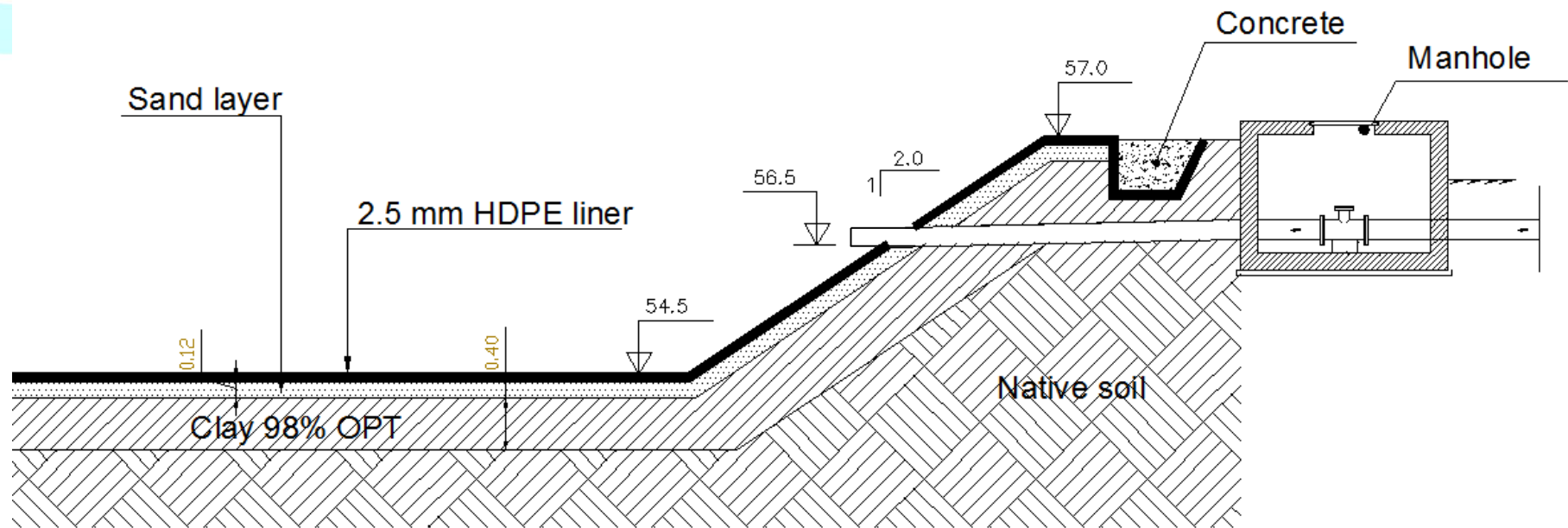
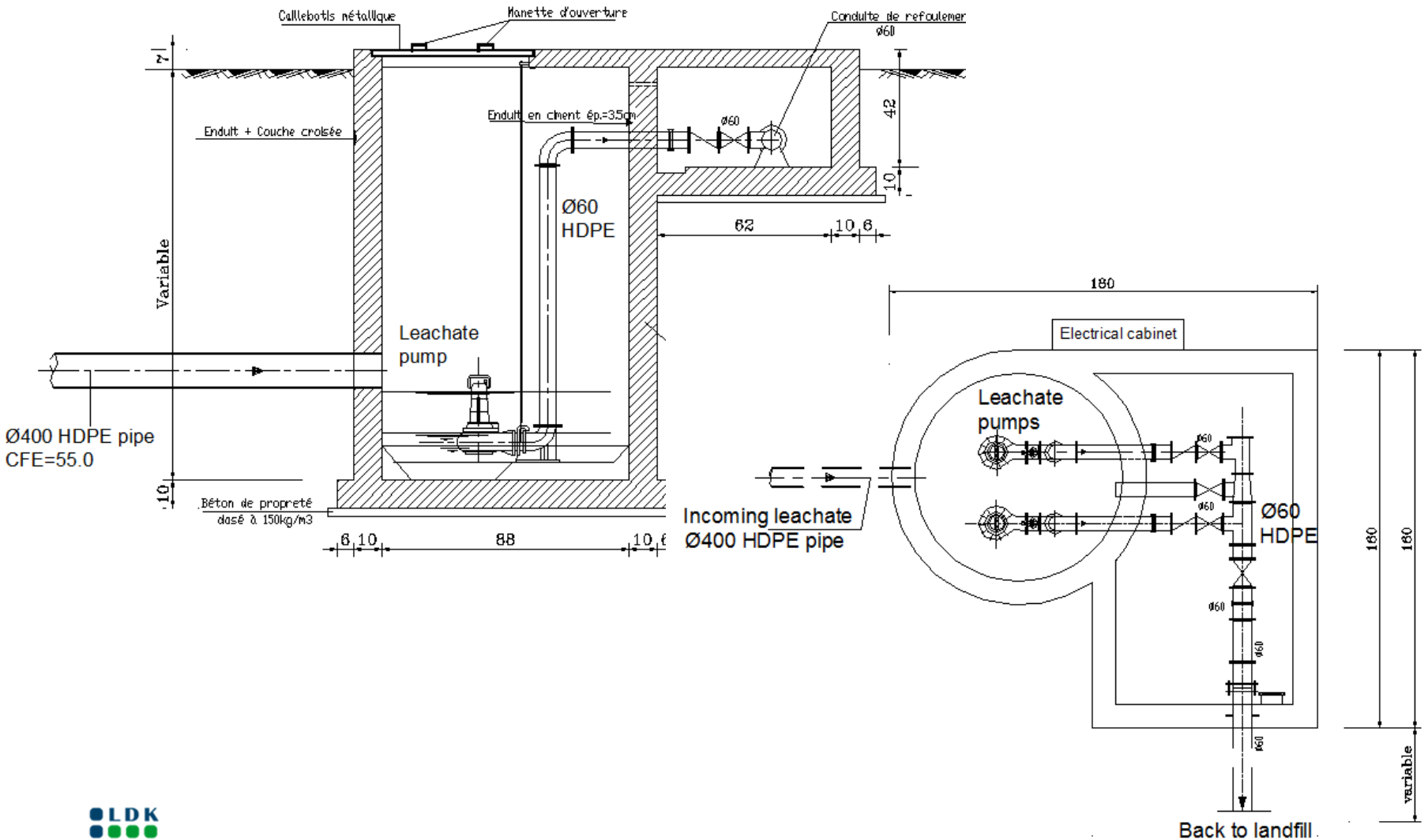


Leachate management – Leachate storage pond



Leachate management systems

Leachate recirculation manhole



Landfill design - Lining systems

There is no worldwide standard for bottom lining systems. But the standards of Europe and USA can be taken as a good basis. All bottom liners have to fulfill the same requirements:

- The bottom liner system must ensure that no pollutant can infiltrate into the underground and especially into groundwater
- The selected liner system must achieve consistent performance and be compatible with the expected leachate for the design life of the landfill
- A bottom liner system usually consists of different natural and/or artificial layers:
 - ✓ A geological barrier (this means a landfill site has to be chosen which fulfills this criterion)
 - ✓ A bottom liner (mineral, geosynthetic or asphalt)
 - ✓ A drainage layer (and leachate collection pipes)

Landfill design - Lining systems

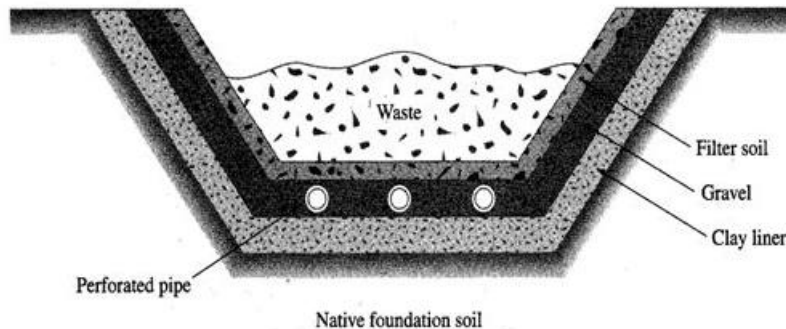
Alternative liner materials

1. Mineral liner (Also called compacted clay liner (CCL))
2. Flexible membrane liner (FML) also called geomembrane
3. Geosynthetic clay liner (GCL)
4. Asphalt liner
5. Composite liners

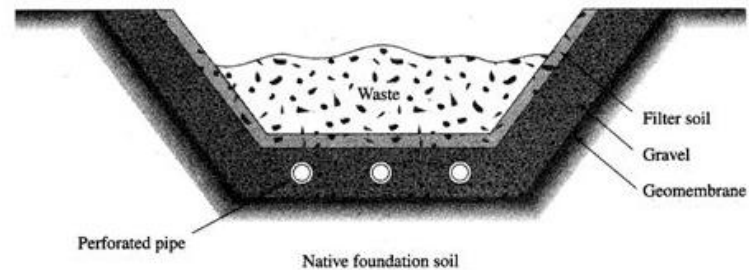
Landfill design - Lining systems

Single liner systems

A single liner system consists of one sealing element (mineral, asphalt or geosynthetic liner) and a drainage layer above, which collects and removes the leachate



Cross section of single clay liner system for a landfill

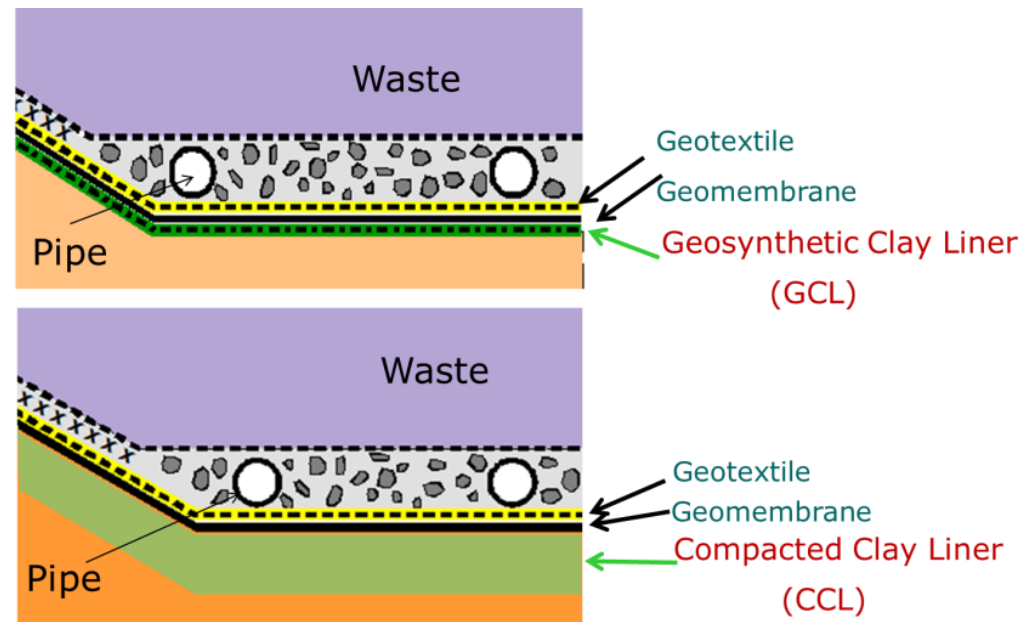


Cross section single geomembrane liner system for a landfill

Single liners are commonly used in western Europe mainly for bottom barriers of landfills for inert wastes; in other countries often a single liner system is assessed to be sufficient as bottom barrier of landfills for nonhazardous wastes

Landfill design - Lining systems

Composite liner systems



Composite liners consist of a mineral liner and a geosynthetic- or asphalt sealing element. They facilitate the combination of the advantages of both types of sealing elements and thereby minimizing advection as well as diffusion

Composite liners are typically used for bottom barriers of landfills for nonhazardous waste (domestic solid waste) and also for bottom barriers of landfills for hazardous waste

Landfill design - Lining systems

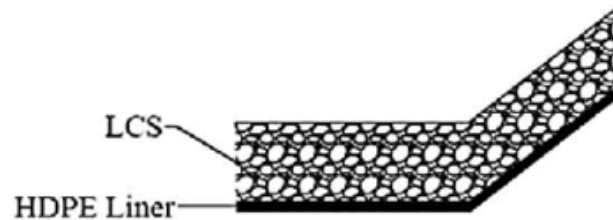
Double liner systems

Double liner systems have **two sets of liners and drains**. The leachate collection system is placed above the primary (upper) liner. Between the primary (upper) liner and the secondary (lower) liner a secondary drainage layer is installed to serve as leak detector and to remove the leachate in case of failure of the upper liner. **Mineral or geosynthetic** products can be employed for liners and drainage layers.

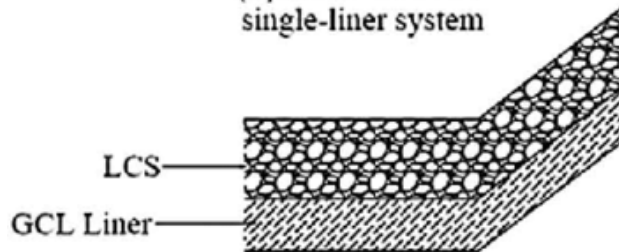
Double liner systems are used in some countries (e. g. USA) **for hazardous waste landfills**. They permit the observation of leakage rates. If the observed leakage rate exceeds a certain value (response leakage rate) prescribed by the supervising authority, actions must be taken.

Lining systems - Single and double liner systems

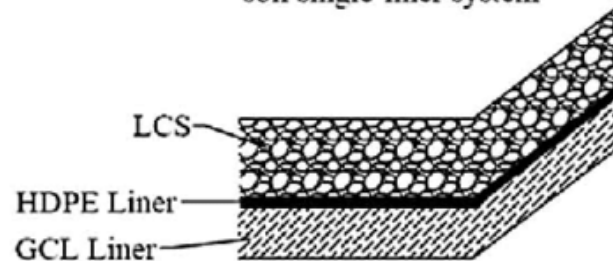
Single-liner systems



(a) Geomembrane single-liner system

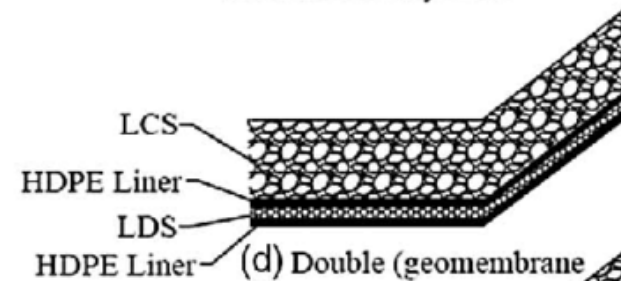


(b) Low-permeability soil single-liner system

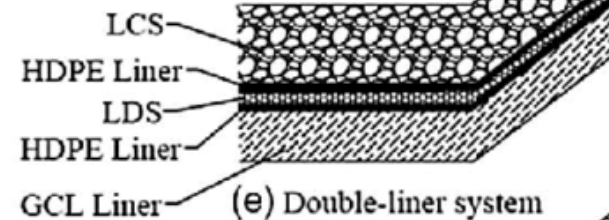


(c) Single composite liner system

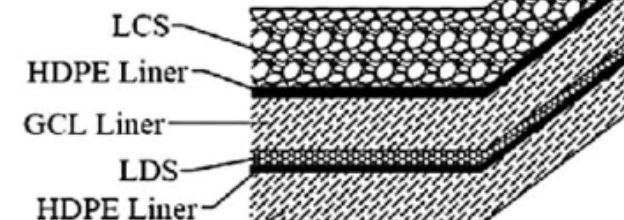
Double-Liner systems



(d) Double (geomembrane liner system)



(e) Double-liner system with bottom composite liner



(f) Double composite liner system

LCS=leachate collection system, GCL= geo-synthetic clay liner, LDS=leachate detection system

Lining systems - Requirements on a HDPE geomembrane

Description*	Standard*	Unit	Value
Raw material	-	-	HDPE**
Thickness	SR EN 964-1:1999 SR EN ISO 9863-2:1996 prEN 1849-2	mm	min. 2.0
Density	STAS 5886-68 ISO R 1183 prEN 1849-2	g/cm ³	min. 0.95
Surface structure Slopes Base	textured/textured smooth		
Tensile strength at yield	EN ISO 527-3	N/mm	min. 30
Elongation at yield	EN ISO 527-3	%	max. 12
Tensile strength at break	EN ISO 527-3	N/mm	min. 32
Elongation at break	EN ISO 527-3	%	max. 300
Tear resistance	ISO 34	N	min. 280
Puncture resistance	EN ISO 12236	N	min. 700
Carbon black content	ASTM D 1603	%	min. 2

Lining systems - HDPE geomembrane placement



Lining systems - Requirements on CCL

Parameter	
Thickness	0,50 m
Permeability	$\leq 5 \times 10^{-10} \text{ m/s}$
Fines (grain size < 0,002 mm)	$\geq 20 \%$ by weight
Content of clay minerals	$\geq 10 \%$ by weight
Maximum grain size	$\leq 20 \text{ mm}$
Lime content (CaCO_3)	$\leq 15 \%$ by weight
Content of organic substances	$\leq 5 \%$ by weight
Water content (w)	$W_{pr} \leq w \leq w_{0,95}$
Density	$\geq 95 \%$ of Proctor density

w_{pr} = Water content at optimum Proctor density

$w_{0,95}$ = Water content at 95 % Proctor density (wet side of the Proctor curve)

Lining systems – CCL placement



Lining systems – Asphalt concrete

Properties	Asphalt liners construction
<ul style="list-style-type: none">• flexible• resistant against a lot of media• environmentally sound• wear resistant• water tight (impermeable)	<ul style="list-style-type: none">• up to a slope of 1 : 4 asphalt liners → with usual road finishers• up to a slope of 1 : 2.5 asphalt liners → with adapted road finishers• for steeper slopes special equipment is necessary (up to 1 : 1.5 is possible)

Lining systems – Asphalt concrete placement



Lining systems – Asphalt concrete

- Minimum 2 asphalt layers (1 bearing layer and 1 asphalt liner), a bitumen membrane can be used to reach 100 % impermeability
- Special care has to be taken at the seems
- Special care has to be taken at pipe penetration structures, pipe bedding etc.
- A bearing layer (base course) beneath asphalt layers is helpful.
- Building asphalt layers on a mineral liner (CCL) is very difficult
- Quality assurance is essential

Lining systems – Protection layer

- The type of the protection layer depends on the load and the grain size of the drainage layer
- **Geotextiles** and/or **sand** layers can be used as protection layers
- **Geotextiles** must have a specific weight of minimum 2000 g/m²
- **Sand layer** must have a minimum thickness of 10 cm
- The best solution is to install first a **geotextile** (of about 600 g/m²) and then to install a **sand layer** of minimum 10 cm thickness