart decisions about tool and infrastructure spending, and ensuring that the team's efforts are focused on high-ROI projects [43].

II.3.4 Return on investment:

Return on Investment (ROI) is a financial indicator that measures the profitability of an investment. It is used to assess the effectiveness of an investment by comparing the profit generated with the initial cost of that investment[44].

II.4 Hamici Landfill's estimated investment Costs:

II.4.1 Class II Landfill (MSW)

Table II.6 shows the estimated investment expenses for building a Class II landfill for municipal solid waste. It covers both technical research and the purchase of construction materials like compactors and bulldozers. The enormous variation in site-specific variables and construction requirements is reflected in the landfill construction cost, which ranges from 5 to 6.5 billion DZD. The sizeable investment demonstrates how expensive waste infrastructure development is.

Table II.6: Class II landfill estimated investment costs [39]

Equipment	Quantity	Price (MILLION DZD)
Technical landfill site design study	/	5,000-6,500
Bulldozer	2	115.30
Compactor	1	1.94

II.4.2 Class III Landfill (Inert Waste)

Table II.7 shows the estimated expenditure needed for a Class III landfill used for the disposal of inert waste. Various heavy machinery, including loaders, dump trucks, bulldozers, and excavators, is included. Planning and resource allocation are crucial in waste infrastructure projects, as evidenced by the high estimated expenditures required for proper management of inert waste streams.

Table II.7: Class III landfill estimated investment Cost [39]

Equipment	Quantity	Price (MILLION DZD)
Crusher+ Screener	/	90,00
Bulldozer	1	57,65
Dump Truck	1	15,42
Crawler Excavator	1	32,17
Crawler Loader	1	27,43
Backhoe Loader	1	1,34

II.4.3 Sorting Center

Table II.8 represents the equipment and associated expenses required to set up a municipal waste sorting facility. Sorting lines, compacting presses, and necessary vehicles like loaders and dump trucks are among the items. To increase the effectiveness of recovering recyclable materials and decrease landfill input, automatic sorting systems are required, as evidenced by the financial expenditure.

Table II.8: Sorting Center's estimated investment cost [39]

Equipment	Quantity	Price (MILLION DZD)
Sorting Line 900T/24h	3	100,00
Film Processing Line 250 kg/h	1	250,00
Lifting Trolley (3 Tons)	1	3,69
Weighbridge (2 Tons)	2	0,60
Mini loader	2	12,93
Wheel Loader	1	21,40
Backhoe Loader	2	26,28
Dump Truck	6	9,23

II.4.4 Composting Station:

Table II.9 shows the estimated expenses for establishing a composting station. It consists of specialized machinery such as windrow turners, sieves, and crushers made to turn organic waste into compost. The large expenditure shows how important composting is to sustainable waste management, especially when it comes to lowering the amount of biodegradable trash that ends up in landfills.

Table II.9: Composting Station's Estimated Investment Costs [39]

Equipment	Quantity	Price (MILLION DZD)
Hammer mill 60m3/h Bio 930	2	35,52
Palm Crusher 3m3/h Skorpion 280	1	9,00
Screener 4m3/h Vaglio 3000	1	12,672
Winder 1000m3/h Rivo 300	1	10,66
Bag Welder	1	0,0021

II.4.5 Leachate Treatment Facility

Table II.10 represents leachate ponds and concentrate basins for storage and waste management, as well as a membrane bioreactor and reverse osmosis units for improved filtration, are among the necessary equipment for a leachate treatment station that is projected to cost this amount. These elements are essential for reducing environmental hazards because they guarantee that landfill leachate is effectively treated.

Table II.10: Leachate treatment station's estimated investment cost [39]

Equipment	Price (MILLION DZD)
Membrane Bioreactor	400,00
Reverse Osmosis	250,00
Leachate Ponds	30,00
Basins of Concentrates	1,30

II.5 Cost effectiveness and ROI calculations

a. Cost-effectiveness

In the context of a landfill facility, it measures the cost per unit of waste effectively processed or diverted from landfills.

i. Formula:

$$Cost\ effectiveness\ = \frac{Total\ Annual\ Costs}{Total\ Waste\ processed\ or\ diverted\ (tons)}$$

Components:

- **Total annual costs:** Sum of all operational expenses, including those from the sorting center, Class II and III landfills, composting station, and leachate treatment facility.
- **Total waste processed or diverted:** Total tonnage of waste managed through recycling, composting, or other diversion methods [45]

$$Cost\ effectiveness = \frac{Total\ investment\ Cost}{Total\ waste\ processed\ or\ diverted\ (tons)}$$

Components:

- **Total investment cost:** Sum of all the costs of the materials, trucks, and construction of GECETAL's activity areas [45]

b. Return on investment:

ROI measures an investment's profitability, indicating the investment's efficiency in generating returns.

i. Formula:

$$ROI = \frac{Net\ Profit * 100}{Total\ Investment}$$

Components:

- **Net Profit:** Total revenue generated from the facility minus total operational costs.
- **Total Investment:** Initial capital expenditures for constructing and equipping the facility[46].

c. Estimated operational Cost:

This standard proportional estimation method is often used in infrastructure project evaluations, especially when precise cost records are unavailable but investment values are known.

i. Formula:

$$Operational\ cost\ (annual) = Investment\ cost * operational\ cost\ rate\ (\%)$$

Components:

Operational cost rate (%): This is an approximate percentage that represents the average annual cost of landfill operations about the initial investment cost, and it usually falls between:

3–6% for well-maintained constructed landfills.

4–8% for composting stations and sorting facilities.

10–15% for intricate systems such as waste-to-energy units or leachate treatment plants[47].

Chapter III: Results and Discussion

Chapter III: Results and Discussion

Results & Discussions

Operational and financial performances of several parts of the Hamici landfill are thoroughly examined in this chapter. It assesses overall investment costs, operating expenses, revenue generation, and return on investment (ROI) across all activity areas, including the Class II and III landfills, sorting center, composting station, and leachate treatment plant, using data from 2024 that the company supplied [47].

The data shown in this chapter are the results of calculations made in Annex B

III.1 Total Investment costs

TableIII.1 shows that among the many activity areas; the investment costs fluctuate considerably. Comparatively speaking, the Composting Station and Leachate Treatment Station require far less capital than the Class II Landfill. The revenue generated has a similar pattern, with the Sorting Center and Class II Landfill contributing the most turnover.

Table III. 1: Total estimated investment costs in all the activity areas

Activity Area	Total Investment Cost (MILLION DZD)
Class II Landfill	5,135.04 - 6,635.04
Class III Landfill	235.81
Sorting Center	507.43
Composting Station	68.06
Leachate Treatment Station	695.00
Total	6,641.34 - 8,141.34

Discussion

The various waste management operations exhibit a glaring disparity between income and investment:

- Class II Landfill is extremely expensive but also generates a sizable amount of revenue, indicating moderate efficiency.
- Sorting Center seems to be very productive about its investment, suggesting a strong return on investment.
  • Class III Landfill has low investment and even lower revenue, indicating restricted profitability.

- Composting Station, despite reduced investment, yields modest income, raising doubts about its financial viability. If strategic investments were reallocated to more productive sectors, such as the Sorting Center, overall profitability may be improved.

III.2 Income

Table III.2 shows that:

Despite having a low unit price, Class II landfills contribute about half of the entire revenue. • The Sorting Center's high unit pricing allows it to generate the largest single-source income (764M DZD).

- Despite having the highest unit price, the Composting Station processes a very small volume (2800 tons).
- Despite processing a large volume, Class III landfills generate very little revenue.

Table III. 2: Turnover by area of activity in 2024[40]

Area of Activity	Total Amount (MILLION DZD)
Sorting Center	76.42
Class II Landfill	692.42
Class III Landfill	39.28
Composting Station	1.29
Total	8.09

Discussion:

- Sorting Center: Excellent revenue generation because of the high unit price and respectable volume, underscoring the material recovery's economic potential.
- Composting Station: Although the high unit pricing (perhaps because of the high-quality compost) is encouraging, the incredibly low volume renders it almost meaningless in terms of revenue. The ability to scale input volumes is a huge potential.
- Class II Landfill: This is a major source of revenue despite having a low unit price (310 DZD/ton) due to the extremely high waste quantity (808197,79 tons). However, it has high operating and capital costs, which reduce profitability.
- Class III Landfill: the extremely low unit pricing and low overall revenue indicate that this facility is mostly used for dumping rather than for generating profits.

III.3 Operational costs

Table III.3 shows that the Class II landfill is taking up the majority of the budget, the Hamici landfill's operating costs show a significant gap across the various activity sectors. Interestingly, the Class III landfill and composting station likewise have significant costs in comparison to their meager profits, indicating inefficiency.

Table III. 3: Estimated operational costs of the hamici landfill in 2024

Activity Area	Operational cost
Class II Landfill	231.08– 298.58
CLASS III Landfill	42.45
Sorting Center	30.45
Composting Station	4.08
Leachate Treatment Facility	86.88
Total	394.93 – 462.43

Discussion:

The Hamici landfill's operating expenses, according to the data shown in the table , fall between about 394.9 million and 462.4 million DZD. There is a significant financial burden because more than half of these costs are related to the Class II landfill alone. Yet, both the composting station and the Class III landfill have poor returns on investment despite costing more than 42 million and 4 million DZD, respectively. This calls for a thorough performance analysis and raises questions regarding these units' economic viability. Optimizing waste processing, expanding revenue sources like compost sales, or using improved sorting techniques to boost profitability and lower losses are a few possible improvements.

III.4 Cost Effectiveness

III.4.1 Cost-effectiveness concerning the quantity of waste admitted

- Compared to other places, the Composting Station has the greatest cost per ton (1458,39 DZD).
- The Class III Landfill has the lowest cost per unit of operation.
- The Sorting Center displays moderate prices.
- The outlier Composting Station drives up the overall average cost, which ranges from 301.52 to 353.06 DZD/ton.

Table III. 4: Price per ton of waste admitted and generated in all the activity areas in Hamici landfill

Activity area	Price (DZD/TON)
Class II Landfill	285,92 – 369.44
Class III Landfill	97.43
Sorting Center	482.34
Composting station	1458.39
Total	301.52 – 353.06

Discussion

Composting Station: The high expense points to inefficiencies, such as costly machinery, high human expenses, or intricate procedures, even though income was high (see the preceding table). good-value compost products may yield a good return on investment, but at such a high cost per ton, sustainability is called into question.

- Class III Landfill: Extremely low cost implies a passive, low-tech operation. But it probably has no environmental protections and makes very little money. • Sorting Center: Given its high revenue and return on investment, its relatively high cost (482.34 DZD/ton) is justified. Effective but not inexpensive.
- Class II Landfill: This type of landfill operates in a broad range (285.92–369.44 DZD/ton), suggesting variable cost efficiency that may be influenced by the disposal method or volume of waste.
- While determining if Class III Landfill offers sufficient advantages to continue operating, a strategic objective should be to lower composting expenses and preserve sorting effectiveness.

III.4.2 Cost-effectiveness concerning the investment cost

The table offers a thorough summary of the DZD/Ton capital investment needed for each of the various waste management activity sectors. It makes it abundantly evident that Class III Landfill requires the least amount of infrastructure or technology, as seen by its lowest investment cost of 541.26 DZD/Ton. However, the Composting Station has the greatest investment cost (24,306.46 DZD/Ton), indicating that it is a capital-intensive operation that probably requires specific equipment and treatment facilities. In the middle are the Class II Landfill and the Sorting Center, which have moderate to high investment requirements. The large range of investment (5,070.56

– 6,215.79 DZD/Ton) highlights the financial burden of sophisticated treatment facilities, such as composting programs.

Table III. 5: Cost effectiveness concerning the investment cost

Activity Area	Cost-effectiveness DZD/Ton
Class II Landfill	6353.69 – 8209.67
Class III Landfill	541.26
Sorting center	8039.08
Composting Station	24306.46
Total	5070.56 – 6215.79

Discussion:

Important insights into long-term planning and economic efficiency can be gained from comparing the operational expenses (Table III.3) and investment costs (Table III.4) across several waste management activity areas:

Class II Landfill :

Operating Cost: 285.92 to 369.44 DZD/Ton;
Investment Cost: 6,353.69 to 8,209.67 DZD/Ton

Analysis: Although this alternative requires a moderate to high initial investment, it has low operating costs, indicating that the system can eventually prove to be cost-effective due to its low maintenance and operating costs.

2. Class III Landfill:
Investment Cost: lowest, 541.26 DZD/Ton
Operational Cost: lowest at 97.43 DZD/Ton

Overall, this is the most economical choice in terms of both operating and investment costs. Municipalities with limited funds might find it perfect, but its environmental performance might not be as good as that of more sophisticated systems.

3. Sorting Center:

Cost: 8,039.08 DZD/Ton.
Operational Cost: 482.34 DZD/Ton.

Analysis: The sorting center has a moderate operational cost and a large investment, suggesting a reasonably balanced but expensive process. This implies that to make the investment worthwhile, there must be a strong return on materials recovered.

The maximum investment cost for a composting station is 24,306.46 DZD/ton. The greatest operational cost is 1458.39 DZD/ton.

Analysis: In terms of both investment and operational efficiency, this activity is the least profitable. Only in areas with a high need or policy for organic waste treatment and environmental preservation may it be justified, as it significantly raises the average cost.

5. Range of Total Costs: Operating Total: 301.52 – 353.06 DZD/Ton;

Investment Total: 5,070.56 – 6,215.79 DZD/Ton

In summary, the operational cost is comparatively low about the investment cost, suggesting that initial capital availability and long-term return on investment should be given top priority when making decisions.

Conclusion: Although Class III landfills offer the most cost-effective option in terms of both investment and operation, composting stations are a significant financial burden even though they are environmentally beneficial. Class III landfilling for residuals and a modest investment in sorting, combined with selective composting when organic waste amounts and environmental restrictions warrant it, could be a balanced waste management approach.

III.5 Return on investment

The table represents the return on investment in 2024, and it shows that:

- The Sorting Center has a 9% ROI.
- The overall return on investment is still poor, averaging between 4% and 6% for the entire system.
- Both the Class III Landfill and Composting Station fall short of ideal ROI standards.

Table III. 6: Return on investment for each area

Activity Area	ROI (%)
Class II Landfill	6% - 9%
Class III Landfill	-1%
Sorting center	9%
Composting station	-4%

Total return on investment proportion	6% – 4%

Discussion

- Class III Landfill: It makes little money, the low return on investment indicates that it's currently operating at a loss, this suggests a need to reassess operational efficiency or revenue strategies to improve financial performance.
  • Sorting Center: Because investment and operating income are balanced, it offers a dependable and long-lasting return on investment. In terms of operational and financial balance, it is the clearest performer.
  • Composting Station: -4% ROI indicates a significant financial shortfall, due to the high cost per ton, even with significant revenue.
  • Class II Landfill: A return on investment (ROI) of 6% to 9% is reasonable, although the payback period could be lengthy due to the high capital requirements.
  • The poor system-wide return on investment (ROI) indicates that, despite strong performance in certain areas, there is a great deal of inefficiency throughout the system

Conclusion

This chapter’s analysis demonstrates that the Hamici technical landfill’s various components don’t all function with the same degree of financial efficiency. The Sorting center is the most economical of them all, offering a good return on investment, robust revenue, and a fair investment. However, because of its extremely low processing throughput and high cost per ton, the Composting Station seems to be working poorly. Despite being an essential component of the waste system, the Class II landfill has high costs and relatively modest financial benefits. The Class III landfill, on the other hand, generates virtually little revenue despite having modest operational costs. These results demonstrate that to improve Algeria’s waste management performance, more strategic investment and improved financial planning are required.

Conclusion and Perspective

Conclusion and Perspective

This research aimed to assess the economic viability and cost-effectiveness of the Hamici technical landfill in Algiers, which incorporates a range of integrated waste management activities: a Class II landfill for municipal solid waste, a Class III landfill for inert waste, a sorting center, a composting station, and a leachate treatment facility. Through detailed analysis of operational data from 2024, the study evaluated investment costs, operational efficiency, income generation, and return on investment (ROI) across each component of the facility.

The results highlight significant disparities in both cost structures and financial returns across the different activity areas. The Sorting Center stands out as the most economically effective unit. Despite its moderate investment cost (approximately 507 million DZD), it generated one of the highest incomes (around 764 million DZD) due to a unit price of(482,34 DZD/ton) and robust waste recovery rates. Its ROI and cost-per-ton metrics indicate a strong balance between profitability and operational efficiency, making it a key pillar for future investment.

Conversely, the Composting Station, while benefiting from a high unit sale price (1458,39 DZD/ton), processes a very small volume of waste (2800 tons in 2024), resulting in a disproportionately low total income (~1.29 million DZD). This raises concerns regarding its financial viability and operational sustainability unless significant scale-up or cost optimization measures are introduced.

The Class II Landfill, which receives the highest waste volume, plays a central role in waste disposal and income generation (~692 million DZD). However, it also demands the highest investment (5.1–6.6 billion DZD) and incurs high operational costs (231 million – 298 million DZD), yielding a modest ROI of 6–9%. While essential for regional waste management, its cost structure requires optimization to maintain economic balance.

The Class III landfill, which requires a relatively small investment of about 236 million DZD, has the lowest cost per ton 97.43 DZD/ton. The facility has a negative return on investment (ROI) of -1% because it only makes about 39 million DZD in revenue, despite being cost-effective to operate. According to this, the landfill is not financially viable in the current economic climate, even though it might be economical in terms of the tons processed. Therefore, enhancements in revenue generation, operational optimization, or outside funding would be required for this alternative to be feasible.

The Leachate Treatment Facility, necessary for environmental compliance, involves high capital expenditure (~695 million DZD) and significant operational costs due to advanced technologies like membrane bioreactors and reverse osmosis. While not a revenue-generating unit, it is critical for mitigating environmental risks and ensuring long-term regulatory compliance.

In conclusion, the Hamici landfill presents a hybrid model of waste management that achieves varying degrees of financial and operational success. The study underscores the need to:

Enhance performance and scale in high-potential units like the Sorting Center.

Reassess the operational strategy of underperforming units, especially the Composting Station.

Optimize expenditure and streamline operations in capital-intensive units like the Class II Landfill.

And maintain essential but non-revenue-generating infrastructure such as leachate treatment for environmental safeguarding.

Overall, this case study provides practical recommendations for improving waste management infrastructure in Algeria. A more targeted allocation of resources and integration of economic performance metrics into planning could significantly boost both the sustainability and efficiency of landfill-based waste treatment in developing contexts.

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Annexes

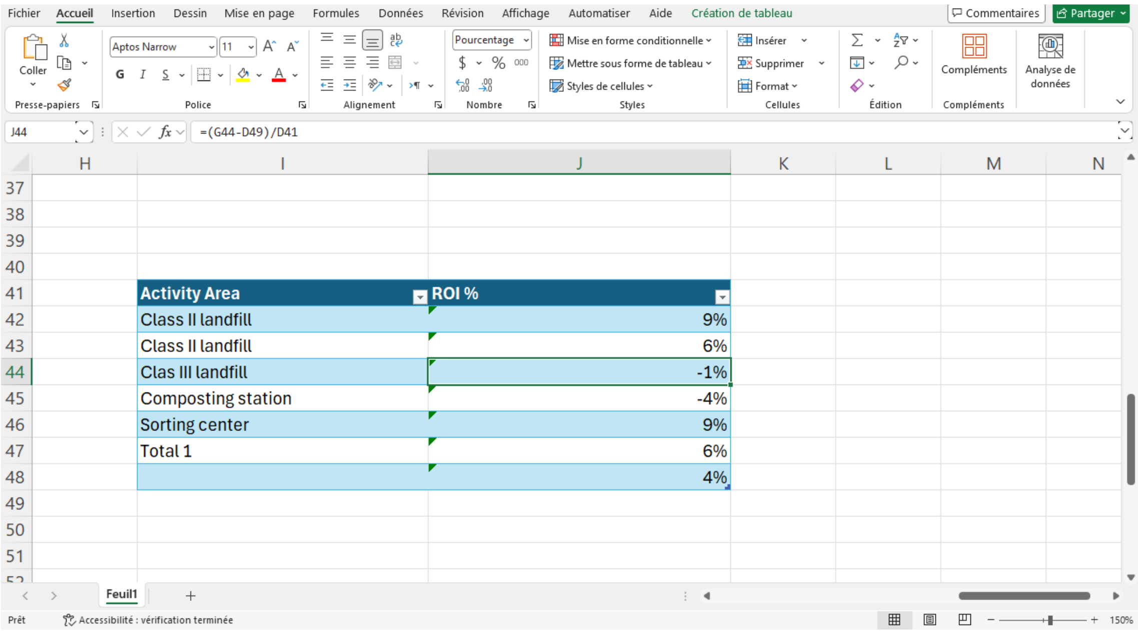
Annexes

Annex A: Waste management Legislation in Algeria

- ✓ Executive Decree no. 07-145 of Jumada El Oula 2nd, 1428 corresponding to 19 May 19th, 2007, determining the scope, the content, and approval procedures for the environmental impact studies and notices of a multiple geomembrane or associated materials of a composite geomembrane.
- ✓ Executive Decree no. 2007-144 of Jumada El Oula 2nd, 1428 corresponded to May 19th, 2007, establishing the nomenclature of classified installations for environmental protection.
- ✓ Executive Decree no. 06-198 of Jumada El Oula 4th, 1427 corresponding to May 31st, 2006, defining the regulations applicable to establishments classified for the protection of the environment.
- ✓ Executive Decree no. 2006-104 of Moharram 29th, 1427 corresponding to February 28th, 2006, establishing the waste nomenclature, including special hazardous waste.
- ✓ Executive Decree no. 04-410 of Dhou El Kaada 2nd, 1425, corresponding to December 14, 2004, setting out the general rules for the design and operation of waste treatment facilities and the conditions for the admission of such waste at these facilities.
- ✓ Executive Decree no. 93-160 of July 10th, 1993, regulating the discharge of industrial liquid effluents.
- ✓ Directive 3011/SG of October 8th, 2005, on the management and operation of technical landfills.

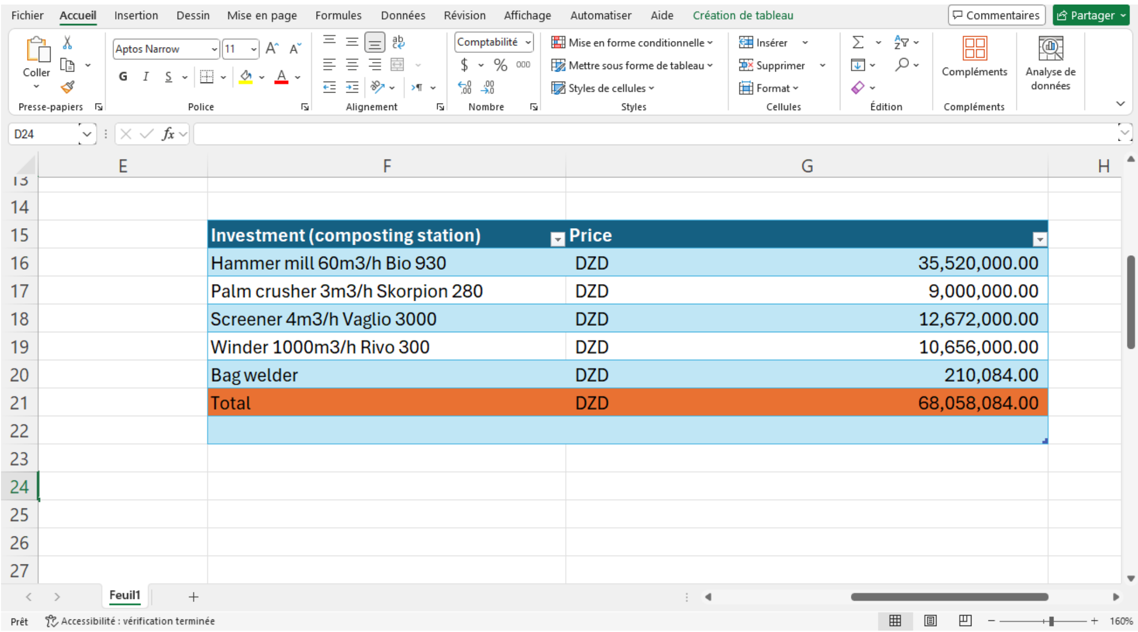
Annex B: Calculations

Annex B.1: Return on Investment Calculations



Activity Area	ROI %
Class II landfill	9%
Class II landfill	6%
Clas III landfill	-1%
Composting station	-4%
Sorting center	9%
Total 1	6%
	4%

Annex B.2: Composting Station's investment Costs.



Investment (composting station)		Price
Hammer mill 60m3/h Bio 930	DZD	35,520,000.00
Palm crusher 3m3/h Skorpion 280	DZD	9,000,000.00
Screener 4m3/h Vaglio 3000	DZD	12,672,000.00
Winder 1000m3/h Rivo 300	DZD	10,656,000.00
Bag welder	DZD	210,084.00
Total	DZD	68,058,084.00

Annex B.3: Class III Landfill investment cost

Investment (Class III Landfill)	Price (DZD)
Crusher+ screener	DZD 90,000,000.00
Bulldozer	DZD 57,647,526.25
Dump truck	DZD 15,421,080.17
Crawler Excavator	DZD 32,167,761.10
Crawler Loader	DZD 27,427,152.32
Backhoe Loader	DZD 13,142,348.78
Total	DZD 235,805,868.62

ANNEX B.4: Quantity of waste generated in 2024

type of waste	quantity generated (2024) (Tons)
MSW	808197.79
Inert Waste	435664
Sorting center	63120.94
Compost	2800
Total	1309782.73

*ANNEX **B.5:** 2024 Turnover*

Area of activity	Turnover (2024)	
Class II landfill	DZD	692,501,325.42
Class III landfill	DZD	39,277,572.80
Sorting center	DZD	76,417,515.96
Composting station	DZD	1,294,382.50
Total	DZD	809,490,796.68

ANNEX B.6: Operational costs

Activity area	operational costs	
Class II landfill (estimation 1)	DZD	231,076,707.42
Class II landfill (estimation 2)	DZD	298,576,707.42
Class III landfill	DZD	42,445,056.35
Composting station	DZD	4,083,485.04
Leachate treatment station	DZD	86,875,000.00
Sorting center	DZD	30,446,064.40
Total (estimation 1)	DZD	394,926,313.21
Total (estimation 2)	DZD	462,426,313.21

***ANNEX B.7:** Total investment costs*

Activity area	investment costs	
class II landfill (estimation 1)	DZD	5,135,037,942.70
class II landfill (estimation 2)	DZD	6,635,037,942.70
Sorting center	DZD	507,434,406.65
Composting station	DZD	68,058,084.00
Leachate treatment station	DZD	695,000,000.00
Class III landfill	DZD	235,805,868.62
Total (estimation 1)	DZD	6,641,336,301.97
Total (etimation 2)	DZD	8,141,336,301.97

ANNEX B.8: Leachate treatment station's investment costs

Investment (Leachat treatment station)	Price	
Membrane Bioreactor	DZD	400,000,000.00
Reverse Osmosis	DZD	250,000,000.00
Leachate Ponds	DZD	30,000,000.00
Basins of concentrates	DZD	15,000,000.00
Total	DZD	695,000,000.00

ANNEX B.9: Sorting Center's investment costs.

Investment (sorting center)	Price	
Sorting line 900T/24h	DZD	100,000,000.00
Film processing line 250kg/h	DZD	250,000,000.00
Lifting trolley (3 Tons)	DZD	3,690,000.00
Weighbridge (2 Tons)	DZD	600,000.00
Mini loader	DZD	12,933,773.10
Wheel loader	DZD	21,399,455.00
Backhoe loader	DZD	26,284,697.55
Dump truck	DZD	92,526,481.00
Total	DZD	507,434,406.65

ANNEX B.10: Class II Landfill's investment costs

Investment (Class II Landfill)	Price (DZD)
Bulldozer	DZD 115,295,052.50
Compactor	DZD 19,742,890.20
Technical landfill site design study (estimation1)	DZD 5,000,000,000.00
Technical landfill site design study (estimation2)	DZD 6,500,000,000.00
Total (estimation 1)	DZD 5,135,037,942.70
Total (estimation 2)	DZD 6,635,037,942.70