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Technico-economic study of treatment and valorization of leachate by composting the fermentable fraction of household and assimilated waste in the Mohammedia- Benslimane and OumAzza Landfill, Morocco

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Abstract

Based on a research and development study that we have conducted, we propose a treatment of leachates of wastes consisting in sorting the wastes and composting the fermentable fraction which presents 60% of wastes. This treatment will allow to consume 325 liters of leachate for each ton of wastes. The techno-economic study carried out in this work concerns two controlled landfills namely the landfill of Mohammadia and the landfill of Rabat. From this analysis, we note the feasibility of installing with profitability a unit of treatment and valorization of leachate, hence the proposal of a new model of management of leachate through the creation of green enterprises. Taking into account the achievements made both nationally and internationally, as well as considering the current situation, our contribution within the scope of this project involves proposing alternative approaches for managing the leachate generated in controlled landfills in Morocco.

Keywords: Techno-economic study, Waste sorting, Leachate, Waste composting.

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1. Introduction

In recent years, the management of solid waste has become a critical environmental concern for many countries. With the increasing population and urbanization, the volume of waste generated has reached alarming levels, posing significant challenges for municipalities and waste management companies. In this context, the treatment and valorization of leachates from controlled landfills have emerged as a promising solution to mitigate the environmental impact of waste disposal and promote sustainable waste management practices [1, 2]. A comprehensive technical-economic study conducted by Charkaoui et al. (2019) [3, 4] sheds light on the potential of composting the fermentable fraction of household and assimilated waste for the treatment of leachates. This study showcases the feasibility and profitability of implementing a sorting center and an in-situ composting facility within landfill sites, presenting a new model for HAW (household and Assimilated Waste) management [5, 6]. By effectively treating leachate and recovering valuable by-products, this approach not only reduces the space required for landfill and leachate storage but also demonstrates significant environmental and economic benefits [7]. This study focuses on the specific context of Moroccan landfills, where the management of solid waste poses significant challenges. Landfills in Morocco, like many other developing countries, face issues related to limited space, inadequate infrastructure, and environmental concerns. The implementation of effective waste management strategies becomes crucial to address these challenges and ensure sustainable practices [8]. The technical-economic study discussed in this work provides insights into the treatment and valorization of leachates from controlled landfills in Morocco. By analyzing the potential of composting the fermentable fraction of household and assimilated waste, the study highlights the feasibility and profitability of this approach in the Moroccan landfill context. The findings of this research offer valuable guidance to local authorities, waste management companies, and stakeholders involved in waste management operations, presenting a sustainable model that can contribute to improved waste management practices, reduced environmental impact, and enhanced resource recovery in Moroccan landfills [9, 10].

2. Materials and methods

The treatment of leachate presents significant challenges from technical, environmental, and economic standpoints. In Morocco, the suggested technical solutions have proven ineffective due to these limitations. As a result, most controlled landfills in the country store leachate volumes in natural evaporation ponds (as shown in Table 1). Unfortunately, these volumes continue to accumulate and surpass the treatment capacities of the proposed methods, which include:

• Physico-chemical processes such as ozone or hydrogen peroxide oxidation, coagulation, concentration, precipitation, evaporation, forced evaporation, and evaporation-incineration;

• Processes based on reverse membrane separation, including reverse osmosis, nanofiltration and ultrafiltration;

• Biological process such as aerated lagoon, fixed culture, and membrane bioreactor. In Table 1, the final column presents the leachate production ratio in cubic meters per ton of HAW. It is evident that the average value of this ratio is 0.375 m^3/t.

In Morocco, several accomplishments have been implemented at the level of controlled landfills as notable examples:

- *The Oum Azza landfill* : One example of a successful implementation at the controlled landfill level in Morocco is the Oum Azza landfill. Managed by the company PIZZORNO and spanning an area of 100 hectares, it produces 480 cubic meters of leachate per day from 1792 tons of HAW. The leachate is treated using the reverse osmosis process, with a treatment cost of 214 Moroccan Dirhams per cubic meter of leachate. However, it's important to note that the treatment currently only covers 10% of the total leachate volume, and the concentrate generated from the treatment still presents challenges. In addition to the treatment, natural evaporation in basins is also employed as part of the leachate management process. [11]
- *Fes landfill:* Another example is the 110-hectare landfill in Fez, which is managed by the ECOMED Company. [12] This landfill generates 360 cubic meters of leachate per day from 900 tons of HAW, amounting to 328,500 tons of HAW per year. To manage the leachate, the approach involves utilizing the heat produced from the biogas to induce evaporation. The residual sludge is then reintroduced into the landfill. However, the implementation of this evaporator has revealed certain drawbacks, including foaming, emission of toxic gases, and high energy consumption. These challenges need to be addressed for the effective and sustainable management of the leachate. [13]
- *Mohammedia landfill:* The interprovincial landfill, spanning 110 hectares and catering to the waste from both Mohammedia and Benslimane, has a daily storage capacity of 500 tonnes of HAW and produces 180 cubic meters of leachate per day. Apart from employing natural evaporation as a treatment method, a portion of the leachate is also subjected to treatment through the physicochemical process of coagulation flocculation. [14]
- *The Agadir landfill:* managed by the TECMED Company, covers an area of 41 hectares and serves approximately ten municipalities. It receives 360 tonnes per day of HAW and produces 150 cubic meters per day of leachate. Initially, natural evaporation was employed as a means to eliminate the leachate through a recirculation and sprinkling system. However, the results obtained from this process were not satisfactory. Over the last six years of operation, only 155,380 cubic meters of leachate were eliminated using this method [15]. This amount is equivalent to just three years' worth of leachate production.

Taking into account the achievements made both nationally and internationally (The Global Leachate Treatment market research report 2020-2026), as well as considering the current situation, our contribution within the scope of this project involves proposing alternative approaches for managing the leachate generated in controlled landfills in Morocco [16]. In a pilot study conducted at the Mohammadia controlled landfill, as part of a research contract with the Ministry of Mine, Energy, and Environment, and in collaboration with the landfill management company, we have demonstrated the feasibility of treating all of the leachate from the HAW. The process begins by sorting the HAW and recovering the fermentable fraction, which constitutes 60% of the waste and generates leachate. In a second stage, this fraction undergoes composting, which eliminates the production of leachate. Additionally, the composting process can utilize the leachate stored in the basins. It has been shown that one ton of HAW can consume more than 325 liters of stored leachate [17]. The objective of this study, building upon the pilot tests conducted, is to conduct a comprehensive technical and economic analysis in two landfills. The aim is to demonstrate the efficiency and profitability of the proposed process for leachate management. By assessing both the technical feasibility and economic viability, we seek to provide evidence of the effectiveness and financial benefits associated with implementing the proposed approach.

3. Results and Discussions

Technical study of the proposed process

3.1 Presentation of the sorting center

In this section, we will present the design and sizing of the sorting center, considering the incoming waste volumes to the two landfills and their variations over time. Additionally, we will take into account the depreciation period of the equipment used in the sorting center.

3.1.1. Mohammedia-Benslimane controlled landfill

Under the management of ECOMED, the landfill is characterized by a daily tonnage of 500 tons of HAW and a daily leachate volume of 180 cubic meters.

3.1.1.1 Presentation of the design of the sorting center

The process proposed in the present study, which aims to develop a technically and operationally efficient and economically viable sorting-composting system while taking into consideration the main difficulties encountered in the experiments, carried out in Morocco.

- The trucks unload the 500 tons per day of HAW onto a metal grid with a mesh that allows 100 cubic meters per day of free water to pass through to a liquid retention basin. The solid fraction (400 tons per day) is isolated and then directed to the trommel.
- The isolated solid fraction undergoes visual sorting to separate out bulky waste, which is then sent to the trommel with a capacity of 35 tons per hour. The trommel is equipped with a grid size of 10 to 8 mm, allowing the separation of the fermentable fraction (240 tons per day).
- A conveyor system is used to transport the fraction with a particle size greater than 10 mm to undergo the sorting operation.
- The solid fraction of 160 tons per day, consisting of recyclable materials such as metals, glass, and plastic, is recovered through positive sorting. These recyclable materials are then placed in eight drums, each with a capacity of 200 liters. Additionally, the fraction intended for energy recovery (Alternative Fuel - AF) is also recovered and directed accordingly.

The necessary infrastructure and equipment required for the operation of this workshop include a sorting platform, a press, two conveyors, a metal grid, as well as a leachate or water pumping system. These components are essential for the efficient functioning of the sorting process and the overall management of the facility. Table (2) provides a comprehensive material balance for all the fractions derived from the HAW at the Mohammedia landfill. Figure (1) depicted below, illustrates a simplified layout of the sorting workshop.

3.1.1.2. Sizing of the Mohammedia-Benslimane landfill sorting center

- The surface required to deposit the 3 m high piles of HAW is:
- 500 t / 0.4 / 3 = 416 m2
- The surface necessary to deposit the Fermentable Fraction (FF) separated by the trommel is: 240 t / 0.4 / 3 = 200 m2
- The area of the sorting hangar containing two sorting lines with a capacity of 160 t / d is 600 m2.
- The free area for traffic is 784 m2
- With the forecast evolution of the annual increase of around 3% and for a period of 10 years, we can estimate an additional area of 1000 m2 as the necessary reserve for possible extensions, which gives a total area required for the 3,000 m2 sorting center.

3.1.1.3. Equipment depreciation period

The duration of the employment contracts between the municipalities and the management companies of controlled landfills is 20 years. This extended timeframe enables us to select equipment with a depreciation period of 20 years. By aligning the equipment's depreciation period with the contract duration, it ensures a balanced and efficient utilization of the assets throughout the operational lifespan of the landfill.

3.2.2. Controlled landfill of OUM AZZA

Under the management of the company PIZZORNO, the landfill is characterized by a daily tonnage of 1792 tons of HAW and a daily leachate volume of 480 cubic meters.

3.2.2.1. Presentation of the design of the sorting center

- The trucks unload the 1792 t / d of HAW on a metal grid with a mesh allowing the passage of 360 m^3 / d of free water to a liquid retention basin and the retention of the solid fraction (1430 t / d) which will be routed to the trommel.
- This fraction undergoes visual sorting to isolate bulky waste and sent to two 70 t / h capacity trommels with a 10 to 8 mm grid in order to separate the fermentable fraction (858 t / d).
- Two conveyors convey the fraction with a particle size greater than 10 mm to undergo the sorting operation.
- The recyclable solid fraction of 572 t / d (metals, glass, plastic) and that oriented towards energy recovery (AF) are recovered by positive sorting and placed in eight drums of 200 liters each.

Table 2 summarizes the material balance relating to all the fractions from the HAW from the OUM AZZA landfill similar to that of Mohammedia and figure 1 shows a simplified layout of the sorting workshop.

3.2.2.2. Sizing of the sorting center of the OUM AZZA landfill

- The surface required to deposit the 3 m high piles of HAW is: 1792 t / 0.4 / 3 = 1493 m^2
- The surface necessary to deposit the fermentable fraction (FF) separated by the 2 trommels is: 1430 t / 0.4 / 3 = 1191 m^2
- The area of the sorting hangar containing 4 sorting lines with a capacity of 572 t / d is 1,200 m^2.
- The area free for traffic is 1500 m^2
- The total area required for the sorting center is 5,384 m^2

With the forecast evolution of the annual increase of around 3% (table 2) and for a period of 10 years, we can estimate an additional surface area of 2000 m^2 as the necessary reserve for possible extensions, which gives a total surface area required for the sorting center of 7,384 m^2.

3.2.2.2. Equipment depreciation period

The employment contracts between the municipalities and the management companies of controlled landfills typically have a duration of 20 years. This extended contract period provides the opportunity to select equipment with a depreciation period of 20 years. By aligning the equipment's depreciation schedule with the contract duration, it ensures a suitable timeframe for the recovery of investment costs and supports the long-term operational sustainability of the landfill.

3.3. Simulation of the design of composting

A simulation will be conducted to design and size composting/stabilization centers at the two landfills. This simulation aims to assess the overall treatment cost associated with these centers. By considering factors such as waste composition, processing capacity, operational efficiency, and cost of equipment and maintenance, the simulation will provide insights into the optimal design and sizing of the composting/stabilization centers. The assessment of overall treatment cost will help in making informed decisions regarding waste management strategies and ensure efficient utilization of resources. Based on the composting process tested during the pilot test, the proposed design involves arranging the fermentable fraction (FF) in the form of swaths. These swaths are spaced 4 meters apart and have a height of 3 meters and width of 6 meters. Each windrow is created using the 7-day fermentable fraction, as illustrated in figure 2. This design allows for effective composting and ensures proper aeration and decomposition of the organic waste, leading to the production of high-quality compost [18]. The maturation period of the composting process lasts for 70 days, following the operating mode outlined below:

3.3.1. Operating mode

- The first swath is placed at a distance of 60 m from the Sorting platform.
- The assembly of the 1st swath takes 7 days.
- From the eighth day, we start to deposit the 2nd swath which lasts another 7 days, at the same time, we proceed to the inversion of the 1st swath for the aeration phase.
- On the 15th day, reversals of the 1st and 2nd Andean then we begin to assemble the 3rd Andean.
- On the 22nd day, reversals of the 1st, 2nd and 3rd Andean and the assembly of the 4th Andean begins.
- On the 29th day, reversals of the 1st, 2nd, 3rd, 4th Andean and the assembly of the 5th Andean begins.
- On the 70th day of the composting process, the 1st windrow is moved for storage in a Hangar with an approximate area of 500 m2, providing protection from adverse weather conditions. The 1st windrow will undergo the maturation phase, which lasts for 30 days.

As the 1st windrow is moved to the storage area, the 2nd windrow takes its place, the 3rd windrow takes the place of the 2nd, and so on, creating a sequential movement of the windrows. This process allows for continuous compost production. Each windrow undergoes a total of 10 turns during the fermentation phase, with a turn conducted once a week. This regular turning helps maintain proper aeration and distribution of organic materials within the windrow, promoting the decomposition process. [19]

By following this cycle and management approach, the composting operation can efficiently process the organic waste and ensure a consistent production of high-quality compost.

3.3.2. Sizing of the composting / maturation center of the Mohammedia-Benslimane controlled landfill

The daily fermentable fraction (FF) is 240 t has a volume of about 600 m^3. According to figure 2, each swath line is obtained after 7 days with an area of: 600 x 7 x2 / 3 = 2800 m^2, which gives a total area for the composting of the FF of: 474.4 x 104 = 49.337.6 m2 according to figure 2.

3.2.3. Sizing of the composting / maturation center of the OUM AZZA landfill

The daily FF 860.6 t has a volume of 2150.4 m^3, each swath occupies an area of 10,035 m^2, which gives a total area for the composting of the FF of 1680.5 x 104 = 174,772 $m^{2.}$

3.2.4. Justification of the consumption of all the leachate produced in the two landfills by the fermentation process

Given that the stages of the HAW FF composting process require a humidity of around 50% and that each tonne of HAW consumes 270 liters of leachate to produce a 9% moisture compost, we can calculate the leachate consumption for the Oum Azza landfill. With a daily tonnage of 1792 t of HAW, the leachate consumption can be determined as follows:

*1792 t * 0.270 m3/t = 483.84 m^3/day*

Therefore, for the Oum Azza landfill, the consumption of leachate would amount to approximately 483.84 m^3/day in order to achieve the desired moisture content in the composting process. This estimation is based on the findings of the pilot tests conducted during the technical study.

For the Mohammedia-Benslimane landfill, with a daily tonnage of 500 t of HAW and considering that each tonne of LEACHATE consumes 270 liters of leachate, we can calculate the leachate generation and consumption as follows:

*500 t * 0.270 m3/t = 135 m^3/day*

Therefore, the Mohammedia-Benslimane landfill generates approximately 135 m^3 of leachate per day, and if the goal is to achieve the desired moisture content in the composting process without using leachate, water sprinkling can be used as an alternative. If the goal is to produce compost without using leachate, water can be used as an alternative to maintain the required moisture content for the composting process. By sprinkling water onto the HAW FF during the composting process, the desired humidity level of around 50% can be achieved. This ensures that the composting process progresses properly and results in good quality compost [20].

4. Discussion

The findings of the technical-economic study conducted on two major controlled landfills in Morocco demonstrate the potential for profitable treatment of leachate. This can be achieved through the implementation of a sorting center to maximize the value of by-products and an on-site composting facility to utilize leachate and produce compost. This approach enables the recovery of 60% of HAW, reduces the required landfill space, minimizes the need for leachate storage, and introduces a new model for leachate management [21].

5. Conclusion

The technical-economic study conducted on the sorting and treatment of the fermentable fraction of HAW highlights the advantages of consuming approximately 325 liters of leachate per tonne of HAW and producing compost. This scenario demonstrates a favorable cash flow and job creation through the implementation of leachate treatment and recovery units, as well as the composting process. The key advantages of implementing this scenario in an HAW processing unit include:

-Utilization of stored leachate from basins;

-Treatment and recovery of the fermentable fraction through composting, resulting in the elimination of 60% of leachate;

Table 1: Quantities of HAW and leachate produced at different landfill sites.

City	HAW t/d	HAW t/year	Leachate m^3/d	Leachate $m^3/year$	Leachate /HAW m^3/d
Agadir (2)	360	131.400	150	54750	0,42
Tangier (3)	572	208.780	262	95630	0,46
Fes (4)	900	328.500	360	131400	0,40
El Jadida (5)	425	155.125	156	56940	0,37
Rabat (6)	1792	654080	480	175200	0,27
Casablanca (7)	3800	1387000	1400	511000	0,37
Oujda (8 et 9)	418,8	152862	100	36500	0,24
Meknes (10)	554	202210	271	98915	0,49
Mohammedia (11)	500	182500	180	65700	0,36

Source: created by the authors.

Table 2: Composition of LEACHATE with an average density of 0.4 m3 per t from the Mohammedia landfill

<table>
<tr><th colspan="3">Fractions</th><th colspan="3">Percentage</th></tr>
<tr><td rowspan="10">COMBUSTIBLE PART (AF)</td><td rowspan="3">Plastic</td><td>PET with stopper</td><td>1,34%</td><td rowspan="3">12,73%</td><td rowspan="10">38,76 %</td></tr>
<tr><td>PEHD and PP</td><td>0,81%</td></tr>
<tr><td>PEBD plastic bags</td><td>10,58%</td></tr>
<tr><td colspan="2">Cardboard and paper</td><td colspan="2">7,47%</td></tr>
<tr><td colspan="2">Various fuels</td><td colspan="2">7,52%</td></tr>
<tr><td colspan="2">Baby diapers</td><td colspan="2">5,95%</td></tr>
<tr><td colspan="2">Tetra Pack Cardboard</td><td colspan="2">1,18%</td></tr>
<tr><td colspan="2">Textiles</td><td colspan="2">3,26%</td></tr>
<tr><td colspan="2">Wood</td><td colspan="2">0,37%</td></tr>
<tr><td colspan="2">Shoes and elastomer</td><td colspan="2">0,28%</td></tr>
<tr><td colspan="3">Fermentable organic matter (FF)</td><td colspan="2">58,26%</td><td>58,26 %</td></tr>
<tr><td rowspan="3">METALS</td><td colspan="2">Iron</td><td colspan="2">0,64%</td><td rowspan="3">0,87 %</td></tr>
<tr><td colspan="2">Aluminum</td><td colspan="2">0,19%</td></tr>
<tr><td colspan="2">Aluminum powder</td><td colspan="2">0,04%</td></tr>
<tr><td>MISCELLANEOUS WASTE</td><td colspan="2">Glasses</td><td colspan="2">1,34%</td><td>2,10%</td></tr>
<tr><td rowspan="4"></td><td colspan="4">Demolition waste</td><td>0,58%</td></tr>
<tr><td colspan="4">DEEE</td><td>0,10%</td></tr>
<tr><td colspan="4">DMP</td><td>0,06%</td></tr>
<tr><td colspan="4">Batteries and batteries</td><td>0,02%</td></tr>
<tr><td colspan="5">Total %</td><td>100 %</td></tr>
</table>

Source: created by the authors.

Table 3: Estimate of the quantity of waste buried at the Oum Azza CET until 2027.

Year	Quantity of waste (in tons)	Year	Quantity of waste (in tons)	Year	Quantity of waste (in tons)
2008	511 000	2015	628 466	2022	772 933
2009	526 330	2016	647 320	2023	796 121
2010	542 120	2017	666 739	2024	820 005
2011	558 383	2018	686 741	2025	844 605
2012	575 135	2019	707 344	2026	869 943
2013	592 389	2020	728 564	2027	896 042
2014	610 161	2021	750 421		
Total (in tons)			13 730 761		
Annual Average			686 538		

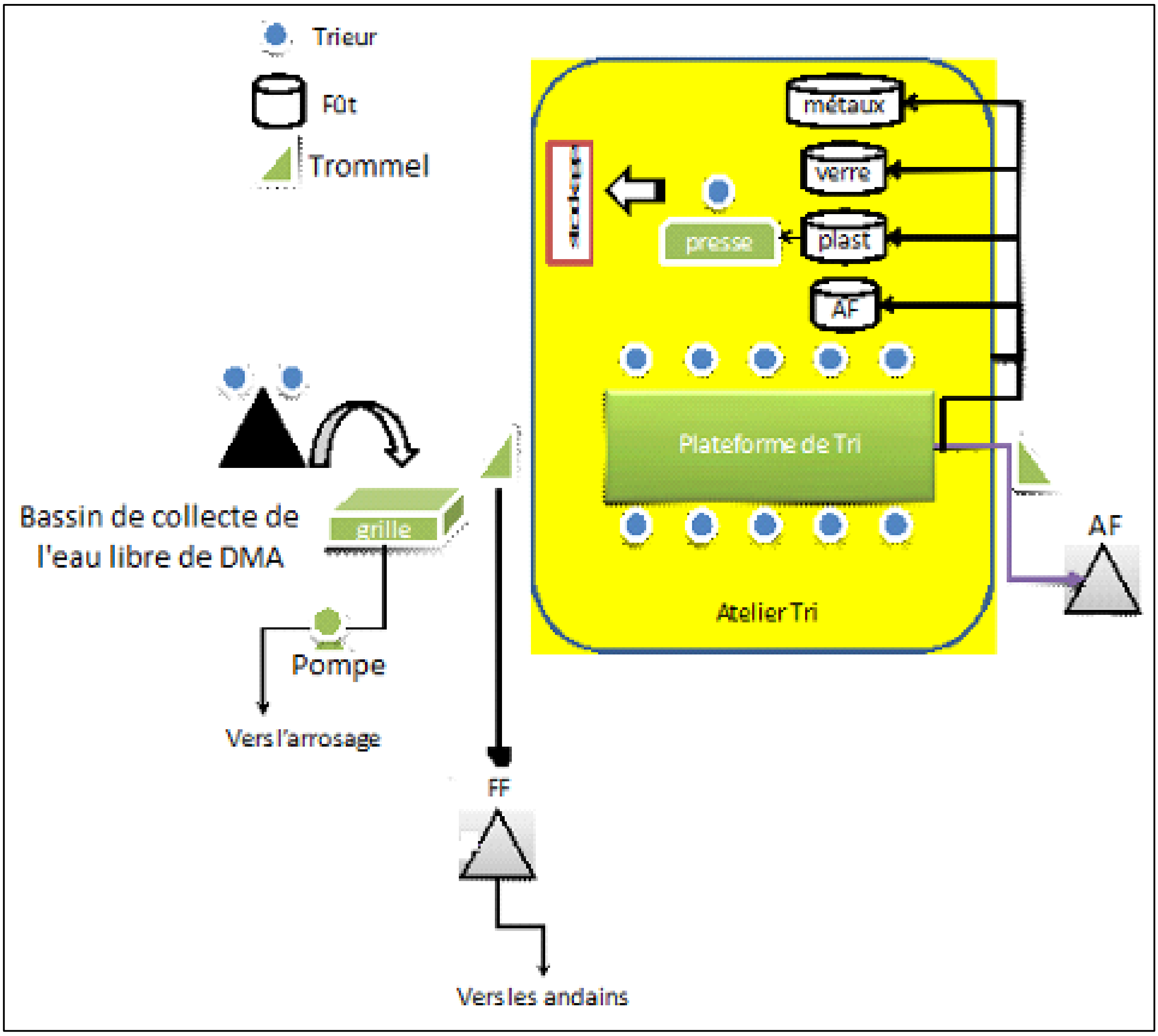

Figure 1 : Design of the sorting center

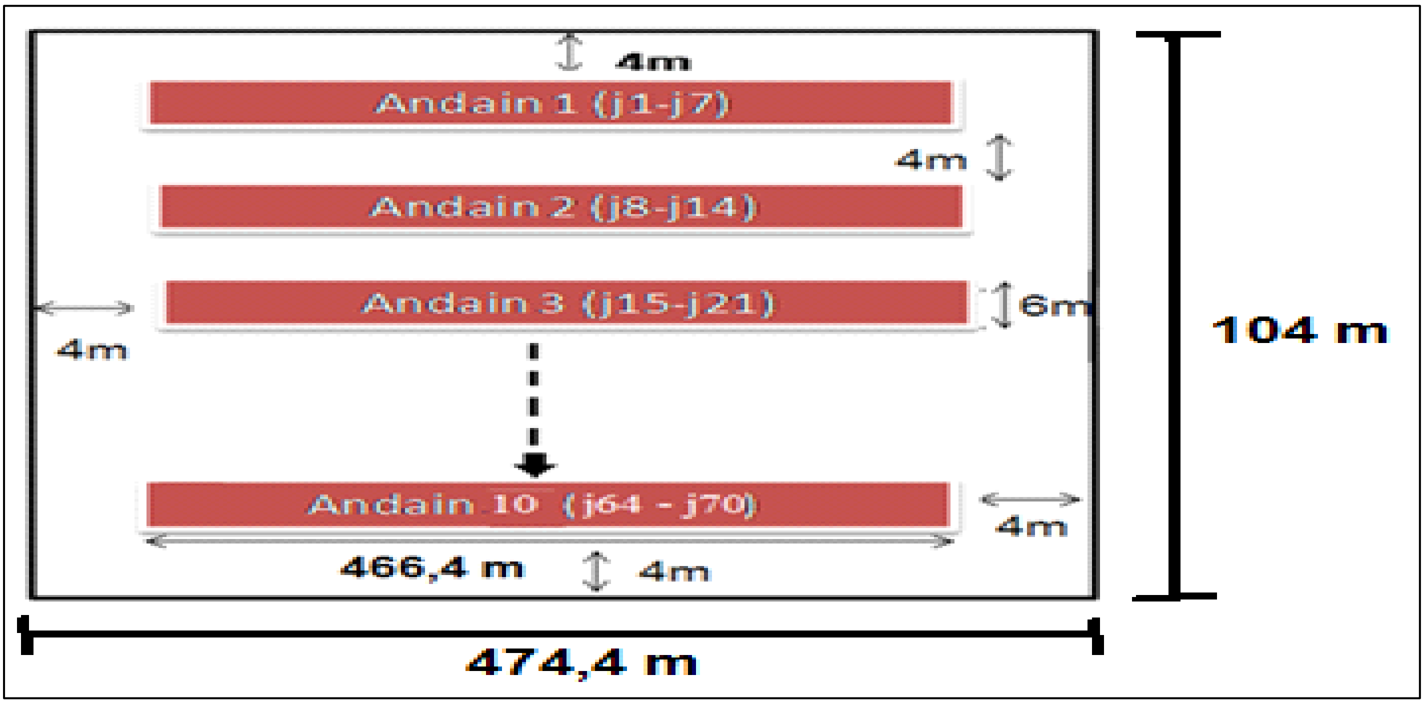

Figure 2 :Arrangement of windrows in the fermentation area

Figure 3: Preliminary sorting

Figure 4: Trommel

Figure 5: Sort line

Figure 6: Composting windrows

-Production of high-quality compost;
-Reduction in storage space for leachate, allowing for allocation to ultimate waste;
-Availability of space for installing a composting unit;
-Recovery of valuable by-products through sorting;
-Feasibility of implementation from a technical standpoint;
-Potential for profitability;
These advantages underscore the potential benefits and viability of the proposed scenario for leachate management.

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