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Environmental policy for landfills and role of geosynthetics, in Italy

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ABSTRACT: A short review of Italian policy about landfilling is reported , with the main references to EEC Directives and to national laws. Every Italian region can autonomously issue a proper code, with its own minimal technical and environmental requirements. Design solution employing geosynthetic materials are also presented, with particular attention to Italian application and research.

1 ITALIAN POLICY FOR LANDFILLS

The national Italian regulation is given by DPR (Decree of the President of the Republic) no. 915/1982 and subsequent modifications, in fulfilment of EEC Directives nos. 75/442, 76/403, 78/319. This decree classifies refuses in Municipal Solid Waste (MSW), Special Waste and Toxic Noxious Waste.

Technical applications of the law are demanded to an Intragovernmental Committee for the related technical codes, which (Deliberation on July 27th, 1984) classified landfills in three categories (Tab.1), requiring proper characteristic of materials for artificial barriers.

The national regulation indicates some hydrological, hydrogeological and engineering geological preliminary criteria to the site selection. Hydraulic, geotechnical and environmental design criteria should allow to protect both surface-water and ground-water from pollution. Even if a synthetic membrane protection is provided, an underlying compacted mineral liner is required. Both bottom and side leachate collection systems are required; moreover, biogas recover and reuse is desired. The geotechnical design must include internal and external stability analyses. As for landfill completion, the design must report indications for surface water drainage, final reclamation and land use of the area.

These rules are in agreement with the EEC Directives on Landfilling of Waste, where refuses are classified into Inert (IW), Non Hazardous (NHW) and Hazardous Waste (HW): for NHW landfilling a geological barrier with a lower hydraulic conductivity is required. Every regional authority promulgates autonomously provisions with minimal technical and environmental requirements for landfills.

Some Regions (e.g. Regione Lombardia, Circ. no. 10, Feb. 25th, 1994) give a methodology for a quality control. The authority checks the construction, operating and post operating phases of landfills, with specific requirements for geosynthetics materials, laboratory and field tests on sheets and weldings and with a final check by geoelectric systems for the bottom liner and analysis of tensions induced on waterproofing sheets.

Table 1. Classification of landfills according to DPR 915/82 and subsequent modifications

CATEGORY	ADMITTED WASTE
I (EEC NHW Landfill)	Municipal solid waste and other special waste, if their leachate has the same degree of risk for human health and for the environment; sewage sludge stabilized and made workable for a mechanical loader
II A (EEC IW Landfill)	Construction waste and demolition rubble; fired ceramic material; glass; rock fragment
II B (EEC NHW Lanfill)	Untreated or treated, toxic and hazardous waste, if for any toxic substance $C_0 < 0{,}01\ C_L$; further limits are also given for the content of toxic metal in the leachate
II C (ECC HW Lanfill)	Untreated or treated, toxic and hazardous waste, if for any toxic substance $C_0 < 10\ C_L$; sludges deriving from treatment of special wastes, stabilized and made workable for a mechanical loader
III (EEC HW Landfill)	All kind of highly toxic wastes, having $C_0 > 10\ C_L$

Legend: C_0 = concentration of a toxic organic substance; C_L = limit concentration for the same substance, as indicated by the national law.

2 APPLICATION OF GEOSYNTHETICS IN LANDFILLS

The main structural elements forming a typical MSW landfill include (starting from the bottom): foundation soil and subgrade, bottom and side lining system, leachate collection system, biogas extraction system, waste body (including both compacted wastes and interstrata capping), reinforced soil embankments (if any), top capping and final reclaimed top surface. In every element, geosynthetics could be used successfully for containing costs, with positive effects on environmental impacts (Cancelli 1994).

2.1 *Subsoil and subgrade*

The essential requirements of a sanitary landfill foundation soil are to perform as a natural hydraulic barrier and to possess sufficient bearing capacity and low compressibility. The best "natural" solution is very uncommon and in the large majority of cases artificial hydraulic barriers (including geomembranes) are truly necessary.

Coming to the bearing capacity problem, although soft clays or organic silts should be preliminary avoided as foundation soils, numerous examples of base failure due to the low undrained cohesion of foundation soils are reported from different parts of the World. Serious foundation problems can also be given by unforeseen voids of various origin (tension cracks, sinkholes, dissolution cavities) or by depression due to differential settlements (Giroud et al. 1990).

For these reasons a reinforced subgrade, having the scopes to homogenise settlements, to reduce tension stresses in the geomembrane and to increase the ultimate bearing capacity, is often realised below the bottom liner. To this aim, bioriented HDPE geogrids (or, alternatively, geocomposite reinforcements, or twin layers of mono-oriented geogrids) can be used as reinforcing elements, co-operating with medium to coarse grained soils, within a multilayer subgrade.

Another solution is the cellular foundation mattress (or "georaft"), forming a high stiffness and resistance to deformations base layer, with properties of capillary and ground water drainage too (Fig.1) (Rimoldi, personal communication).

Similar problems are encountered when an existing landfill has to be expanded vertically with addition of new waste: if the existing waste accumulation is an old, uncontrolled landfill, the expansion has to be intended as a completely new waste landfill.

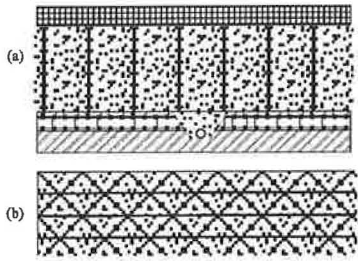

Fig 1: Cellular foundation mattress. a: section; b:plane view

2.2 *Bottom and side lining system*

The essential function of a lining system is to act as a hydraulic barrier against the leachate, so protecting groundwater from pollution.

Due to the specific nature of leachate, the barrier should be effective against both seepage and diffusion phenomena: the latter may be an important transport mechanism in a clay liner. The barrier function of clay minerals can be affected also by the destruction of the clay mineral structure by acids and by the affection of the adsorption capacity caused by the charge blocking of the clay surface (Bradl 1995).

All these requirements can be satisfied only by a composite, multilayer lining system, including natural materials and a combination of different kinds of geosynthetics, according to the different design strategies.The most common solutions are reported in Fig. 2 (Cossu 1995).

The *single compacted clay layer* (a) represents the simplest lining which is still widely adopted in presence of a natural, "geological" barrier. A geomembrane only does not afford any safety guarantee and is not used.

The *single composite liner* (clayey soil plus geomembrane) (b) is the most widely recommended for MSW landfilling and is included in the guidelines of many developed countries. The safety level concerned is hard to predict. In order to maximise the advantage of composite liners, geomembrane should be positioned at direct contact with the mineral liner, avoiding the interposition of any drainage layer between synthetic and mineral liners. This point is rather controversial and a leakage control layer is often imposed by some Regional Authorities: this appears the consequence of the old concept considering the synthetic liner as "totally impervious" (Cossu 1995). On the contrary several authors advise against this kind of barrier, that may favour migration of leachate into subsoil (Fratalocchi et al. 1995). A study for assessing the integrity of synthetic liners using Geomembrane Leak Location

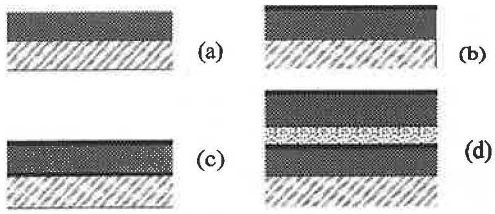

Figure 2. Types of lining system: a = single clay liner, b = single composite liner, c = single sandwich composite liner, d = double composite liner with leak control (From Cossu, 1995, modified)

System over 25 Italian landfills (of MSW and IW) has detected an average of 15 leaks per hectare of inspected geomembranes (Colucci et al. 1995).

A *single sandwich composite liner* (c) increases the safety level of the single composite liner and can prevent desiccation and cracking of the mineral liner.

The *double composite liner* fully exploits the possibility for an intermediate leakage control (d). This solution is just applied in Italy in some landfills of HW and MSW in order to minimise any adverse environmental impact (Cossu 1994).

As for synthetic liners, the most widely used material is HDPE, with a thickness of 2 -2.5 mm. Recently LDPE has been proposed, due to its better flexibility.

On the sides of depression or slope landfills, the hydraulic barrier should respect the same requirements as on the bottom. The realisation of a lining system in these conditions presents, despite of the common hydraulic requirements, some peculiar aspects, mainly due to the difficulties in putting in place adequately compacted clay liners. Prefabricated products, as geomembranes, geocomposite clay liners (GCL) and geocomposite membrane liners (GCM), are largely preferred as barriers, while geonets and geonets-based geocomposites are used as intermediate drainage layers instead of natural gravel or sand. Mineral liners slopes are often substituted by a geotextile-bentonite composite. The composite liner system made up of a GCL and a HDPE geomembrane in close contact, with the GCL under the plastic liner, allows, through the self sealing properties of GCL, to seal any hole or tear occurring in the geomembrane (Bressi et al. 1995).

2.3 *Leachate collection system*

A leachate collection system is a necessary condition for every modern sanitary landfill. Permittivity and in-plane trasmissivity are the essential qualifications, together with good performances as a filter. For long term performances, non-susceptibility to clogging, resistance of material to chemicals and high temperature, internal stability and shear resistance are necessary. The gravel blanket used as drainage can be substituted by a geonet (lying on the primary geomembrane), overlaid by a geotextile (as filter), in turn covered with a soil protective layer, or by using prefabricated geocomposite drains, all including a geonet.

Designing geosynthetics drainage systems can present peculiar difficulties and uncertainties when these hydraulic structures come into contact with waste instead of natural soil. Design indications for dimensioning geonet-based drainage systems are also available in the literature (Cancelli & Rimoldi 1994).

Geotextiles are used both as separator and as filter. In the latter case, their performance with regard to leachate is a matter of contest: remarkable biological clogging of geotextile has been found by laboratory tests (Cazzuffi et al. 1991).

Moreover, in landfills where the low hydraulic conductivity of interstrata capping layers or of the waste itself does not allow a full drainage of the produced leachate, vertical drainage wells are also required. Such wells must have a warping structure, in order to adapt themselves to vertical settlement and horizontal deformation of the waste body: to this scope, HDPE geogrid rings are preferable with respect to concrete rings.

2.4 *Biogas extraction system*

Applications of geosynthetics in the gas extraction system include:
- the use of HDPE for vertical and horizontal pipes and for the different elements of biogas picking up system;
- the use of HDPE geonets, instead of granular earth materials, all around the horizontal perforated pipes;
- the application of a GCL to sealing the outcoming upper portion of gas extraction wells.

2.5 *Waste body and reinforced soil embankments*

When the external or internal stability requirements of a waste landfill are not satisfied, reinforcement with horizontal geogrid layer can become necessary.

Reinforced soil embankments are often built at the toe of waste embankments in order to improve the stability of the landfill slopes. A typical case history is the landfill of Modena, reinforced with mono-oriented HDPE geogrids (Cazzuffi el al. 1988). This solution allows to increase the volume of wastes that can be disposed, with evident positive impacts from an environmental point of view.

2.6 *Top capping and final reclaimed top surface*

The functions of top capping are to separate the waste body from the external environment, to control both water infiltration in the landfill and the releasing biogas. The typical elements are showed in Fig. 3.

Geosynthetics applications include:
- geotextiles with the function of protection and/or support;
- geonets as drainage instead of sand-gravel layers;
- geomembranes (HDPE or GCL) as sealing layers.

The system is completed by the cover soils, which can vary in composition and thickness, essentially depending on the climatic regime. The superficial top cover has to be sufficiently resistant to wind or to water erosion processes. To this aim, satisfactory results can be obtained by an appropriate use of the many geosynthetics and/or bioproducts. Design constraints include the external stability of the waste body, the internal stability of the cover system itself, the erosion of cover soils and, of course, the hydraulic behaviour of the lining materials. In terms of required performances as barrier, gas permeability represents the critical design constraint: the presence of a geosynthetic liner within the system is recommended.

In addition, the control of water entering the landfil system is strictly connected to the design concept and management of the landfill and to general climatic conditions. The consequent design aims at controlling water inflow in hydrological balance. A simple control measure, even if not so efficient with respects to other ones, can be achieved by using a provisional synthetic cover (Cossu 1995).

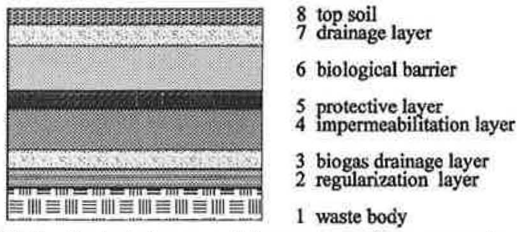

Fig.3 : Typical elements of the most complete top capping (Pasqualini, personal communication)

3 CONCLUSION

Building sanitary landfills in a densely populated and highly developed country as Italy had been more and more concern, for both designers and executors. Nowadays, design solutions employing geosynthetic materials, available to solve different problems, allow to face the increasing demand for the landfill safety, also decreasing its environmental impact.

The Italian Policy and EEC Directives are going to become rapidly obsolete and can induce erroneous design concepts, while knowledge grows very quickly: Consequently, a Technical Committee on Landfills has been proposed and formed after Sardinia 93 (3rd Int. Landfill Symp.), with the aim to create common guidelines to projecting and managing landfills with minimal and reliable environmental criteria. This Committee includes several experienced people working in different operative spheres and fields. The guidelines, still in draft version, are not yet compulsory, but they offer the latest updated state of art of landfilling design and management.

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