Atelier Rabat 2012

Atelier de Réflexion sur "Assurance Qualité"

Quality Management of Landfill Construction

Part 1: QM-Principles and Liner Systems

Prof. Dr.-Ing. Hans-Günter Ramke

on behalf of

GIZ PGPE Maroc

Quality Management of Landfills

Overview

- Principles of Landfill Technology
- Principles of Quality Management
- Bottom Liner Systems
- Leachate Collection Systems
- Surface Sealing Systems

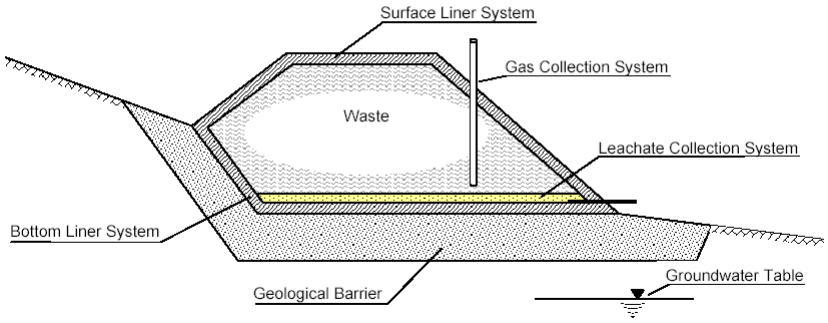
Principles of Landfill Technology
Emissions of Landfills

- Emissions
  - leachate
  - landfill gas
  - surface run-off
  - noise, odour, litter and dust
  - birds, vermin and insects
- caused by
  - landfill operation
  - climate
  - degradation processes

Principles of Landfill Technology
Typical Environmental Problems

- Typical Problems
  - life threats for „waste pickers“ and their families
  - health risks for people in the neighbourhood
  - air pollution caused by burning waste
  - greenhouse effects of landfill gas
  - soil contamination
  - pollution of surface water and groundwater
  - rapid reproduction and spreading of vermin

Principles of Landfill Technology
Multiple-Barrier Concept - Scheme



Principles of Landfill Technology
Multiple-Barrier Concept - Explanation

- Independent Barriers of a Landfill
  - the site (the geological barrier)
  - the bottom liner system
  - the landfill body (waste)
  - the surface liner system
  - the landfill operation
  - the treatment of leachate and landfill gas
  - the controlled post-closure use of landfill area
  - the long-term monitoring

Principles of Landfill Technology
Landfill Categories - According to UNEP

- "Open Dump"
  - without technical installations
  - without any real operation
- "Controlled Dump"
  - suitable site
  - minimum construction standard
  - daily cover, site "management"
- "Sanitary Landfill"
  - collection of emissions
  - treatment of emissions
  - compaction of waste
  - controlling and monitoring

Principles of Landfill Technology
Necessary Regulations

- Definition of wastes allowed to be disposed of
  (characterization of categories of waste)
- Geological and environmental requirements
  (site selection, geological barrier)
- Technical requirements
  (bottom barrier, leachate and gas collection, surface liner)
- Requirements on landfill operation
  (leachate and gas treatment, dumping techniques, monitoring)

Principles of Landfill Technology
Classes of Landfills - Overview

Classes of Landfills - EU-Directive and German Standards

Class	Types of Waste	EU	Germany
0	soil	-	x
I	inert waste	x	x
II	non-hazardous waste	x	x
III	hazardous waste – surface	x	x

Principles of Landfill Technology
Classes of Landfills - According to EU-Directive

- Class I
  - landfill for inert waste
  - like soil and construction debris
- Class II
  - landfill for municipal waste
  - household waste
  - waste from public areas etc.
  - immobilised hazardous waste
- Class III
  - landfill for hazardous waste
  - hazardous wastes with low solubility

Principles of Landfill Technology
Classes of Landfills - Requirements on Waste

- Regulations of the European Union
  - Council Directive "Landfill of Waste"
  - Council Decision "Establishing Criteria and Procedures for the Acceptance of Waste"
- Requirements for Landfill Classes I, II and III
  - basic characterisation and compliance testing
  - leaching limit values (elution or percolation)
  - limit values for total contents in solid matter

Principles of Landfill Technology
Structure of Legal Standards

- Laws on Waste Management
  - general principles
  - responsibilities
  - legal base for directives
- Directives
  - standards for landfills and other facilities
  - permitting and licensing procedures
  - requirements on particular types of waste

Principles of Landfill Technology
Development of National Standards - Part 1

- Criteria for Suitable Standards
  - ecological effectiveness
  - economical resources
  - regional experience in construction
  - availability of construction materials
  - hydrological and climatic conditions

Principles of Landfill Technology
Development of National Standards - Part 2

- Typical Mistakes in Development of Standards
  - requirements economically not realisable
  - requirements technically not realisable
  - requirements organisationally not realisable
- Necessary Regional Differentiation
  - hydrological and climatic conditions
  - conditions of waste management
  - economical conditions

Principles of Landfill Technology
Development of National Standards - Part 3

Map of Morocco - Marking of different regions

(Source: Spiegel Online, Länderlexikon, 27.02.07)

Principles of Landfill Technology
Conclusions

- Landfilling is a basic element of waste management
- Dumping causes serious environmental damages
- Landfilling means control of wastes and emissions
- Landfills follow the multiple barrier concept
- Technical requirements depend on waste properties
- National standards must consider local situation

Principles of Quality Management
Elements of Quality Management

- Elements according to ISO 9000:2000
  - quality planning
  - quality control
  - quality assurance
  - quality improvement

(Source Principles of QM: Gartung, 2008)

Principles of Quality Management
Quality Management on Landfills

- Landfill related elements of QM
  - planning and design
  - manufacturing of construction products
  - workmanship in assembling and implementing construction materials and construction products for the generation of structural components
  - inspection and approval

Principles of Quality Management
Definitions - Part 1

- Quality Planning
  - Quality planning as part of quality management is directed towards the specification of quality goals and the necessary production processes as well as the pertinent resources to meet the quality goals.
  - Quality planning has to be carried out as early as possible.
  - The preparation of quality management plans (formerly quality assurance plans) including specification of quality require-ments (minimum requirements) is part of quality planning.

Principles of Quality Management
Definitions - Part 2

- Quality Control
  - Quality control as part of quality management is directed towards fulfillment of quality requirements (meeting minimum requirements).
  - Quality control encloses preventive and corrective measures which serve the purpose of using only suitable construction materials and products and to assure their correct handling and implementation.
  - Quality control assists the contractor to conform with project plans and specifications.
  - Quality control comprises construction quality control (CQC) and manufacturing quality control (MQC).

Principles of Quality Management
Definitions - Part 3

- Quality Assurance
  - Quality assurance as part of quality management is directed towards elimination of mistakes in planning and towards minimization of the probability of material- and workmanship faults by intense quality assurance measures and testing.
  - Quality assurance has to warrant the required quality, to provide assurance that the facility was constructed in accordance with the contract and technical specifications.
  - Quality assurance comprises construction quality assurance (CQA) and manufacturing quality assurance (MQA).

Principles of Quality Management
Definitions - Part 4

- Quality Assurance Measures
  - reviewing implementation plans (drawings and design computations)
  - suitability testing of construction materials and products
  - in-house supervision of production
  - third party supervision of production
  - in-house quality testing of construction execution
  - third party quality testing of construction execution
  - supervision by regulatory authority

Principles of Quality Management
Definitions - Part 5

- Quality Improvement
  - Quality improvement as part of quality management is directed towards augmentation of the capabilities to fulfill the quality requirements.

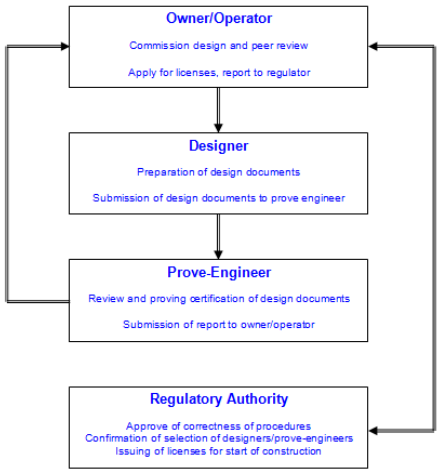
Principles of Quality Management
Quality Management Plan - Part 1

- Elements of QM-Plans for Construction Works - 1
  - type and extent of quality assurance during manufacture of construction products at least by in-house and external supervision
  - if appropriate with reference of pertinent regulations or approval documents
  - responsibilities and tasks of the construction supervisors (in-house and external testing party)
  - description of the lining system stating the process to be inspected

Principles of Quality Management
Quality Management Plan - Part 2

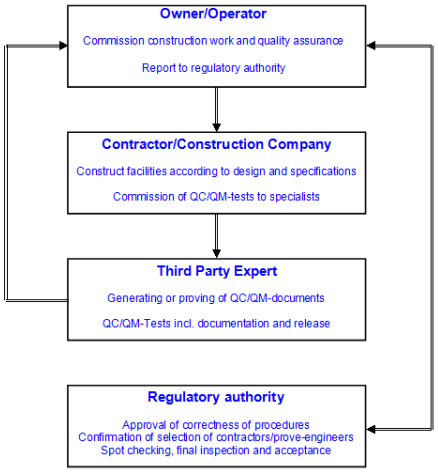
- Elements of QM-Plans for Construction Works - 2
  - specification of quality requirements (minimum standards)
  - type and number of quality tests to be undertaken
    - on the construction materials and products (initial test)
    - on their processing (processing test) and
    - on the completed component (commissioning test)
  - documentation of production and quality assurance of the components

Principles of Quality Management
Tasks and Responsibilities - Part 1



Tasks and Responsibilities in the Design Phase

Principles of Quality Management
Tasks and Responsibilities - Part 2



Tasks and Responsibilities in the Construction Phase

Bottom Liner Systems
Overview

- General Requirements on Bottom Liners
  - prevention of leachate percolation into the sub-soil
  - long-term biological, chemical and physical resistance
- Sealing Elements
  - a mineral liner
  - a geomembrane
  - a geosynthetic clay liner
  - a composite liner
  - an asphalt liner
  - cohesive soil
  - PE-HD
  - bentonite mate
  - combination of two elements
  - bearing layer and liner

Bottom Liner Systems
Requirements of the EU - Part 1

- Landfill Class I
  - no artificial sealing liner required
- Landfill Class II
  - artificial sealing liner required
- Landfill Class III
  - artificial sealing liner required

→Details can be defined by the Member States.

Bottom Liner Systems
Requirements of the EU - Part 2

EU Requirements on Bottom Liner Systems

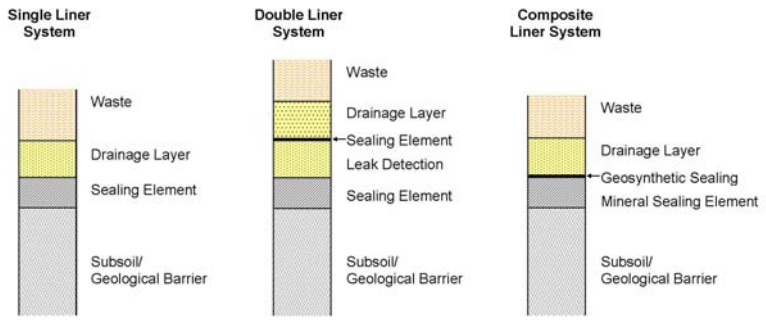
Landfill Category		I	II	III
Type of Waste	no particular landfill category for soil	Inert Waste	Non-hazardous Waste	Hazardous Waste
System		-	Single Liner	Composite Liner
Geological Barrier		$k \leq 1 \cdot 10^{-7}$ m/s $d \geq 1{,}0$ m	$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 1{,}0$ m	$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 5{,}0$ m
Artificial Sealing Liner		-	required	
Drainage Layer		-	required $d \geq 0{,}5$ m	

Bottom Liner Systems
Requirements in Germany

German Requirements on Bottom Liner Systems

Landfill Category	DK 0	DK I	DK II	DK III
Type of Waste	Soil	Demolition Waste	Municipal Waste	Hazardous Waste
System	Suitable Site	Single Liner	Composite Liner	Composite Liner
Geological Barrier	$k \leq 1 \cdot 10^{-7}$ m/s $d \geq 1{,}0$ m	$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 1{,}0$ m		$k \leq 1 \cdot 10^{-9}$ m/s $d \geq 5{,}0$ m
Mineral Liner	-	-	$d \geq 0{,}5$ m $k \leq 5 \cdot 10^{-10}$ m/s	$d \geq 0{,}5$ m $k \leq 5 \cdot 10^{-10}$ m/s
Geomembrane	-	(PE-HD) $d \geq 2{,}5$ mm		
Protective Layer	-	necessary		
Drainage Layer	$d \geq 0{,}3$ m $k \geq 1 \cdot 10^{-3}$ m/s	$d \geq 0{,}5$ m (0,3 m) $k \geq 1 \cdot 10^{-3}$ m/s		

Bottom Liner Systems
Types of Bottom Liner Systems - 1



General Principles of Bottom Liner Systems

Bottom Liner Systems

Types of Bottom Liner Systems - 2

- Single Liner Systems

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

  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 non-hazardous wastes.

Bottom Liner Systems

Types of Bottom Liner Systems - 3

- Composite Liners

  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 non-hazardous waste (domestic solid waste) and also for bottom barriers of landfills for hazardous waste.

Bottom Liner Systems

Types of Bottom Liner Systems - 4

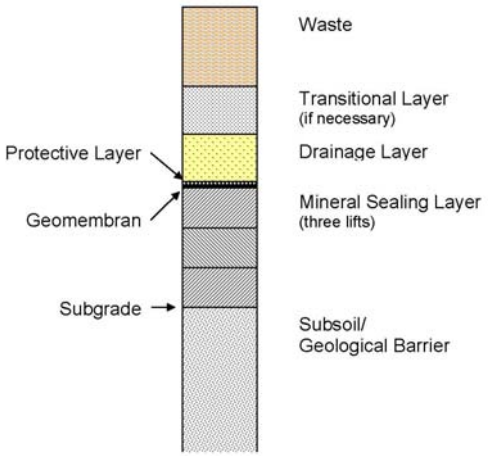
- Double Liner Systems

  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 blanket is installed to serve as leak detection system 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), actions must be taken.

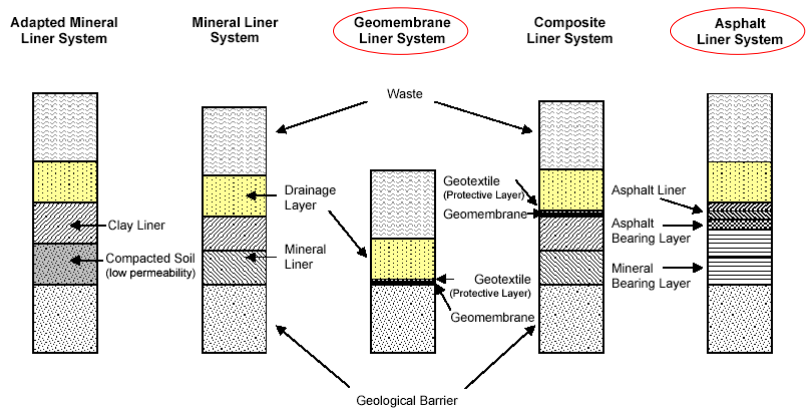
Bottom Liner Systems

Bottom Liner Components



Scheme of a Composite Bottom Liner System

Bottom Liner Systems
Sealing Materials



Bottom Liner Systems (Cross Section)

(Source: Ramke, 2001)

Bottom Liner Systems
Case Study

Comparison of Two Scenarios of Selection of Liner Systems

	Scenario1	Scenario 2
Type of Waste	municipal	municipal and industrial
Quantity of Waste	low	high
Leachate Quantity	low	high
Leachate Composition	low concentrations	highly loaded, polluted
Geological Barrier	good up to nearly perfect	
Groundwater Layer	unimportant or of minor importance	
Bottom Liner	re-compacted cohesive soil	engineered bottom liner

Bottom Liner Systems

Comparison of Systems - Technical Assessment

Suitability of Bottom Liner Systems in the Middle East

Alternative/ Criteria	Hydraulic Permeability	Long-term Behavior	Complexity of Con-struction	Availability of Raw Material	Local Experience in Con-struction	Costs
Improved Profiling of Subsoil	--	--	0	++	++	++
Adapted Mineral Liner System	0/-	0	-	++	+	++
Mineral Liner System	0	0	-	+	0	0
Geomem-brane Liner System (HDPE)	++	++	0	-	0	+
Geo-synthetic Clay Liner	++	0	+	-	0	0
Asphalt Liner System	++	++	+	++	+	-

Bottom Liner Systems

Quality Control of Mineral Liners

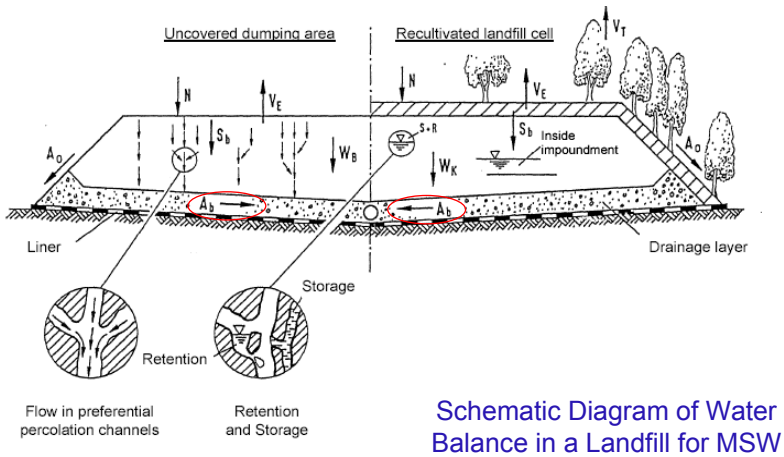
Suitability Testing and Construction Control

Parameter	Suitability Test	Field Test	Control of Construction	Grid/ Testing Area
Geotechnical Classification				
Grain Size Distribution	x	x	x	per 4000 m²
Content of Clay Minerals	x	x		
Water Content	x	x	x	per 1000 m²
Atterberg Limits	x	x		
Content of Organics	x	x		
Content of Limestone	x	x		
Construction Criteria				
Visual Control		X	x	total
Water Intake Capacity	x	x		
Proctor Density	x	x	x	per 4000 m²
Density		X	x	per 1000 m²
Stress -Deformation-Behavior				
Module of Elasticity	x	x		
Shear Strength	x	x		
Test of Hydraulic Conductivity				
Coefficient of Hydraulic Conductivity	x	x	x	per 1000 m²

Leachate Collection Systems
Importance

- Importance
  - leachate is the main emission of the landfill
  - groundwater and surface water could be polluted by leachate
  - lining of landfills means leachate collection and management
  - knowledge of leachate quantity and quality is precondition for design of leachate management

Leachate Collection Systems
Leachate Generation - Part 1



Schematic Diagram of Water Balance in a Landfill for MSW

Leachate Collection Systems
Leachate Generation - Part 2

- Water Balance
  - Water Balance Equation

$$N - ET_a - S \pm R - A_B - A_O \pm W_B + W_K = 0$$

N = precipitation
ET_a = actual evapotranspiration
S = (permanent) storage
R = (temporary) retention
A_B = leachate discharge at landfill bottom
A_O = surface runoff
W_B = water generation or consumption by biological degradation
W_K = water generation caused by consolidation processes

Leachate Collection Systems
Leachate Generation - Part 3

- Influences in the Water Balance
  - Climatic water balance
    (precipitation – actual evapotranspiration)

    The positive climatic water balance – higher precipitation than evapo-trans-piration – is the dominant factor for leachate generation in humid climates, other factors are of less importance.

  - Moisture of waste (consolidation processes)

    Moisture of waste as main source of leachate becomes of importance in arid climates. Here very often moisture of waste is very high, and the climatic water balance is negative. Most of the leachate gene-rated or collected at the bottom can be attributed to consolidation processes, pressing the moisture out of the waste.

Leachate Collection Systems
Requirements and Risks

- General Requirements on LCS
  - to collect leachate
  - to discharge it at defined points out of the dumping area
  - to avoid leachate accumulation at the bottom of the landfill
- Risks for Leachate Collection Systems
  - clogging of drainage material and pipes
  - deformation of PE-HD pipes
  - crushing of shafts or manholes

Leachate Collection Systems
Clogging Processes - Part 1

Landfill Geldern-Pont - Overview of the excavated drainage layer

Leachate Collection Systems
Clogging Processes - Part 2

Landfill
Geldern-Pont
- Detail of drainage material around the drain pipe

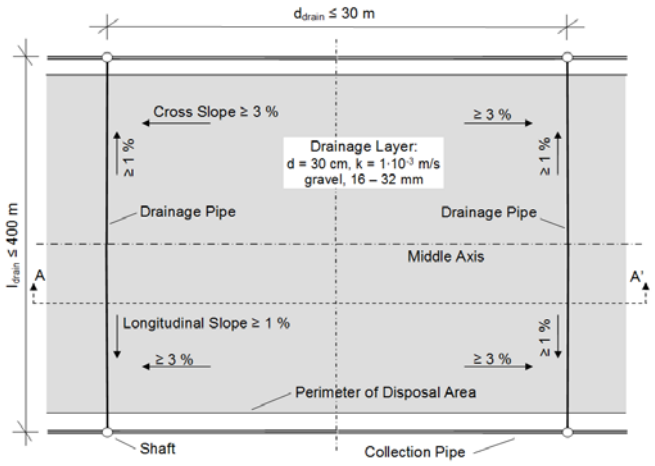
Leachate Collection Systems
Clogging Processes - Part 3

Landfill
Altwarmbüchen
– Fresh Flushing Material

Leachate Collection Systems
Standard Design - Part 1

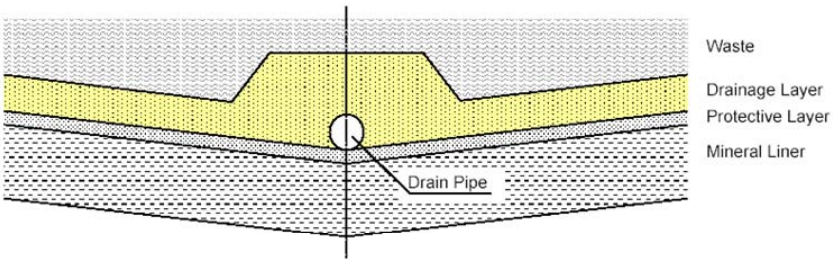
- Profile and Geometry
  - drainage pipes rectilinear to landfill edges
  - shafts placed outside the landfill body
  - no pipe joints
  - minimum slopes be kept after settlements
- Drainage Layer
  - coarse drainage material 16 – 32 mm
  - no limestone, solid material with round surface

Leachate Collection Systems
Standard Design - Part 2



Leachate collection system

Leachate Collection Systems
Standard Design - Part 3



Cross Section of a Standard Leachate Collection System

Leachate Collection Systems
Standard Design - Part 4

- Requirements of the EU
  - Landfill Class I
    - no requirements defined by the EU
    - Member States can define specific requirements
  - Landfill Class II and III
    - leachate collection system required
    - drainage layer ≥ 0,5 m
    - specifications can be made by the Member States

Leachate Collection Systems
Standard Design - Part 5

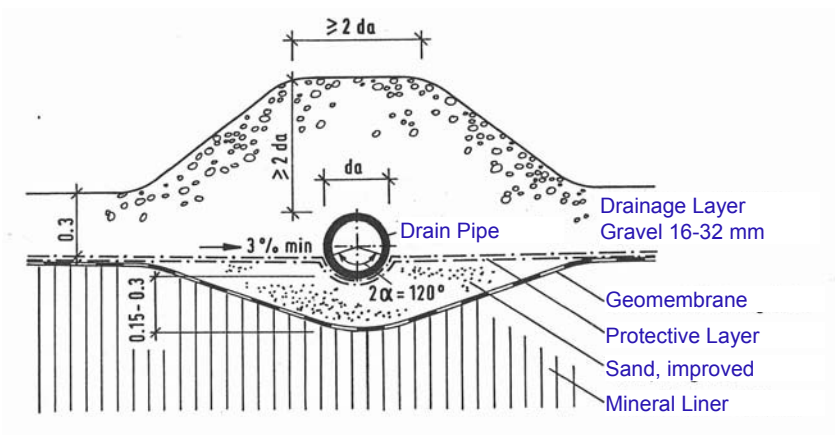
German Requirements on Leachate Collection Systems

Class	0	I	II	III
Drainage Material	gravel 16/32 mm; $k \geq 1 \cdot 10^{-3}$			
Drainage Layer	height ≥ 30 cm			
Drain Pipes	PF-HD; DN 250			
Slopes	$i_{cross} \geq 3$ %; $i_{long} \geq 1$ %			
Drain Pipes Spacing	≤ 30 m			

Leachate Collection Systems
Standard Design - Part 6

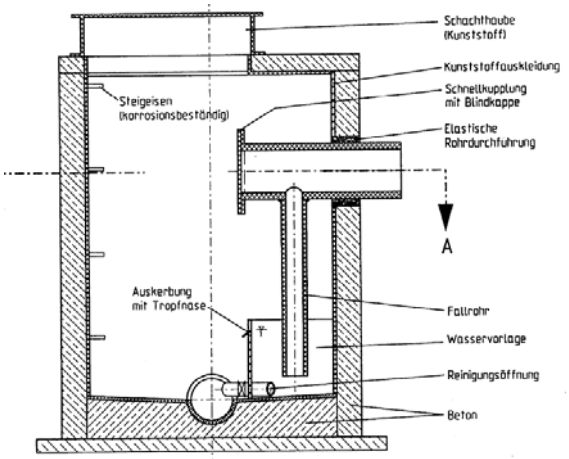
- Drainage Pipes
  - inner diameter ≥ 250 mm, PE-HD
  - necessary for inspection, maintenance and cleaning
  - slots with a diameter ≥ 12 mm
  - no vertical penetration
- Shafts
  - diameter ≥ 1.5 m, manhole ≥ 1.0 m
  - outlets of drainage pipes: prevention of intrusion of air
  - material resistant against landfill gas and leachate

Leachate Collection Systems
Standard Design - Part 7



Example for the bedding of drainage pipes in the liner system

Leachate Collection Systems
Standard Design - Part 8



Example for an inspection and cleaning shaft

Leachate Collection Systems
Standard Design - Part 9

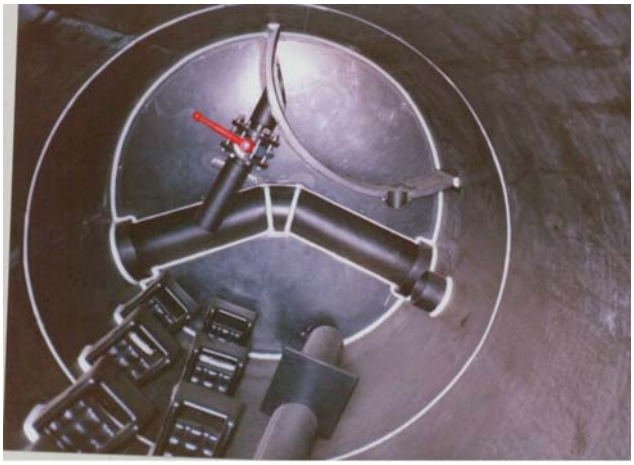


Photo of an inspection and cleaning shaft according to the example

Surface Sealing Systems
Introduction

- Tasks of a Surface Cover System
  - isolation of the wastes from environment at the surface
  - provision of long-term minimisation of leachate production
  - control of venting of landfill gas
- Components of a Surface Cover System
  - bearing layer and/or gas drainage layer
  - sealing layer (mineral liner and/or geomembrane)
  - drainage layer
  - top soil cover (vegetation layer) and vegetation)

Surface Sealing Systems
EU Requirements

Directive on Landfills - Requirements on Surface Sealing Systems

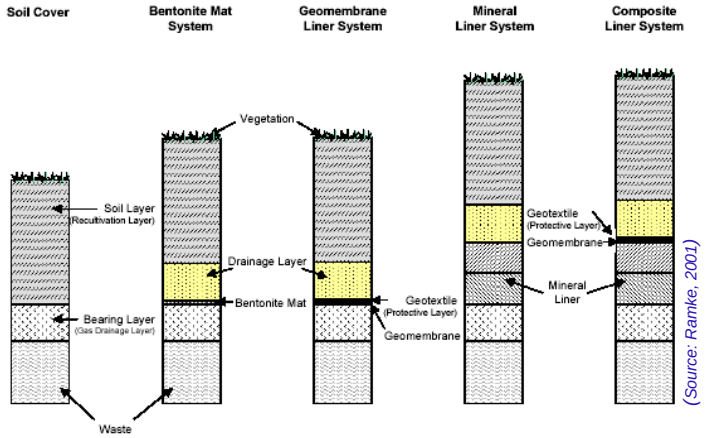
Class	I	II	III
Vegetation Layer	no requirements specified	thickness ≥ 1.0 m	
Drainage Layer		thickness ≥ 0.5 m	
Mineral Liner		required	
Geomembrane		not required	required
Gas Drainage Layer		required	not required

Surface Sealing Systems
German Requirements until 2009

Directive on Landfills - Requirements on Surface Sealing Systems

Class	0	I	II	III
Vegetation Layer	thickness ≥ 1 m; limitation of contaminants			
Drainage Layer	-	thickness ≥ 0.3 m; $k \geq 1 \cdot 10^{-3}$		
Mineral Liner	-	$d \geq 0.5$ m; $k \leq 5 \cdot 10^{-9}$		$d \geq 0.5$ m; $k \leq 5 \cdot 10^{-10}$
Geomembrane	-	-	thickness 2.5 mm; PE-HD	
Bearing Layer	-	thickness ≥ 0.5 m; non-cohesive		

Surface Sealing Systems
Overview of Alternatives



Surface Cover and Liner Systems (Cross Section)

Surface Sealing Systems
Construction - 1

Construction of a Capillary Barrier

Surface Sealing Systems
Construction - 2

Construction of a Drainage Layer

Surface Sealing Systems
Local Characteristics - 1

- Criteria for System Selection
  - risk potential of the landfill
  - availability of liner and drainage soils
  - local experience in construction
- Important Local Characteristics
  - general climatic conditions - arid or humid
  - distribution of precipitation - dry weather periods
  - risk of surface runoff, local vegetation

Surface Sealing Systems
Local Characteristics - 2

Erosion Channels at a Landfill Site in the Middle East

Surface Sealing Systems
Local Characteristics - 3

Local Vege-tation at an Arid Landfill Site

References
Regulations

Council Directive 1999/31/EC on the Landfill of Waste
26 April 1999

Council Decision establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC
(2003/33/EC), 29 December 2002

German Directive on the Landfill of Waste
(Verordnung über Deponien und Langzeitlager)
April 27, 2009, BGBl I 2009, 900

References
Books and Papers - Part 1

Gartung, E.; 2008: Principles of Quality Management in Landfill Design and Construction
in: Technical Committee Landfill Technology (ed.), 2008: Toolkit Landfill Technology, Chapter 1.8
internet publication from the German Geotechnical Society (DGGT), www.landfill-technology.info

Ramke, H.-G., 2001: Appropriate Design and Operation of Sanitary Landfills
in: Sustainable Economic Development and Sound Resource Management in Central Asia, Proceedings of an International Conference, planned October 2001
Tashkent State University, Tashkent, Uzbekistan and Nottingham Trent University, Nottingham, United Kingdom

References
Books and Papers - Part 2

Ramke, H.-G., 2005: Particular Requirements on Landfill Technology under Arid Climatic Conditions in Developing Countries and Countries in Transition - Experiences of the Design of a New Landfill for Tehran
in: Klappperich, H.; Katzenbach, R.; Witt, K. J. (Hrsg.), 2005: 2. Symposium Umweltgeotechnik, CiF e.V. publication 3, Freiberg

Ramke, H.-G., 2009: Leachate Collection Systems in Bottom Liner Systems
in: Sardinia 2009: Twelfth International Waste Management and Landfill Symposium, Sardinia, Italy, October 05 – 09, 2009

References
Books and Papers - Part 3

UNEP/IETC, 1996: International Source Book on Environmentally Sound Technologies for Municipal Solid Waste Management
UNEP International Environmental Technology Centre (IETC)
Technical Publications Series, Issue 6

Addresses

Professor Dr.-Ing. Hans-Guenter Ramke

Publicly Certified Expert on Waste Management and Landfill Technology
certified by the Chamber of Engineers of Lower Saxony, Germany
Ludwig-Beck-Strasse 1, 38116 Braunschweig, Germany
Phone: ++49/531/5160917; Fax: ++49/531/5160918
E-mail: hg.ramke@gmx.de

University of Applied Sciences Ostwestfalen-Lippe
Campus Hoexter
Department of Environmental Engineering and Applied Informatics
Professorship of Waste Management and Sanitary Landfilling
An der Wilhelmshoehe 44, 37671 Hoexter, Germany
Phone: ++49/5271/687-130; Fax: ++49/5271/687-130
E-mail: hans-guenter.ramke@fh-luh.de