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The Role of Innovation in Waste Management

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Abstract:
The increasing amount of waste daily in our time constitutes an important environmental and economic challenge, requiring the construction of integrated strategies aimed at creating an integrated management of this waste, based on innovative techniques and special technologies to deal with it and manage it in effective and safe ways. This study was designed to provide a comprehensive theoretical analysis of the innovation element, and examine The concept of various types of waste, to highlight the problem of waste management and the role of innovation in it by clarifying the most important strategies followed, as well as the various innovative techniques and modern technologies used in this, with a focus on the reality of solid waste management (domestic and similar) in the state of Khenchela, for the technical backfilling center as a model Innovative, we relied on conducted interviews and field observations, to convey a realistic simulation of the center's working method, based on real data provided by it over a specific period of time, to apply an innovative waste management model, which contributed to analyzing the effectiveness of innovation in reducing the amount of waste sent to landfills, even if Relatively, enhancing the environmental and economic sustainability of waste management operations.

Keywords: Innovation, Waste, Waste Management.
JEL Classification: O3 ; Q53 ; Q55

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Introduction

In light of the increasing environmental challenges facing the world today, innovation has become an inevitable necessity, and as a refuge to find correct paths and effective and sustainable solutions, in order to control and relative control the crisis of the great increase in waste around the world as a result of human activities and continuous, which requires and inevitably work to develop innovative strategies to deal with this issue effectively and efficiently, innovation today is not just a new technology, but a set of processes that improve previous processes, develop new policies and businesses, and adopt sustainable practices that aim to transform waste from an environmental threat and burden to a valuable resource.

In addition to this, innovation directly contributes to changing the way individuals and communities deal with waste by promoting environmental awareness and encouraging sustainable practices such as recycling and reuse, the continuous development of innovative technologies transforms the perception of environmental challenges and threats associated with waste into real economic opportunities, transforming waste into valuable resources used in energy production on the one hand and the manufacture of new materials on the other.

Innovation is a powerful tool to address the environmental challenges associated with waste management, by adopting new and innovative models and practices that optimize current processes, adapt them to current conditions, promote sustainability, and create new economic and social benefits.

Research Question:

- What is the role of innovation and innovative technologies in ensuring sound waste management?

Study Hypotheses:

- Innovation has a direct role in adopting real models of waste control and proper waste management.
- Innovative technologies develop sustainable solutions to deal with waste and its risks.
- Waste management technologies provide environmental solutions to the waste issue, as well as economic and social opportunities.

Significance of the Study:

- Highlighting the important role played by innovation by adopting truly innovative models in waste management and adapting them to new conditions and characteristics.
- Introduce the various modern technologies related to waste management and the development in this field.

- To give a real picture of the methods adopted to manage household and similar waste in the study organization.

Objectives of the Study:

The study seeks to achieve a number of objectives:

- Trying to understand innovation and recognize the content of innovative adoption by highlighting its most important models.
- Highlighting the role of innovation in the process of waste management within the waste management issue.
- To give an insight into the continuous evolution of technologies and techniques dedicated to waste management and highlight their role in protecting the environment and creating economic and social opportunities.

Methodology and tools used:

In order to reach the previously mentioned objectives, we relied in our study on the descriptive and analytical method in the theoretical aspect to identify the theoretical framework of innovation and its models, including the most important concepts related to waste and its types, and to highlight the relationship between innovation and its important role in waste management by addressing the most important innovative techniques and modern technologies adopted in waste management, while in the applied aspect, the interview method was used in addition to inspecting the activity of the institution under study, in order to present a virtual simulation of an innovative model of waste management for this institution within the scope of the study.

Structure of the Study:

1. Theoretical Framework of Innovation;
2. The concept of waste and its types;
3. Innovation and its role in waste management;
4. The Technical Landfill Center as an innovative model for waste management.

1. Theoretical Framework for Innovation

Innovation is centered around the aspects of progress and change in various fields and sectors, as it revolves around the processes of introducing new ideas and improving existing ones, with the aim of producing new products, services or processes that add value and achieve tangible benefits. Innovation includes various new technologies, innovative management methods, as well as social and creative solutions that contribute to improving daily life and enhancing sustainability.

1.1. The concept of innovation:

Innovation concepts, definitions, and scientific origins are numerous, as they have many facets according to research directions or scientific disciplines. In general, innovation is called the processes of introduction,

change, development, and innovation, each of which may express innovation from a specific angle and a special vision (Atallah, 2005, p. 11) .
The Austrian thinker Joseph Schumpeter incorporated the term innovation into his evolutionary theory. According to him, innovation involves various processes that aim to implement new methods in the production process and changes in various aspects of product design, focusing directly on radical technological developments, which have a profound impact on the production process, stimulate economic growth, and promote the creation of new businesses in various sectors (Mark & David, 2014, p. 30). Schumpeter and Drucker see innovation as a facet of creative destruction, which can becharacterized as the demolition of the old and the continuousgeneration of the new (Drucker, 1994, p. 514).
Holmquist sees innovation as the process of giving solutions to problems in new, previously unrecognized forms (Holmquist, 2012, p. 58).
Verloop also explained that innovation is the process of creating a business by transforming ideas into real-life actions.
Verloop also presented the idea of the innovation bridge, through which he showed that innovation is not limited to the creation of new ideas, but rather the ability to transform these ideas into valuable commercial products and services. His view of innovation reflects the process of linking intellectual capital and commercial capital (Verloop, 2013, p. 05).
Caraballo's conceptualization of innovation has three key elements, namely novelty, development and change, which helps future researchers to focus more on the concept of development and change in their view of innovation in general (Caraballo, 2009, p. 24).
The content of the innovation process is based on the ability to explore various new concepts that have the potential to be cultivated within or outside the organizational boundaries, which arise from many sources, where the process of collecting these ideas aims to raise and increase the progress of innovation, and works to refine, modify and develop them, in order to transform them into real and tangible projects (Samarkandi, 2018, p. 229).
Several factors can influence the innovation process: (Rogers, 2003)
- Individual Perception;
- Values and beliefs;
- Social and cultural factors;
- Participation and teamwork.

Innovative processes arise from various sources, which may include technological research and development, individual creativity, market needs, as well as changes within the economic, social and technological environment.

In general, innovation can be considered a key pillar in the process of development and progress, as it translates the prosperity and progress of societies and economies, by contributing to productivity and enhancing competitiveness.

❖ **Characteristics of Innovation** :

Innovation has a number of characteristics, which are summarized below:

- Innovation implies differentiation: The act of offering something different from competitors, creating a new market segment that fulfils specific needs in unique ways;
- Innovation represents novelty: The introduction of profound and effective new solutions, whether macro or micro, which contributes to maintaining and expanding market share;
- Innovation is the discovery of opportunities: It means reading the needs and expectations of the market in innovative ways, and developing new products that fulfill these needs and open up new markets and prospects for expansion (Bilal Khalaf, 2008, p. 54);
- Innovation is being proactive within the market: By working to come up with new ideas and technologies or improving existing products in efficient ways to lead the market.

1.2. Creative Adoption:

Everett Rogers presented an objective conceptualization of innovation adoption, explaining that this process is the result of a social interaction where individuals exchange information and experiences about the innovation within social networks built on communication channels through which the innovation is transferred between a group of people within a specific period of time (Yahya, 2020).

In addition, the term early adopters of technology stems from the innovative practices and behaviors of the leaders, who have been divided into the following :(Yahya, 2020)

- **Innovators:** People who endeavor to introduce various new ideas within the system;
- **Early adopters:** These are the people who have the greatest impact on the local adoption of innovation;
- **The Proactive Majority:** These are the people with a deliberate desire to adopt innovation;
- **Late Majority:** This category includes those who are forced by circumstances to adopt the innovation by being pressurized by external forces;
- **The laggards:** This is the last group to adopt the change process.

Implicitly, Everett Rogers defined it as an approach in which innovation is used continuously according to the triad (idea, product, brand) by the innovator himself who belongs to a particular social system (Cheikho, 2015, p. 43).

Robersonel took a different approach and followed Zugars' lead, defining it as the continuous use of new products and considering it as a commitment rather than a trial purchase (Cheikho, 2015, p. 43).

❖ **Innovation adoption models:**

Innovation adoption processes can be considered one of the most important factors that usually affect the success or failure of any change or development in the innovative field, as these various processes depend on the correct understanding of the various psychological, social and organizational factors forming the environment of adoption of new technologies and practices, and the most important of these models are the following**:**

- **Adoption and rational action theory** (Darpy & Volle, 2007, p. 142)**:**

According to Rational Action Theory, the intention to adopt innovation is determined by two main points: self-interest and social impact.

- **Self-interest:** This is the user's evaluation of the innovation space, either positively or negatively, based on expected personal benefits.
- **Social influence:** This is the extent to which individuals build the expectations of others and the extent to which they are motivated to comply with these built expectations, as it stems directly from the surrounding environment (the individual's social space), and is perceived by the consumer subjectively.

- **Rogers' model and the diffusion of innovations theory :**(Yahya, 2020)

In introducing the concept of diffusion, Rogers described diffusion as a form of social exchange in which innovation is communicated between individuals through different channels in a specific timeframe, where this process takes place by linking certain communication channels that connect members of the social system and includes the following:

- The innovation.
- The unit with knowledge and experience of the innovation and how to use it.
- The unit with limited or no knowledge of the innovation.
- The communication channel connecting the two units.

He explained that the original exchange of ideas does not need any prior planning, as the structure of the social system plays the main role in the spread of innovations, whether by facilitating or hindering.

2. Concept and Types of Waste

Waste management represents a difficult and multi-polar challenge faced by the global community, as the current development and modern life results in increasing consumption, which is directly reflected in a direct relationship with the amount of waste produced and continuously presented, and these resulting challenges and multiple and complex issues require the adoption of effective and efficient strategies and solutions, aimed at preserving environmental and human health.

2.1. Definition and characteristics of waste:

Waste is defined as all products, components, resources and structures that are unnecessary or of no value to the final consumer, usually in solid or liquid form, excluding radioactive and radioactively contaminated waste. Waste is usually divided by experts and specialists, separating municipal waste and industrial waste by appointing a technical device that controls the waste in each section to control explosive and toxic waste, which transmits various diseases and epidemics and has the potential to pose many dangers to human health on the one hand and environmental safety on the other (Yolin, 2015, p. 25).

We can also define it as those materials that have been abandoned and used, which have been discarded or intended to be discarded, and it is natural that various human activities result in many wastes, some of which are disposed of permanently, which are waste and may take many forms, including liquid and solid, depending on their degree of danger (Al-Ghamri & Aboul Atta, 1997).

According to the Algerian legislator, waste is defined as "all residues resulting from production, transformation or utilization processes and, more generally, any material, product or movable that the owner or possessor disposes of, intends to dispose of, or is obliged to dispose of or remove " (Law No. 19.01 on Waste Management and Removal, Issue 77).

In addition, the UN expert defined it as everything related to waste and debris, regardless of size and type, which is usually produced by households, markets and administrations, as well as various garbage found on sidewalks and roads (Mubaraka, 2021, p. 281).

From the above, we conclude that waste is the various materials and objects that are usually discarded because they are no longer needed, or when their use expires, and the characteristics of waste vary according to its type and source, the most prominent of which are as follows :(Roundabout, 2017, p. 223)

- **Waste or garbage:** Anything that is left over and not needed, and what we express as residue and waste, regardless of its source, components and compositions, whether it is:

- Waste resulting from direct consumption.
- Various residues of production and transformation processes and what is spent.
- Residues from utilization processes.

- **Solid or liquid:** Where we express the form and physical state of the waste, solid and cohesive among themselves, dominated by rigidity, such as stones and gravel, metal residues used in manufacturing processes, scrap and inert residues such as rubble and building waste, or liquid such as sewage, various fluids released by industrial processes, as well as hospital waste such as expired solutions or those that have been used... etc.
- **Hazardous or nuisance:** Wastes of all kinds lead to many damages and risks to the ecosystem and thus generate many economic and social threats if they are improperly disposed of, their damages and risks may be immediate and direct, based on their dangerous nature such as toxic or radioactive waste, as well as those that are flammable or explosive, while non-hazardous wastes can also pose threats that may be considered temporary or indirect, such as odors spread from waste dumps in urban areas, or those dumped in public spaces and places.
- **Treatability:** Regardless of the source, type or size of the waste, it is always characterized by the possibility of treatment and can be treated in various ways, such as collection and sorting, conversion and recovery, incineration and technical landfilling, or safe and hygienic disposal in an external environment for final disposal.

2.2. Types of waste:

In many programs and initiatives, the United Nations aims to preserve the environment, reduce the phenomenon of pollution and the spread of various types of waste in the environment in which we live and reduce its serious negative effects on the ecosystem. Based on the United Nations classification of waste and its sources, we present the following table that shows the types and technical analysis of waste in brief:

Type	Technical analysis
Civil waste	Includes organic waste such as food, paper and plastics, and inorganic waste such as glass, metals and plastics.
Industrial waste	It includes solid, liquid and gaseous wastes that result from industrial production, material processing and transformation.
Electronic waste	It contains various materials such as plastics, heavy metals such as lead, mercury and cadmium, hazardous oils, glass, and electronic boards.
Medical waste	It includes blood-contaminated medical instruments, hazardous chemicals, expired medicines, and genetically modified biological materials.
Construction waste	Waste from construction and building renovation activities, and waste generated after disasters
Agricultural waste	Agricultural waste, crop residues, fertilizers and chemicals
Marine waste	Marine litter and products dumped at sea, including plastics, metals, glass and organic matter that accumulates in the oceans

Source: Researchers based on: (UNEP Governing Council 2008, p. 06-07)

3. Innovation and its role in waste management:

Innovation plays a pivotal role in modern processes to improve waste management, by intensifying the development of new technologies and methods that directly reduce pollution and improve the efficiency of recycling processes. These innovations cover many fields and areas, such as the development of new biodegradable materials, improving collection and sorting processes, as well as designing advanced models and systems for waste management.

3.1. Wast management issues:

The concept of waste management surrounds those processes that follow a specific program and system: the collection, sorting, recycling and disposal of waste, as well as the extraction of oily juices and chemicals that can be used in energy generation, and organic materials that are used in soil bioremediation (Fien & Attard, 2018, p. 375).

Waste management refers to the comprehensive, organized and coordinated process of dealing with waste in an efficient and sustainable manner by working in an innovative and sequential system to (Mubaraka, 2021, p. 283 284):

Collection process: The process of collecting waste from various sources such as homes and institutions and then transporting it to either storage or treatment sites directly, the process is carried out according to a special program subject to a specific work system in order to facilitate its classification and treatment in safe and effective ways.

- **Sorting process:** It is the step that directly follows the collection stage, through which the waste is separated into different categories according to its type, characteristics and degree of danger, the process is usually manual or automated at times or a hybrid of both.
- **Processing:** The treatment process includes a number of processes that transform waste into products intended for recycling and reuse, or disposal as a final step according to environmentally safe and healthy techniques.
- **Safe and proper disposal**: It is the last step of the waste management process, in which waste that is not amenable to treatment and automated recycling is transported to the place of disposal and final disposal, through specialized protocols that work in accordance with health and environmental safety standards, by carefully identifying disposal sites and ensuring that their hazardous and negative impacts on environmental safety and public health are prevented, where various preventive measures are taken to minimize gaseous emissions and ensure that their liquid discharges are isolated from entering the soil.

❖ **Principles of waste management:**

To achieve effective and efficient waste management, you need to adopt a set of basic principles, exemplified by those developed by the European Union, including (Adimi & Saidi, 2017, p. 872):

- **The 3R principle:** is a guiding principle that refers to the three steps that minimize waste and optimize the use of resources effectively by working to reduce the amount of waste generated (Reduce), reuse (Reuse) and recycle (Recycle).
- **Local Disposal Principle:** This principle focuses on the need to dispose of waste internally, i.e. at the local level and in treatment centers that belong regionally to the collection area, while avoiding exports or external transfers.
- **Quality control principle:** This principle emphasizes the quality of the waste collected and destined for recycling, and the need to improve and develop the quality of the processes and mechanisms used in processing.
- **Producer Responsibility Principle:** This principle emphasizes the need for producers to take responsibility for the management of their waste, including disposal costs and safe and hygienic disposal.

- **The precautionary principle:** This principle emphasizes the prevention, environmental security and health measures necessary to protect humans from the potential and certain dangers of waste due to the high degrees of risk it contains, and not just superficial assurances about its safety.

These principles form a set of frameworks and protocols in the field of waste management, as they seek to achieve sustainability, preserve the ecosystem and protect human health and the ocean from any repercussions or threats caused by the indiscriminate handling of waste and residues within the ecosystem, causing inevitable degradation of the system as a whole.

3.2. Innovative technologies and waste management technology:

Innovative technologies in waste management refer to the adoption of various modern technological developments in specific fields and areas of environmental and ecological sciences and ways of dealing with waste in more effective and environmentally friendly ways, by working to apply various modern technologies in the processes of collecting, sorting and processing waste (R3), in addition to working to develop these innovations to adapt to the nature of the future waste, and to recycle it and convert it into useful resources and ready-made products. The most important of these technologies are as follows (Kaartinen, 2004):

- **Mechanical treatment:** Waste is processed through a series of mechanical and biological processes that reduce the size of the waste as well as stabilize it, as it separates the waste material into different parts and is then processed more precisely by stripping, shredding and grinding the material.
- **Biodegradation and bioremediation:** Biological processes usually include the production of fertilizers and anaerobic decomposition of organic matter, the production varies according to the size of the treated material, and the production process can take place in special facilities with optimized and adapted conditions, in addition to the filtering of the emitted gases, thus achieving major reduction rates of the volume of organic matter destined for landfill up to a range of 40-50%.
- **Microwave treatment**: The microwave treatment process relies on the technology of heating the waste with wet heat and steam generated from the energy generated by these waves, where it is directed to heat and raise the temperature of the water in the waste, at a specific frequency and wavelength, after which the waste becomes safe to handle after treatment, and is disposed of appropriately away from any danger or threat (Organisation World Health, 2022, p. 21) .

- **Thermal analysis:** This technique is based on the reaction of carbon containing substances at high temperatures up to 1650 degrees Celsius, in an oxygen-free environment. The waste is dried and cut before this process, which produces significant amounts of natural gas and many other usable materials (Alsroury, 2016).
- **Reconstruction:** The International Organization for Standardization (ISO) standards are essential in this context. These standards include ISO 15270 on plastic waste management, which provides various guidelines and practical requirements for the recycling processes in this sector, as well as ISO 14001, which specializes in environmental management in general and environmental monitoring of recycling processes, as these standards provide a clear standard framework for recycling processes and ensure the quality and effectiveness of these processes in particular (Adimi & Saidi, 2017, p. 874).
- **Landfill:** A site used for the disposal of waste through burial, which is a common method of waste disposal, before the development of waste treatment technologies, and landfilling is a common practice today, but in more sophisticated ways that control its environmental risks. It is also worth noting that waste dumped in sanitary landfills can be utilized, especially from the energy aspect, as the methane resulting from the decomposition of waste can be collected and converted into electrical energy using special generators (Ashkar, 2022, p. 13).

In general, innovative waste management technologies encompass a wide range of methods and processes that seek to optimize the collection, treatment and storage of waste in a healthier, more efficient and risk-free manner. Innovation involves adopting a variety of technologies, tools and processes that aim to improve waste management and achieve environmental and economic sustainability goals.

4. Technical Landfill Center as an innovative waste management model

The Technical Landfill Center (TLC) is an innovative model for waste management, by combining several techniques and procedures that work to treat waste in effective, efficient and sustainable ways. The center is concerned with the collection, sorting and treatment of waste from different sources, to ensure safe disposal and reduce its negative impact on the environment, and this model is characterized by the integration of technical, environmental and economic aspects, which contributes to improving the efficiency of waste management on the one hand, and achieving sustainability on the other hand.

4.1. Khenchela Technical Landfill Center:

The Intermunicipal Technical Landfill Center of Khenchela is located 7 km from Khenchela, the state capital, 800 m on the municipal road No. 4 in the municipality of Baghai on an area estimated at 20 hectares, started in 2010, managed by the Public Corporation for the Management of Technical Landfill Centers of the state, with an estimated life span of 20 years, receiving household and similar waste from six municipalities (Ministry of Interior, 2022)

Khenchela, El Hamma, Baghai, Ensaigha, Mtoussa and El Mahmel. It consists of two trenches:

- The first trench: 180 000 m3.
- The second trench: 140 000 m3.

- **Monitoring dumps:**

Eight control dumps have been completed in Babar, Chechar, Ain Twila, Bouhmama, kais, Tamza, Oulad Rechach and Yabous and handed over to the Public Corporation for the Management of Technical Landfill Centers of Khenchela, and two are under construction in the municipalities of Taouzient and Chelya.

- **Hospital Waste Treatment Centers in Khenchela:**

The province has one hospital waste treatment center that has been in operation since 2016.

In addition, six hospitals waste incineration centers are planned across the municipalities of: Bouhmama, Chechchar, Babar, kais, Oulad Rechach and Ain Twila.

- **Khenchela's waste treatment center:**

There is one solid waste treatment center in Khenchela, which has been in operation since 2013.

4.2. Class 2 technical landfill center for household and similar waste:

Our study focused on Baghai Technical Landfill Center for household and similar waste as the main center in the state, through which we presented the working mechanisms of the center in its management of class 2 waste, from the first step to the end of the process as follows:

4.2.1. Collection:

Municipalities work at the level of their territory to meet the needs of their citizens by providing regular and regular collection and transport of waste according to a special program, in addition to the presence of several institutions, including public institutions of different nature, whether commercial or industrial, as well as private institutions, subject to the same program, until reaching the technical landfill center where the waste collection phase ends with:

- **Monitoring of the received waste**: The monitoring process is carried out according to special protocols in which the waste destined for sorting is verified and inspected.
- **load estimation:** Immediately after inspecting the waste, the load weighing process is carried out where the exact weight of each shipment is recorded.

The following tables show the tonnage received by the center during the first eight months of 2023:

Table number (1): Receiving waste data for a number of municipalities in the governorate affiliated to the center

Municipality	Weight/ Tn	Cargo
KHENCHELA	19043.00	6373
ELMAHMEL	1885.10	574
BAGHAI	691.50	309
E'NSIGHA	969.70	423
MTOUSSA	341.93	185
ELHAMMA	1294.00	636
Total	**24445.23**	**8500**

Source: Prepared by researchers using documents from the Technical Landfill Center –Khenchela

Table number (2): Waste data for Abbas Laghrour University campuses in Khenchela

Universities	Weight/Tn	Cargo
CITE UNIV 19 MAI 1956	5,82	8
CITE UNIV ABBES LAGHROUR	34,65	54
CITE UNIV FATMA SOUFI	76,6	32
CITE UNIV 2000 LITS	6,58	8
CITE UNIV 1500 LITS	14,78	19
CITE UNIV 500 LITS	14,78	15
Total	**156,8**	**136**

Source: Prepared by researchers using documents from the Technical Landfill Center –Khenchela

Table number (3): Data of the waste received by the Center's public health institutions.

EPH	Weight/Tn	Cargo
EPSP BAGHAI	0	**0**
EPSP KHENCHELA D-S	0	**0**
EPH HIHI ABED DLMAJID	9,02	**7**
EPH AHMED BEN BELLA	0	**0**
EPH SALHI BELKACEM	12,28	**18**
EPH ALI BOUSHABA	0	**0**
Total	**21,30**	**25**

Source: Prepared by researchers using documents from the Technical Landfill Center-Khenchela

Table number (4): Data of the waste received class - 2 - for a number of customers

Customer	Weight / Tn	Cargo
SARL ECO-EST	477.55	217
ESOA	278.06	136
DIVN DUS	35.14	42
SERK AMMAR	0	0
SNCLAITTERIE ATHMANI	7.6	18
TAHER SADIK	3.3	3
CCLS	232.36	31
ONA	82.96	141
OPGI	2.81	12
NIMR ALGERIE	30.42	46
DRAP EST	0	0
RIYADH CLEANING COMPANY	1.76	2
NAFTAL	0	0
HIGHR SCHOOL OF FORESTRY	7.7	8
Total	**1160.66**	**656**

Source: Prepared by researchers using documents from the Technical Landfill Center in Khenchela contracted with the center.

Table number (5): The following table shows the total waste received by the center between 01/2023 - 08/2023

	Weight / Tn	Cargo
Total	**25783,99**	**9317**

Source: Prepared by the researchers: Based on the data attached above (Tables: No. 4,3,2,1)

4.2.2. Retrieve

Waste recovery takes place in two stages:

- **The first Phase:** The guide worker is responsible for dumping the waste in the landfill trench according to special security protocols, including the location of the dumping site, the method of dumping, and safe exit from the perimeter of the trench.
- **The second Phase:** During this phase, recovery agents go to the landfill to work on recovering reusable and recyclable materials, picking up the aforementioned materials: plastics, cardboard, iron, copper, and aluminum.

After the piles of waste have been pushed back and spread on the trench with specialized machinery, it is the turn of the retrieval officers, in suits, security masks and special tools, to pick up everything that contains one of the above-mentioned materials and direct it to special workshops to start the sorting process.

4.2.3. Sorting

As a third stage, this process takes place immediately after the cargo goes to workshops dedicated to the waste sorting process, during which recyclable and recyclable materials are separated, as the center targets the recovery of five main materials, namely:

- Cardboard
- Plastics of all three types (PET, HDPE, film)
- Iron + steel
- Copper
- Aluminum

Table number (6): The following table shows the recovered and recyclable materials between the first month of January 2023 and the ninth month of the same year.

Materials		Weight/kg	
Cardboard		258400	
Plastic	**PET**	97200	
	HDPE	151800	
	FILM	12200	
IRON		14000	
COPPER		00	
		Total	**533600 = 533,6 Tn**

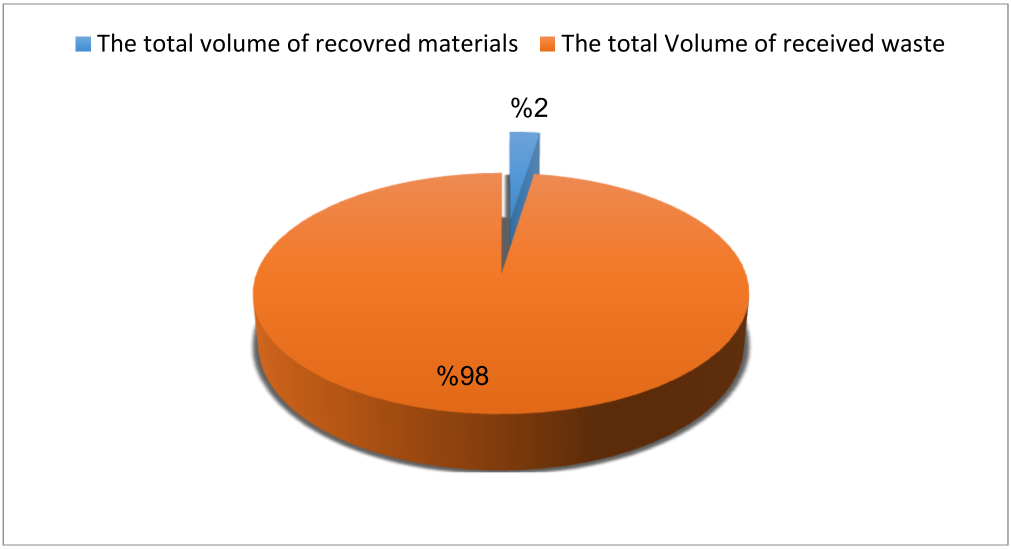
Source: Prepared by researchers using documents from the Technical Landfill Center - Khenchela

Through visual observation, we see the vast difference between what is received and what is recovered and valorized, as detailed below:

➢ **25783.99 tones** are the total volume of materials received during the above-mentioned period.

➢ **6,533.6 tones** are the total volume of appraisable imported materials during the same period.

Figure number (1): The following figure shows the amount of materials recovered in relation to the volume of waste received by the center between 01/2023 and 08/2023.



Source: Prepared by the researchers: Excel outputs based on the data attached above (Table 5,6)

The following relative circle shows two key ratios:

- **Total volume of waste received:** This is 100 per cent of the total volume.
- **Total volume of recovered resources:** Represents 2% of the total volume.

The recovered resources constitute only 2% of the total volume of received waste, which shows the very small percentage of recovered waste destined for recycling, reflecting the urgent need to improve the recovery processes. Given the large difference between the two ratios, there is an urgent need to develop better work strategies, unify efforts and focus on recovery as the goal of the center's existence, while also working on improving sorting and recycling techniques, increasing environmental awareness, and encouraging and promoting environmental practices.

4.2.4. Valorization and sale:

After the recovery process, the process reaches the valorization stage, through which the center aims to transform the recovered waste into a valuable resource, using techniques and methods that serve this process.

Appraisal materials are collected and stored until the warehouse reaches a certain amount of capacity, after which the sale process follows, and according to a special protocol, these materials are counted, recorded and numbered according to each bundle collected.

After the completion of these procedures, advertisements are placed for the public auction of these materials, where the auction determines the prices of each bundle, after which the sale process takes place as dictated by the terms of the auction sale.

We obtained details of the auctioning process for a certain number of customers, for the same period as our study 01/2023 - 08/2023

The public auction sales took place starting on 27/08/2023 and ending with the last sale on 04/09/2023.

The following table shows the extracted items and their financial values according to the sale process recorded for each customer as follows:

Table number (7): Customer A

Description	N° Lot	Quantity (kg)	Price Unit/da	HT	TTC
FILM	4	1220	50	61000	66490
IRON	5	1400	26	36400	39676
PET	2	1660	26	43160	47044,4
PET	2	840	26	21840	23805,6
TOTAL	**-**	**7220**	**-**	**187720**	**204615**

Source: Prepared by researchers using documents from the Technical Landfill Center - Khenchela

Table number (8): Customer B

Description	N° Lot	Quantity (kg)	Price Unit/da	HT	TTC
HDPE	1	1540	35	53900	58751
HDPE	1	1900	35	66500	72485
HDPE	1	2020	35	70700	77063
HDPE	1	1320	35	46200	50358
HDPE	1	1720	35	60200	65618
HDPE	1	1580	35	55300	60277
HDPE	1	1940	35	67900	74011
HDPE	1	1460	35	51100	64855
TOTAL	**-**	**13740**	**-**	**401800**	**429418**

Source: Prepared by researchers using documents from the Technical Landfill Center –Khenchela

Table number (9): Customer C

Description	N° Lot	Quantity (kg)	Price Unit/da	HT	TTC
Cardboard	3	13200	7,5	99000	107910
Cardboard	3	12640	7,5	94800	103332
TOTAL	**-**	**25840**	**-**	**193800**	**211242**

Source: Prepared by researchers using documents from the Technical Landfill Center – Khenchela

4.2.5. Backfilling:

After the collected waste is placed in the trench, the waste is then piled by special machines that compress it inside the backfilling trench, ensuring the permanent accumulation of buried waste, with the aim of reducing its size and increasing the capacity of the trench.

Once the maximum capacity of the trench is reached, the trench is sealed and the final cover is placed to prevent rainwater from seeping into the waste mass, and then the upper part of the trench is planted with vegetation as a final step.

4.2.6. Drainage of decomposition water:

The leachate is one of the most important environmental challenges in landfill management, as it is the liquid that leaks from the buried solid waste, as it contains harmful chemicals including heavy metals sediments such as lead and mercury, and to ensure that groundwater and soil are not contaminated, sedimentation ponds were used to treat the leachate, the process is carried out by three sedimentation ponds The process is carried out by three basins in succession, where the leaking sap is collected in the first basin until it is full to pass to the second basin and also to the third basin, which is rarely visited, the separation process takes place naturally, through the evaporation of basin water and the accumulation of the separated sediment, which is then collected and returned to the trench.

As a future plan, the Center is currently working on adding a new technique of desalination of the water collected from the trench instead of evaporation, based on the establishment of a desalination plant dedicated to this process, for a more sustainable and environmentally friendly solution, in addition to providing clean water for use in the development and cleaning processes.

Putting such projects into service enhances the management of water resources in an environmentally sustainable manner, making it a purely environmental project.

As for the gaseous emissions, the center's technicians worked on placing ventilation openings that reach the depths of the trench to discharge the

gases represented by CH4 and CO2 from the decomposition of waste, in order to avoid any environmental and health risks.
On the other hand, these gases are an important source of renewable energy, instead of allowing these gases to spread in the atmosphere and contribute to global warming, and as a future strategy, the Center is working to innovate new technologies that enable the collection of these gases and use them to generate energy, instead of wasting them and contributing to global warming, through the incineration process, which is used to convert methane and other gases into energy, reducing the emissions of buried gases and turning them into a useful source of energy.

4.2.7. Continuous environmental monitoring:

The Center's environmental monitoring process aims to continuously monitor to prevent the leakage of waste sludge under the insulation layer and the influence of groundwater, and even leakage to surface water, where the Center works according to special protocols and techniques that measure the various compositions of this sludge using special devices:

- **pH meters:** Measures the acidity or alkalinity of the sap.
- **Electrical conductivity meters (EC meters):** Measures the amount of dissolved ions in the juice.
- **Gas and Liquid Chromatography:** For the determination of organic and inorganic compounds in the juice.
- **Atomic Absorption Spectroscopy:** Measures the concentration of heavy metals.

Continuous environmental monitoring can be considered a vital process to protect the environment and public health, requiring the application of modern technologies and comprehensive plans to monitor the quality of the sap and take the necessary measures to prevent pollution and optimize waste management.

Conclusion:

Through what has been discussed, we conclude that building an integrated system for effective and sustainable waste management requires a hybrid model that combines innovation and technology on the one hand and planning and government support on the other, by adopting innovative models that improve the efficiency of waste management and promote environmental sustainability, and thereby work to transform environmental challenges, waste risks and waste resources into real economic and social opportunities through the creation of special projects for waste recovery, recycling, and waste minimization, including turning these wastes into valuable materials with economic value and creating other opportunities.

Key Findings:

- Despite the persistence of the waste management issue, innovation remains the most effective approach to reduce the volume and amount of waste sent to landfills.
- Innovative technologies aim to develop permanent solutions that keep pace with the evolution of resource consumption and waste generation.
- Despite the modest returns of some innovative projects and models in the waste management process, it is still an effective solution when compared to the traditional methods of dealing with waste, which is a deadly danger to the environment and a threat to the ecosystem as a whole.
- The formation of any innovative project aimed at the proper management and valorization of the waste management process guarantees in one way or another new solution to environmental issues and generates economic opportunities aimed at transforming reusable resources into new economic resources, promoting the recycling process, which in turn ensures the minimization of waste of natural resources.
- The formation of an advanced model that incorporates high-tech techniques in waste management will provide new and clean energy sources that can offset the consumption of non-renewable energy resources (fossil fuels) through the development of new technological techniques to deal with buried waste, such as compaction, as opposed to incineration, although relatively speaking, the generation of new energy from landfills remains an important resort to offset the waste of non-renewable energy resources.

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