

Ecological landfills for municipal waste

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Abstract. The paper deals with the conclusions drawn from the design, construction and operation of 28 ecological landfills for municipal waste achieved in Romania from 1995 to 2012 within the European Program. It comprises an introduction into waste management in Romania, the European and national legislation used for landfills, design principles applied for the ecological landfills, the design of new municipal landfills for non-hazardous waste, criteria for choosing the sites in terms of land topography, in compliance with geological/geotechnical conditions, Case Studies – Bistrița Project Location of the CMID Dumitra–Târlău, the impact of conclusions provided by two reports of technical expertise regarding the solutions of the initial projects, the geological barrier and the impact on the operational phase of the landfill CMID Târlău. The paper concludes with technical recommendations for projects of ecological landfills based on the experience gained in previous years, but also for the construction and operation of such important infrastructure with higher performances.

Key Words: ecological landfills, municipal waste, design, construction, operation, case-study, recommendations.

Introduction. In Romania, in 2012, 28 landfills for non-hazardous waste are operational (Figure 1). By 2017, 50 such landfills must be functional, whereas 45 are regional landfills and 5 landfills are developed for remote areas.

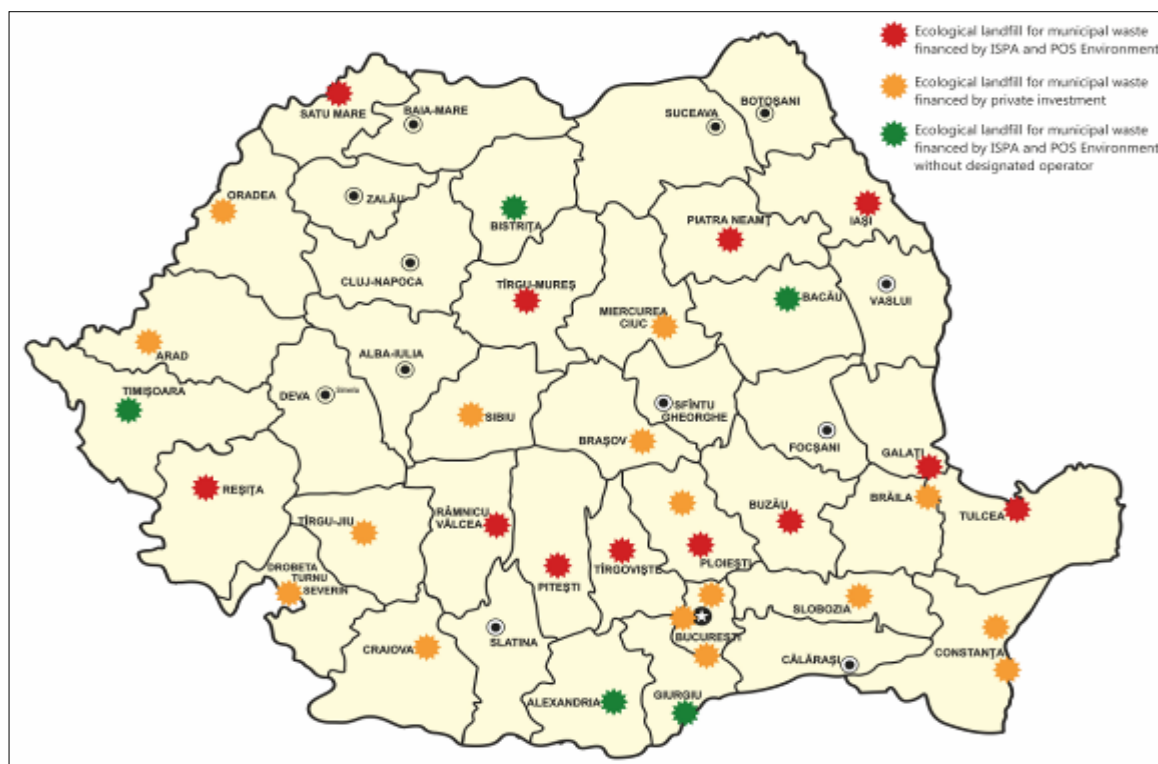


Figure 1. Map of operating landfills for non-hazardous waste.

From the present-day landfills, a total of 16 represent private investment. The construction of another 17 landfills has been funded by ISPA Pre-accession Program and POS Environmental structural program. Technical projects and approval of funding are in various stages for another 17 landfills.

The article provides an analysis based on the case-study of the Bistrița project and on the design solutions adopted in the projects financed within the ISPA-POS Environment program, which generated unforeseen situations during the execution, with an impact on future operating activities.

Applicable legislation. The analysis mentioned above refers to the following legislation:

- Waste Management Framework Directive no. 2006/12/EEC;
- Landfill Directive 1999/31/EC;
- Law 211/2011 regarding waste management;
- HG 349/2005 regarding waste storage (Transposition DE 31/1999);
- OM 757/2004 Landfill Technical Norms (according to DE 31/1999 and HG 349/2005).

Design principles for landfills. In accordance with the current legislation, the design and execution of landfills must follow a few basic rules so that adverse environmental effects may be avoided or reduced to a minimum. This includes surface-water and ground-water pollution, soil and air pollution, together with the greenhouse effect and the risk of harm to human health, throughout the entire life of the landfills, i.e. their construction, operation and post-closure.

As to landfill design, 7 basic rules must be observed in order to achieve a functional landfill, complying with the above conditions:

1. the waterproofing system must provide maximum sealing;
2. the drainage system must be properly sized. The hydraulic gradient must be minimal;
3. the waterproofing and drainage systems must be designed "for eternity", with the requirement that they are operated in a sustainable manner;
4. after filling, a landfill capping is compulsory, and it will be designed depending on the risks of pollution resulting from the contaminated water, gas emissions, and odours;
5. it is strongly recommended, if possible, for the location to provide enough natural seal guarantees in order to take over the problems that may arise in the event of accidental damages to the designed and installed waterproofing system;
6. All liquid waste must be collected from the landfill and will necessarily be treated in a waste-water treatment plant;
7. landfills will be monitored in order to assess their impact on the environment and to take measures in the event of any form of pollution.

In addition to the principles stated above, there are also other criteria that must be taken into account in design and execution. The selected site for a landfill will be away from residential, recreational, urban, and agricultural areas, airports, protected areas, water courses, flood risk areas, areas with high groundwater level, etc. The foundation soil must be stable. Also, the landfill construction must be achieved so as to prevent infiltration of the surface-water or ground-water inside the landfill and to allow permanent control of water from precipitations falling on the uncovered surface of the landfill and penetrating it. The distance between the highest hydrostatic level of the ground-water and the extreme point of the lower surface of the sealing base layer should not be less than 1.00 m.

Designing new landfills for non-hazardous/municipal waste. Landfills designed and achieved until now have rigorously observed the basic regulations, but not the additional set of rules established by the Decision no. 349 of 21 April 2005 regarding waste storage, Annex no. 2 – "General requirements for all classes of landfills", especially those concerning the inspection of the landfill location:

- a) geological, hydro-geological, pedological, and geotechnical conditions at the landfill site and closely adjacent areas;
- b) positioning in areas where land-slides and ground-falls may naturally occur.

The amplitude of geotechnical, pedological and hydro-geological investigations depends on the specific conditions of each site and the class of the landfill to be constructed. In each case a careful investigation of the foundation soil will be necessary, to a sufficiently low depth. The foundation soil must have the stability required in order to take the load of the landfill body, so as to prevent damages to the waterproofing system at the base and to avoid compromising the stability of the landfill.

Choosing locations with regard to topography. All the 16 projects financed by private funds, to which the Țuțora location for the regional landfill Iași can be added, are located on flat lands that met all the criteria and sub-criteria specified in the Decision no. 349 of 21 April 2005 regarding waste storage, Annex no. 2: "General requirements for all classes of landfills". An exception from the rule was Sighișoara, whose location was designed over the existing landfill.

A location on inclined land is the option encountered most often in the remaining applications financed by European funds (Figure 2).



Figure 2. Construction of the landfill at Feteni, Râmnicu Vâlcea.

The Feteni, Râmnicu Vâlcea location is characterized by steep slopes, active landslides and difficult access of the vehicles belonging to the waste collection operator, in winter time.

The following decisions were required, as a result of this choice:

- access to the landfills is done by technological roads with large slopes, hardly accessible in winter;
- in order to compensate the excavation volumes with fillings, it was decided to create fillings over which work platforms were designed, for sorting/composting components in Bistrița, Mureș, and Cluj, and for waste-water treatment plants in Bistrița and Botoșani;
- the earthwork volumes are estimated at 100,000 m³ to over 200,000 m³ for the first cell, with areas varying from 3 to 4 ha.

Slopes with deep excavation and high filling require, from a stability point of view, certain special works: retaining walls, systems of controlled collection/evacuation of the surface water and infiltrations, reinforced earth systems and slope stabilization. Added to the fact that both deep excavations and high fillings require large slopes that

occupy considerable areas, all these works lead inevitably to the diminution of effective operational areas and to heavy access of the wide-ranging machinery.

Observing the geological/geotechnical criteria when choosing a location. The geotechnical criterion was theoretical analyzed at the selection phase of the landfill location and during the elaboration of the Feasibility Study. Geotechnical studies did not observe the requirements and most times they were not even checked by MLPTL authorized inspectors, according to the Law no. 10/1995 on Quality in Constructions.

Wells were constructed less deep than the level where works were carried out. For a surface of 20÷40 ha only 4 wells were built, which did not allow a relevant assessment of the geotechnical conditions at the site location, with severe repercussions on the future execution of works and operation of the installation.

Case Study - Bistrița Project - CMID Dumitra-Tărbu Location. The site location is characterized by a slope of approx. 10% in East-West direction, so that the main technical issues refer to providing:

- overall stability during the works;
- overall stability in operation;
- local stability of each item in the Centre for Integrated Waste Management.

At the start of excavations on site, in March-April 2010, different geotechnical and hydro-geological conditions were detected and varying in certain areas, compared to those known from previous studies that the design was based on (Argif Proiect 2011; Manea 2010; Manea & Olin 2011) (Figure 3).



Figure 3. Centre for Integrated Waste Management at Dumitra-Tărbu during the landfill execution.

Later on, during the execution of earthworks for the composting platform area, although all precautionary measures had been taken, landslides in slopes were visibly reactivated (Figures 4-6).

During the execution, new geotechnical studies were carried out which revealed an old natural valley, known as Rosna Valley, which had been completely covered during a previous landslide.

The displacement of earth mass at the Dumitra-Tărbu site occurred on the slope of the plastic materials storage-platform. The earth material was glomerular destructured clay.



Figure 4. North-West corner of the Dumitra-Tărpiu site, landslide reactivation.



Figure 5. Displacement of the earth mass at Dumitra-Tărpiu.

Figure 6 shows the landslide repair works in the area of the plastic materials storage-platform.

These specific conditions determined the Contractor to order two geotechnical expert reports on the landfill location and on the location of the composting platform/plastic material storage, respectively, i. e. the "Technical report regarding geotechnical conditions on site at the compost platform and adjacent items within the Centre for Integrated Waste Management at Dumitra, Bistrița-Năsăud county", and "Geotechnical monitoring report on the instability situation in the location of the Centre for Waste Management at Dumitra, Bistrița-Năsăud county".



Figure 6. Confining area of the Western dike at Dumitra-Tărpiu storage cell no. 1.

The geotechnical surveys carried out by the Contractor in the execution phase revealed the following aspects:

- the constituent materials of the soil until approx. 4 m deep, where bedrock – marl clay was found, are a cohesive-soil type of fat clays of various colours that can be generally characterized as swelling and shrink clays with high and very high plasticity indices, very active in relation to water, with swelling pressures in natural state up to 150 kPa;
- between these materials, the surface layer of blackish clay, with a thickness of up to 0.6÷1 m, is completely unsuitable as a foundation soil and for the use in earthworks. Practically this material has proven that it cannot be compacted and therefore it is advisable for it to be completely excavated and removed from the location of cell no. 1, from roads, platforms and other construction items within the site;
- due to the morphology of the site and to geotechnical and hydro-geological conditions, there is a potential for the occurrence of general and local instability phenomena;
- both the clay materials, capable of large swelling and shrink (PUCM) of various types, and the films of non-cohesive materials in different sizes, which provide a heterogeneous character of the soil, down to the bedrock, favouring water infiltration and the appearance of springs, create the premises for stability loss by sliding;
- swelling phenomena are cyclical, depending on the local climatic conditions and the appearance of local humidity sources, e.g. springs followed by contraction phenomena, forming large cracks which then lead to a chaotic water infiltration in the slope;
- when torn tangentially by sliding movements on the slopes, swelling pressures of the clays increase these demands and the water reduces shear strength parameters, which may cause local or general slides;
- the other clays have hydro qualities, reduced permeability indices, in order to constitute a natural barrier at the base of the landfill, and compressibility indices that meet the requirements;
- at the level of the foundation soil, temporary springs with variable flow and intermittent appearance were detected, whose occurrence was less predictable in terms of the lithological conditions in site;

- at the location of the Centre for Integrated Waste Management, in various areas, depending on the phasing of excavation works, several drains put into operation before the current project started were found and crossed.

During the execution of sounding operations in the location of the compost platform, in order to establish the causes that favour the repeated sliding of excavated slopes, were found different geotechnical conditions from those revealed by the geotechnical investigations previously carried out for the entire site, including:

- the presence of old drainage polyethylene pipes, 50 mm in diameter, crossing the entire site from West to East. These drainage pipes are installed at a depth of 1.5–2 m. They take the water infiltrated in the slope and discharge it upstream from the plastic material storage platform;

- for a 2-3 m depth, the foundation soil is composed of blackish clay with vegetal traces and a mud odour;

- in the area of the compost platform there previously was a 2-3 m deep valley, which was filled following a landslide. This landslide brought down huge amounts of soil covered with vegetation, which explains the presence of the blackish clay with vegetal remains, like wood pieces, tree roots, and leaves;

- the previous attempts to stabilise the area could possibly explain the existence of the drainage system, partially disclosed when performing the excavation works on site;

- draining out the water infiltrated in the mountain slopes by these old drainage pipes and discharging water upstream the slope of the plastic material storage platform represent factors that could favour and trigger landslide phenomena in this area, during execution works;

- the current foundation conditions of the compost platform, revealed by the geotechnical evaluations, are totally inappropriate and do not provide a fulfilment of the local and general stability requirements for the area.

Impact of these two technical assessments upon the initial project solutions. In august 2011, the General Contractor sent a request to UTCB (Technical University of Civil Engineering, Bucharest), Geotechnical and Foundations Department, to perform a “Study regarding the use of the local resources as backfilling in order to carry out the perimeter dams surrounding the waste landfill” and a Technical Expertise as well, both resulting in one Study and two Expertise Reports based on site findings (technical sightseeing during the execution, in 2010-2011), specific in situ investigations, laboratory testing, and stability calculations. The expertise, in both reports, identified a lot of causes and presented several technical recommendations, which were then transposed in project adapting steps and the elaboration of new design chapters in the project (Table 1).

Following the conclusions of the technical expert several measures were taken:

- completely redesigning the project for the waste landfill - cell 1;

- severe measures were established to collect and evacuate water resulting from rainfalls in the excavated areas;

- slope consolidation measures were taken by providing a reinforced soil structure;

- the composting platform was built on two levels, to comply with the client requirements regarding the total effective area available for the composting process;

- redesigning of all the constructions from the vicinity of the dam closing the landfill, the composting platform, plastic material storage platform and leachate treatment complex (Figure 7), taking into consideration that they were placed at different levels and the slopes occupy a considerable surface. This surface was not considered in the initial project.



Figure 7. Slope repair between road DA2 and the plastic materials storage-platform.

According to the Decision no. 349 of 21 April 2005 regarding waste disposal and the Annex to the Order of the Ministry for Environment and Water Management no. 757/2004, as well as the European legislation regarding non-hazardous landfills, the following conditions and constructive elements must be provided:

- a geological clay barrier with a minimum thickness of 1.0 m and a minimum value of 10^{-9} m/s for the coefficient of permeability;
- a 2 mm thick HDPE geomembrane;
- a drainage layer for leachate, with a thickness of 0.5 m, using sort 16/32 river gravel (Figure 8).



Figure 8. Installation of the waterproofing system at Dumitra-Tărpiu.

Table 1

Beneficiary's requests regarding the main geometrical characteristics of the cells

Cell no.	Base surface (m ²)	Waste volume (m ³)	Embankment volume (m ³)			
			Estimated in SF		Currently executed	
			excavations	backfilling	excavations	backfilling
1	34,035	310,000	25,279	83,980	103.808	124.622
2	23,439	270,914	16,680	52,563	-	-
3	27,051	208,123	6,946	32,490	-	-
4	23,650	233,070	0	0	-	-
TOTAL	108,175	1,022,107	142,713	209,702	-	-

Geological barrier. The Decision no. 349 of 21 April 2005 regarding the waste storage and the Annex of the Order of Ministry for Environment and Water Management no. 757/2004 require a geological barrier under the primary sealing layer. In case of deficiencies in the primary sealing, the geological barrier has the function to prevent water infiltration and afterwards the dispersion of substances underground, which could produce groundwater or soil pollution.

The natural geological barrier must meet the following requirements:

- thickness: minimum 1.0 m;
- permeability coefficient: $K < 10^{-9}$ m/s;
- the foundation material must be homogenous;
- the carbonates content for the clay material of the geological barriers, either natural or built, must be less than 10% by mass;
- organic matter content of the clay material which constitutes the geological barriers (either natural and/or built) in landfills must be less than 5% by mass;
- the clay minerals content with a diameter < 0.002 mm in the natural barrier must be minimum 15%;
- the clay minerals content with a diameter < 0.002 mm in the built barrier must be minimum 20%.

Taking into consideration the special geotechnical situation of the emplacement, where during the geotechnical studies preceding execution black clay layers were found, classified as belonging to the PUCM class, soils with large swellings and shrink under which there is a marl layer of over 1 m thickness, it was necessary to plan certain special works for the vertical systematization of the landfill base, as follows:

- excavation and removal from site of the improper black clay layer, down to the marl layer, and transport in 4 intermediate landfills;
- where the black clay layer thickness exceeded 1.0÷2.0 m, this was all excavated, to the whole depth, and removed;
- in order to achieve the designed quota of the landfill base, filling with appropriate quality clay from the borrow pits of approx. 119,724 m³ was carried out;
- through these works, the condition was fulfilled that the entire landfill base has, at a minimum thickness of 1.0 m, a 10^{-9} coefficient of permeability.

Impact on the operational phase of the CMID Tărbuș landfill. The Bistrița Project is the first project financed through POS Environment which was implemented (Figure 9). Choosing a location with problems has repercussions both on the operational phase and the execution phase of the works. In case of the CMID Tărbuș, the operator will subsequently:

- take over the monitoring of sliding phenomenon, which may occur especially on slopes, on the side road;
- intervene with specific works of slope consolidation, removal of the surface water, preventing cracks during drought periods;
- maintain the grass carpet and the protection of the plantation, recover them whenever necessary;
- maintain the channels of surface water discharge and the inspection chambers;
- keep in operation the entire drainage system.



Figure 9. Cell 1 of the ecological landfill at Dumitra-Tărbuiu.

The operator will have to be endowed with specific equipment for the execution of such works. It is recommended that he performs a study regarding the slope stability on the perimeter road, which requires a viable design solution for their stabilizing and probably a need to purchase additional land, to allow the execution of such works.

Conclusions. In order to prepare the projects and to assess the impact of decisions in this stage on the execution and operation of the future installation, the following comments and conclusions should be taken into consideration:

- the choice of the location was not the best, as the option was a sloping location, $i = 10\%$;
- local authorities did not reveal in notifications the fact that in this location there had previously been works of land reclamation, drainage systems, and landscaping;
- at the stage of the Feasibility Study for Bistrița-Năsăud County no Geotechnical Study was carried out, as required by law for such projects;
- the design solution did not take into account that all the works carried out on slopes which involve installing different constructions at different elevations lead to the design of slopes with gradients correlated with the land nature of minimum 1:2, and occupying large surfaces;
- as a consequence of the errors in the project preparation phase, in the execution phase:
 - geotechnical surveys were performed and revealed the presence of PUCM materials at the location, unacceptable soils for the installation of filling or the foundation of other constructions;
 - a drainage pipes system was detected;
 - the project for the landfill – cell 1, composting platform and plastic storage area was completely revised;
 - an additional drainage system was built;
 - an additional reinforced soil structure was constructed at the base of the composting platform;
 - black clay was excavated from the site and replaced with suitable material;
 - the execution of the division dams of cell 1 was carried out with appropriate material from the borrow pit;
 - 524,794 m³ of earthworks were additionally carried out;

- the execution term was extended over the one established in the contract, motivated by the need for expertise, redesign and additional works that were required;
- the future operator will have additional tasks concerning the monitoring, intervention and maintenance of the completed works, and will also have to carry out new investments in order to stabilize the slopes.

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