

# ECOLOGICAL LANDFILLS: SPECIALIZED CONSTRUCTIONS FOR SUSTAINABLE DEVELOPMENT

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## ABSTRACT:

The quantities of waste, especially solid waste, have increased rapidly; the evolution of modern technologies and the accelerated growth of the world's population have led to serious consequences regarding environmental pollution and the impact on natural geosystems. Industrial and household waste landfills are special constructions; they must be executed with respect for stability both during their use and after their closure. At a global level, waste management has an important effect on the pollution of air, soil and surface water, as well as groundwater. Waste landfills are special structures that differ in their construction materials, working technologies and the waste that is stored there. The execution and systematic operation of landfills, as well as the monitoring of their behavior over time, are regulated by national legislation that is updated in accordance with and in accordance with the environmental protection regulations of the European Union. In this regard, the purpose of our work is the general description of landfills; the presentation was made based on the bibliography with the example of the landfill built in the municipality of Oradea. According to the updated EU regulations, waste must be sorted, recovered and recycled where possible. Through national strategies, the quantity must be gradually reduced, decreasing the pressure on landfills. All EU countries must align themselves with the requirements and regulations in this field, strictly respecting the technical and environmental protection requirements.

## 1. INTRODUCTION

According to Eurostat data, 2.1 billion tons of waste are produced every year. The general trend is to recycle and reuse as much as possible and to use landfills as little as possible in order not to overload them.

The European Union's goal is to promote circular economy models with the reintegration of waste into the production, industry, and energy production processes. According to EU directives on landfills, by 2035 the amount of municipal waste deposited must be 10% of the total collected.

Landfills (Mancia, 2011) can be classified into three main categories:

- landfills for hazardous waste,
- landfills for non-hazardous waste,
- landfills for non-degradable materials.

Municipal household waste is part of the non-hazardous category.

Responsible management of landfills means selective collection, transport, recovery of recyclable waste and permanent

monitoring of the landfills both during operation and after closure for 30 years.

Ecological landfills designed and operated according to the technical regulations in force produce minimal effects on the environment. They are complex civil engineering works with a high impact (Boteanu et.al., 2008).

## 2. SUSTAINABILITY OF ECOLOGICAL WASTE LANDFILLS

The durability of a landfill is related to chemical, physical, mechanical and hydraulic demands. According to the specialized literature, landfills are specially designed sites for storing non-recyclable waste. It is the place where waste is stored above or below ground.

Waste treatment must reduce the impact on the environment. Selective collection with an emphasis on the selection of recyclable materials, the expansion of composting stations located next to landfills are elements that increase the efficiency of exploitation and minimize the generation of waste.

Among the negative effects and risk generators can be:

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- a site that threatens the health of the population by polluting the air with the generation of unpleasant odors and harmful particles,
- pollution of groundwater with toxic substances, but also changes in the landscape.

The classic sealing system of landfills is with compacted non-contractile and very difficult to permeable clay. The chosen system must ensure the collection of leachate and minimize toxic gas emissions resulting from the mass of stored material.

The first step is to choose the location of the landfill depending on its type. Locations are prohibited in:

- areas potentially affected by floods;
- historically protected areas, natural areas;
- drinking water catchment areas;
- areas with underground cables;
- port areas.

Respecting the distance from inhabited areas or other objectives is a primary element. The foundation land must meet the

conditions of stability (Batally, 2020), impermeability and seismicity. The requirements imposed on the land on which the landfill is located also refer to physical, chemical and ecosystem properties. In addition to the natural geological barrier, a constructive barrier is provided and executed by design. By creating ecological landfills, contamination of groundwater is avoided; correct exploitation results in positive changes towards a green, eco-friendly space later, upon closure of the landfill. Landfills are operated based on strict regulations regarding both storage materials and unloading, sorting, and compaction technology. To avoid odors and wind-blown waste, periodic covering is practiced after compaction. The layer must have the optimal thickness so as not to reduce the storage volume (useful volume).

The sealing of landfills can be achieved by using the mineral layer exclusively or by mixed sealing, i.e. using the mixed method, namely protection with a mineral layer and a geotextile layer (Figure 1).

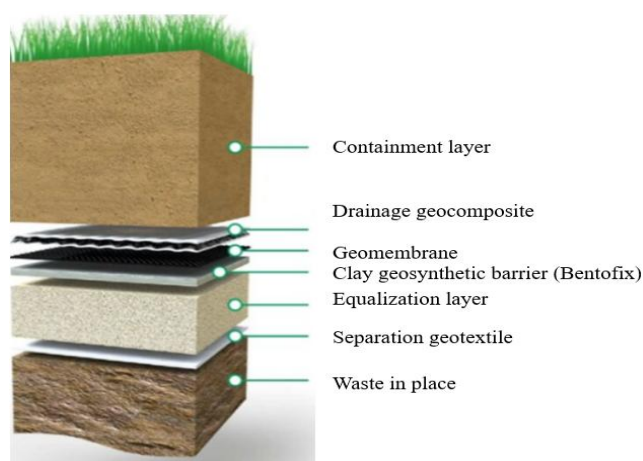


Figure 1. Covering or rehabilitation system for a waste storage center (source: <https://www.naue.com/ro/solutii/constructia-depozitelor-de-deseuri/bariere-de-protectie-a-capacului-de-depozit-de-deseuri/>)

Mechanical stability, resistance to chemical stress, reinforcement and filtration are ensured, depending on the operating conditions. Geotextiles can have a lifespan of up to 100 years; geosynthetics used in Germany have been regulated at national level in accordance with Directive 1999/31/EC of 1999 updated with Directive 2018/851/EC (Figure 2).



Figure 2. Landfill sealing system with geomembrane and geotextile (Geosynthetic Clay Liner)

By using these materials, performance is ensured by:

- the stability of the landfill increases by reducing loads and consolidating the structure;
- the thickness of the base decreases and the useful volume for storage increases;
- execution times decrease through implementation technologies;
- chemical and thermal stability towards the stored waste.

The use of geotextiles (Kellner et.al., 1994), geomembranes and geocomposites ensures both the sealing of the landfill base and the slopes, limiting the ecological impact and ensuring added stability and safety in operation (Figure 3).



Figure 3. Landfill under construction or expansion covered by a white membrane, which is a waterproofing layer, essential to prevent the infiltration of toxic substances into the soil and groundwater

Permanent waste monitoring is a time-based monitoring activity provided by law that mainly deals with:

- waterproofing of the landfill and its operating condition,
- the condition of the protective dams and embankments,
- the degree of settlement of the stored waste,
- treatment of collected wastewater and compliance with technical standards,
- capture of gases resulting from waste storage
- collection of rainwater, interference with waste and evacuation of these waters.

The periodic control system of waste storage is established by technical standards and includes technical verification parameters, methods and frequency of verification (Technical Regulation No. 26/11/2004).

This ensures good exploitation with reduced risk and accidents. Technological self-monitoring is the activity of permanent verification of all components related to a waste storage from access roads, sorting, composting, collection of wastewater / leachate and landfill gases, waterproofing of the premises. The mechanical stability of the landfill loaded with waste (in layers) according to the project is checked periodically; if necessary, the calculations are redone and the necessary corrections are applied.

Ecological waste landfills are executed by compartmentalizing into cells. When the capacity of a cell is exhausted, the technical solutions provided for in the project are applied. The covering is carried out in compliance with the environmental protection requirements, having as objectives:

- waste retention,
- control of the evacuation of leachate and gases,
- post-use of the covered land surfaces.

The covering can be made with different materials: from topsoil to geosynthetic materials, depending on the purpose of the subsequent use. Monitoring of closed landfills is carried out for a period of 30 years in order not to affect the environment.

### 3. THE ECOLOGICAL LANDFILL IN ORADEA FOR NON-HAZARDOUS WASTE

The Oradea ecological landfill was designed for the storage of household and non-hazardous waste after prior selection and treatment. The characteristics of the landfill, according to Eco Bihor, are:

- total area - 36 ha, of which the actual storage area, 22.8 ha, with the compartmentalization into 6 cells and the technical area, 13.6 ha;
- total estimated storage capacity, 4,500,000 tons, i.e. 3,800,000 cubic meters of non-hazardous waste;
- maximum storage height, 18.7 m, and up to 20 m, sealing and drainage systems are located.

The calculations were designed as a rectangle of 400 x 560 m with an area of 38,000 sq m. Each cell has an access road, a perimeter dam and a perimeter canal. The cells also have a drainage system and collection of gases resulting from the fermentation of waste. The cells are executed in stages. Thus, when the volume of waste in compartment 1 reached 75% of the storage capacity, the execution of cell no. 2 began and then the other compartments/cells in stages. The first stage of the ecological landfill project was carried out between 2004 and 2008 (Regulation No. 757/2004). The second stage was completed in 2010 and included a sorting station, an organic waste composting station and a biogas recovery, collection and treatment system.

The material and energy recovery of waste was carried out within a POC project Priority Axis 1. The total value of the project was 1,943,792.32 lei, of which the eligible value was 1,799,855.96 lei and the ineligible value of 143,936.36 lei. Its objective was to develop a gas production technology with superior fuel properties using the biodegradable fraction of municipal waste, but also to optimize electricity consumption in the use of leachate treatment technologies.

In 2010, the works at the Oradea compost station were completed. Biodegradable waste is transformed into compost. The annual capacity of the compost station is 52,000 m<sup>3</sup>/year. In 2022, 1,014 tons of compost for flowers resulted from 1,560 tons of biodegradable waste. Cells 1, 2, 3 and 4 partially no longer have storage capacity (Figure 4). Therefore, by the HCL of the municipality of Oradea of 30.01.2025, the work "Extension of the ecological landfill of non-hazardous waste - Stage IV" was approved. Cell 5 will have an area of 38,000 sq m and a storage capacity of 756,436.8 tons.

The following will also be executed:

- leachate collection pipe, 1.80 m;
- surface water collection ditch, 179 m;
- service road, 175 m long and 5 m wide.



Ecological warehouse



Sorting hall



Compost station



Biogas capture station

Figure 4. Oradea Ecological Landfill: Departments and activities of ECO Bihor (source: <https://ecobihor.ro/activitati-departamente-eco-bihor/>)

In 2020, investment works for the final covering of cells I and II were started. By the HCL of the municipality of Oradea of 26.03.2025, the investment works for the "Closing with final covering of the Ecological Non-Hazardous Waste Landfill, stage III" were approved. The ecological non-hazardous waste landfill of Oradea, which meets the European standards for the storage of non-hazardous waste, took over the waste from the municipality of Cluj Napoca between July 15 and October 15, 2015 (APM Bihor, 2018). The temporary storage ramp at Pata Rât (CJ County) was closed because it had reached maximum capacity. The disposal of waste represented an emergency for the administration of the municipality of Cluj Napoca and the conclusion of a contract in this regard was approved.

The estimated volume of waste to be collected over the three months is 27,000 tons, i.e. 9,000 tons per month, or about 300 tons of waste per day. Oradea City Hall also collected waste on a contractual basis from companies in Cluj, Maramures, Salaj, Alba, Caras-Severin counties, with an estimated volume of 12,000 tons of waste per month.

Romania has developed the National Waste Management Plan (NWMP) which, in accordance with European environmental legislation, outlines measures regarding the selective collection of waste, material recovery, energy and biogas production and material recycling.

The law on waste disposal defines which waste can be disposed of in each category of landfill: hazardous materials, non-hazardous materials and inert materials (Law no 11/2011). Overcrowding or operation at the limit of some landfills, waste burning with toxic gas emissions, illegal landfills without environmental permits are factors for which Romania was condemned by the Court of Justice of the European Union.

According to data published by Eurostat, Romania ranked last in the EU in the production of municipal waste, but also in its recycling. The report published in January 2024 refers to the years 2021 and 2022. The volume of municipal waste produced by some countries in 2022 is (Table 5):

| Country | Waste volume (kg/capita) | Recycled volume (kg/capita) |
|---------|--------------------------|-----------------------------|
| Austria | 827                      | 516                         |
| Denmark | 787                      | 411                         |
| Germany | 710                      | 409                         |
| Romania | 301                      | 36                          |

Table 5. The volume of municipal waste/2022

The average municipal waste produced in the EU in 2022 was 513 kg/capita, and the average volume of recycled waste was 249 lg/capita. Romania was warned for not fully complying with the EU directives on landfills. In Romania, 92 landfills were closed and rehabilitated.

For the period 2026-2028, five landfills have deadlines set by the European Commission for closure and rehabilitation. Four landfills have not established definite closure dates.

According to statistical data published by the Ministry of Environment and ANPN, in Romania the number of compliant municipal landfills is (Table 6):

| Year | No. of landfills |
|------|------------------|
| 2015 | 39               |
| 2019 | 46               |
| 2022 | 47               |
| 2025 | 48               |

Table 6. The number of compliant municipal landfills in Romania

Municipal waste management must be a responsible activity with the application of good practices for reducing landfill volumes, recycling and reusing where appropriate.



#### 4. CONCLUSIONS

In the modern world, waste management is a priority (Black Sea, 2018).

Applying the 3 R's:

\*Waste reduction,

\*Waste reuse,

\*Waste recycling,

represents a goal for environmental protection and sustainable development.

Waste reduction must start at the source, in the production process. By developing and adopting the document "Agenda for Sustainable Development 2030" (ONU, 2015), 17 global sustainable development goals were established for a safe and prosperous future. Goal 12 also includes waste reduction and management.

The competitiveness of the business environment is in continuous dynamics; it has an impact on the environment. Exploiting resources rationally and efficiently with cost reduction, with new technologies, represents a financial effort that, ultimately, symbolizes optimization and sustainable development. In the context of increasing industrial production, global population growth and the exploitation of natural resources, the issue of waste disposal is increasingly discussed.

Ecological landfills are special constructions with a role in the sustainable development of the communities they serve. The European Commission has adopted a series of measures for Europe's transition to a circular economy. The measures proposed in 2015 also include regulations on reducing the amount of waste deposited in landfills, increasing recycling and using waste as secondary raw materials.

In the opinion of European experts, Romania's biggest environmental problem is the overcrowding of existing landfills/wastes and the lack of modern ecological landfills. The correct management of household and non-hazardous waste must have as its objective the protection of citizens' health and the environment: water, air, soil; not to produce noise and odor pollution and not to affect protected areas and landscapes (Agerpres/08.02.2024).

Compliance with EU legislation - Directives 2008/98/EC, 2018/850/EC, 2018/851/EC - adapted to Romanian legislation means efficiency in the use of resources, caution in their exploitation and in production processes, reducing the overall impact on the environment, society and its members.

EU directives and Romanian environmental legislation adapted to them, establish requirements for the prevention of waste generation, for their reuse and recycling in the highest possible percentage. Sustainable production and consumption models are encouraged, for the transformation of products containing valuable raw materials into by-products.

Preventing their transformation into waste is a component of recycling and reuse.

Reducing the generation of household waste, combating food waste, consolidates sustainable development; food production chains and their distribution aim to produce related waste in ever smaller quantities.

The "polluter pays" principle and increased responsibility of the waste producer must lead to the materialization of the concept of protecting the environment, citizens' health and natural resources.

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