Solid Waste Management SS 2012

Exercise 2

Conception of a Landfill

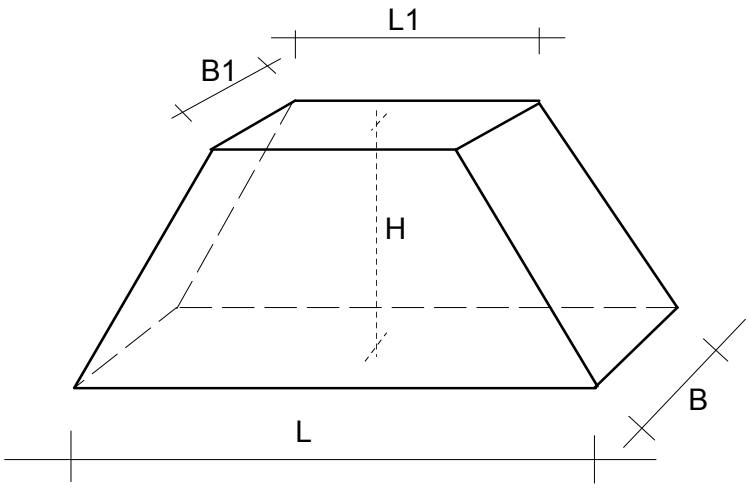
Task 1: Basic Data

Basic Data				
Inhabitants	600,000			
	waste requiring treatment			**waste not requiring treatment**
	domestic and bulky waste	domestic waste-like commercial waste	production specific waste	
specific waste potential [kg/(Inh*a)]	300	125	150	20 % of waste requiring treatment
waste amount [Mg/a]				
material utilization [%]	50	40	50	50
waste amount material utilization [Mg/a]				
residual waste = MBT input [Mg/a]				
MBT output to landfill [%]	30	30	30	0
landfill input [Mg/a]				
landfill input [kg/(Inh*a)]				
annual increase [%]	0.5	0.5	-1.0	-1.0

Task 1: Basic Data

Basic Data				
Inhabitants	600,000			
	waste requiring treatment			waste not requiring treatment
	domestic and bulky waste	domestic waste-like commercial waste	production specific waste	
specific waste potential [kg/(Inh*a)]	300	125	150	20 % of waste requiring treatment
waste amount [Mg/a]	180,000	75,000	90,000	69,000
material utilization [%]	50	40	50	50
waste amount material utilization [Mg/a]	90,000	30,000	45,000	34,500
residual waste = MBT input [Mg/a]	90,000	45,000	45,000	0
MBT output to landfill [%]	30	30	30	0
landfill input [Mg/a]	27,000	13,500	13,500	34,500
landfill input [kg/(Inh*a)]	45	22.5	22.5	57.5
annual increase [%]	0.5	0.5	-1.0	-1.0

Task 2: Landfill Dimensioning



$$V_0 = \frac{1}{6} \cdot [(2 \cdot L + L_1) \cdot B + (2 \cdot L_1 + L) \cdot B] \cdot H$$

Task 2: Landfill Dimensioning

Landfill Dimensioning		
length L	m	600
width B	m	300
height H	m	30
general inclination	-	1:4
filling density $\rho_{MBT\text{-}Output}$ $\rho_{n,\ treated\ raw\ waste}$	Mg/m³ Mg/m³	1.5 1.8
construction waste ratio	Vol.-%	15
subtraction for ogees and offsets	Vol.-%	10
maximum size of a landfill section	ha	3.6
L_1	m	
B_1	m	
V_o	m³	
minus offsets $V_1 = V_{landfill}$	m³	
minus construction waste ratio V_2	m³	

Task 2: Landfill Dimensioning

Landfill Dimensioning		
length L	m	600
width B	m	300
height H	m	30
general inclination	-	1:4
filling density $\rho_{MBT\text{-}Output}$ $\rho_{n,\ treated\ raw\ waste}$	Mg/m³ Mg/m³	1.5 1.8
construction waste ratio	Vol.-%	15
subtraction for ogees and offsets	Vol.-%	10
maximum size of a landfill section	ha	3.6
L_1	m	360
B_1	m	60
V_o	m³	2,736,000
minus offsets $V_1 = V_{landfill}$	m³	2,462,400
minus construction waste ratio V_2	m³	2,093,040

Task 2: Landfill Dimensioning

Operating Time of the Landfill

deposited waste in 1st year: $G_1 = \sum_{n=1}[G_{n,i}] \cdot Inh = \sum G_{1,i} \cdot Inh$

Waste Amount in the 1st year		
G1,1 – domestic/bulky waste	Mg/a	27,000
G1,2 – commercial waste	Mg/a	13,500
G1,3 – production specific waste	Mg/a	13,500
G1,4 – not treated waste	Mg/a	34,500

Task 2: Landfill Dimensioning

Operating Time of the Landfill

	waste requiring treatment			waste not requiring treatment
	domestic and bulky waste	domestic waste-like commercial waste	production specific waste	
waste amount				
1st year [kg/(Inh*a)]				
1st year [Mg/a]				
last year [kg/(Inh*a)]				
last year [kg/(Inh*a)]				
operating time				
deposited waste in nth year G_n				
deposited waste total G_{total}				

Task 2: Landfill Dimensioning

Operating Time of the Landfill

	waste requiring treatment			waste not requiring treatment
	domestic and bulky waste	domestic waste-like commercial waste	production specific waste	
waste amount				
1st year [kg/(Inh*a)]	45	22.5	22.5	57.5
1st year [Mg/a]	27,000	13,500	13,500	34,500
last year [kg/(Inh*a)]				
last year [kg/(Inh*a)]				
operating time				
deposited waste in n^{th} year G_n				
deposited waste total G_{total}				

Task 2: Landfill Dimensioning

Operating Time of the Landfill

deposited waste in n^{th} year:

$$G_n = \sum_{n=1}\left[G_{1,i} \cdot \left(1 + \frac{p_i}{100}\right)^{n-1}\right] \cdot Inh$$

approximate total amount in n years:

$$G_{total} = \frac{G_1 + G_n}{2} \cdot n = V_2 \cdot \rho$$

Rearrangig for n and solving iteratively. Start with n = 30 a.

$$n = \frac{2 \cdot V_2 \cdot \rho}{G_1 + G_n}$$

Averaged density:

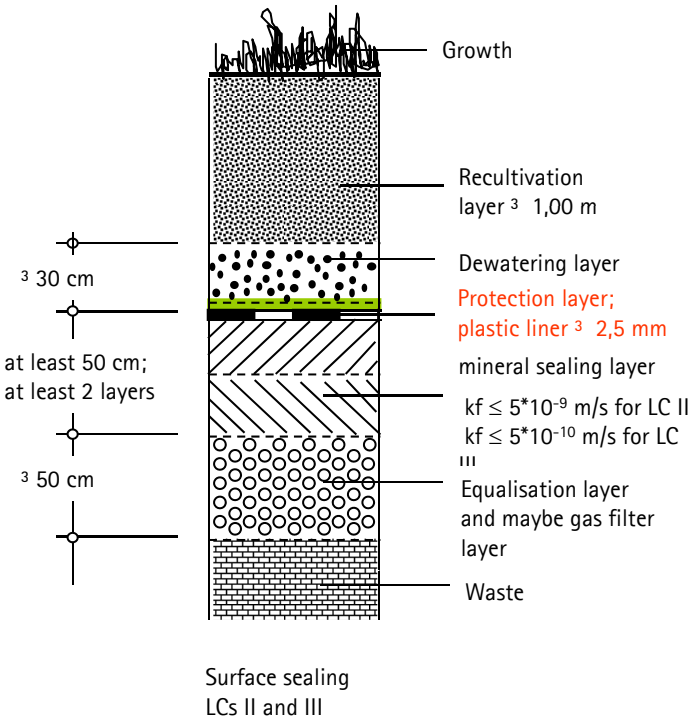
$$\rho = 1.5\ \frac{Mg}{m^3} \cdot \frac{54{,}000}{88{,}500} + 1.8\ \frac{Mg}{m^3} \cdot \frac{34{,}500}{88{,}500} = 1.62\ Mg/m^3$$

Task 2: Landfill Dimensioning

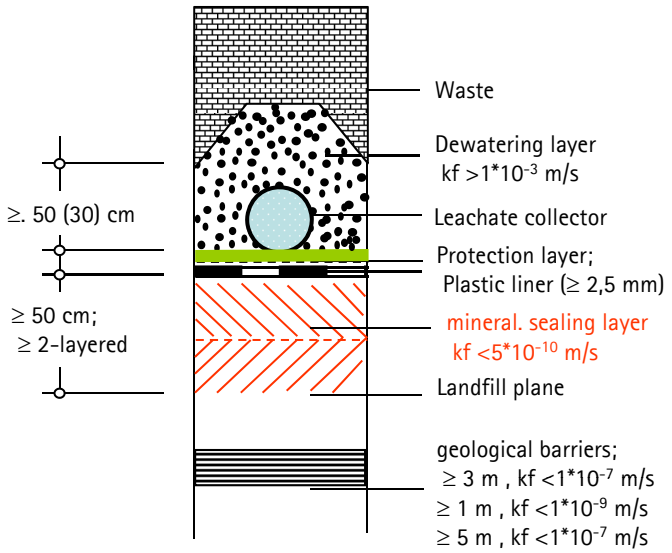
Operating Time of the Landfill

	waste requiring treatment			waste not requiring treatment
	domestic and bulky waste	domestic waste-like commercial waste	production specific waste	
waste amount				
1st year [kg/(Inh*a)]	45	22.5	22.5	57.5
1st year [Mg/a]	27,000	13,500	13,500	34,500
last year [kg/(Inh*a)]	54.5	27.25	15.3	39.09
last year [kg/(Inh*a)]	32,698.33	16,349.16	9,178.16	23,455.29
operating time		a		39,39
deposited waste in n^{th} year G_n		Mg/a		81,680.94
deposited waste total G_{total}		Mg		3,351,975.33

Info: Surface and Bottom Sealing



Surface sealing
LCs II and III



Bottom sealing
Landfill Categories II and III

Task 3: Landfill Gas Calculation

Landfill Gas Calculation

	waste requiring treatment			waste not requiring treatment
	domestic and bulky waste	domestic waste-like commercial waste	production specific waste	
waste to be deposited $G_{1,i}$ [Mg/a]				
composition [%]				
spec. C-Content [kg TC / Mg]				

t_h	half-life [a]	10
k	degradation constant $k=\lvert \ln 0.5/t_h \rvert$	0.069
t	time between the calculated begin and the considered year of the gas production [a]	variable
f_{ao}	initial time factor to consider the gas production during the first half year after depositing [-]	0.8
f_a	degradation factor; ratio of TC gasifiable under optimal conditions to total TC [-]	0.7
f_o	optimization factor [-]	0.7
f_s	system-related collection rate [%]	55 %

Task 3: Landfill Gas Calculation

Landfill Gas Production

$$Q_{a,t} = 1.868 \cdot M \cdot TC \cdot f_{ao} \cdot f_a \cdot f_o \cdot f_s \cdot k \cdot e^{-kt}$$

$$M_1 \cdot TC_{1,i} = \sum G_{1,i} \cdot E \cdot spec.TC$$

Task 3: Landfill Gas Calculation

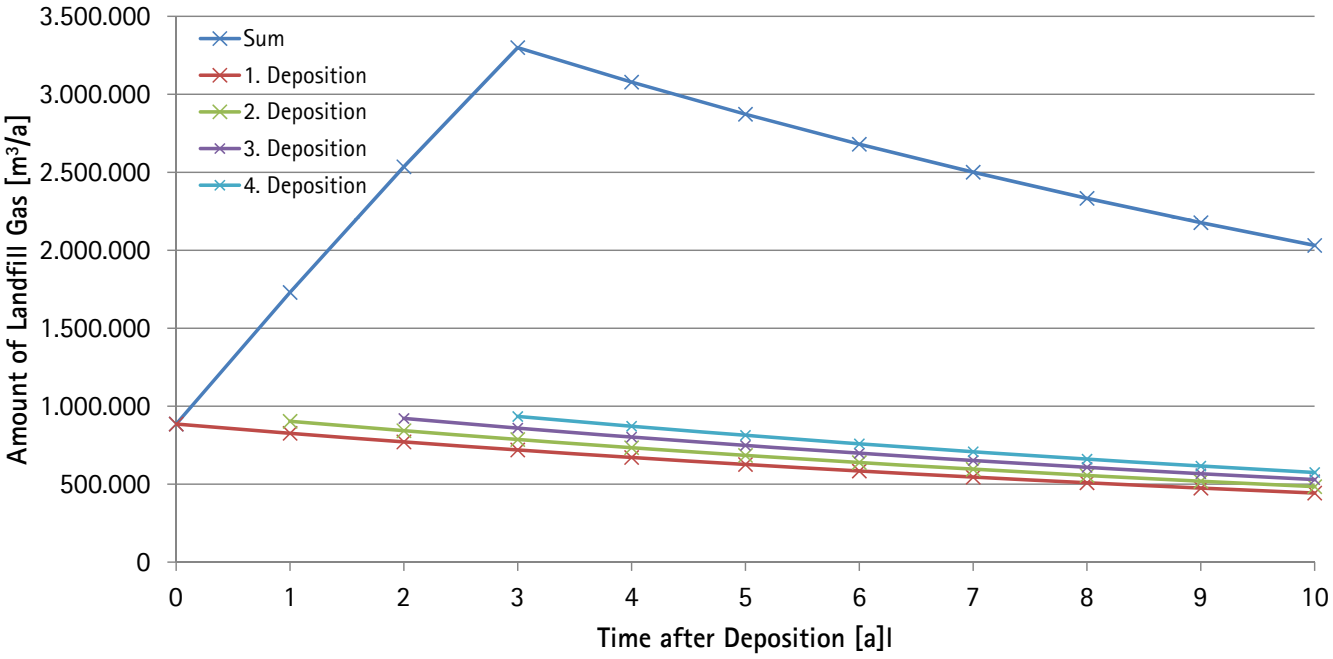
Landfill Gas Production			
annual sum year 1	kg	TC_1	31,725,000
annual sum year 2	kg	TC_2	32,359,500
annual sum year 3	kg	TC_3	33,006,690
annual sum year 4	kg	TC_4	33,463,166

Task 3: Landfill Gas Calculation

Landfill Gas Production					
Time t [a]	Year 1	Year 2	Year 3	Year 4	Σ
0	885.631	-	-	-	885.631
1	826.323	903.343	-	-	1.729.666
2	770.986	842.849	921.410	-	2.535.246
3	719.356	786.406	859.706	934.153	3.299.621
4	671.183	733.743	802.134	871.596	3.078.656
5	626.236	684.606	748.418	813.228	2.872.487
6	584.298	638.760	698.298	758.768	2.680.125
7	545.170	595.984	651.535	707.956	2.500.645
8	508.661	556.073	607.904	660.546	2.333.185
9	474.598	518.835	567.195	616.311	2.176.938
10	442.815	484.090	529.211	575.039	2.031.155

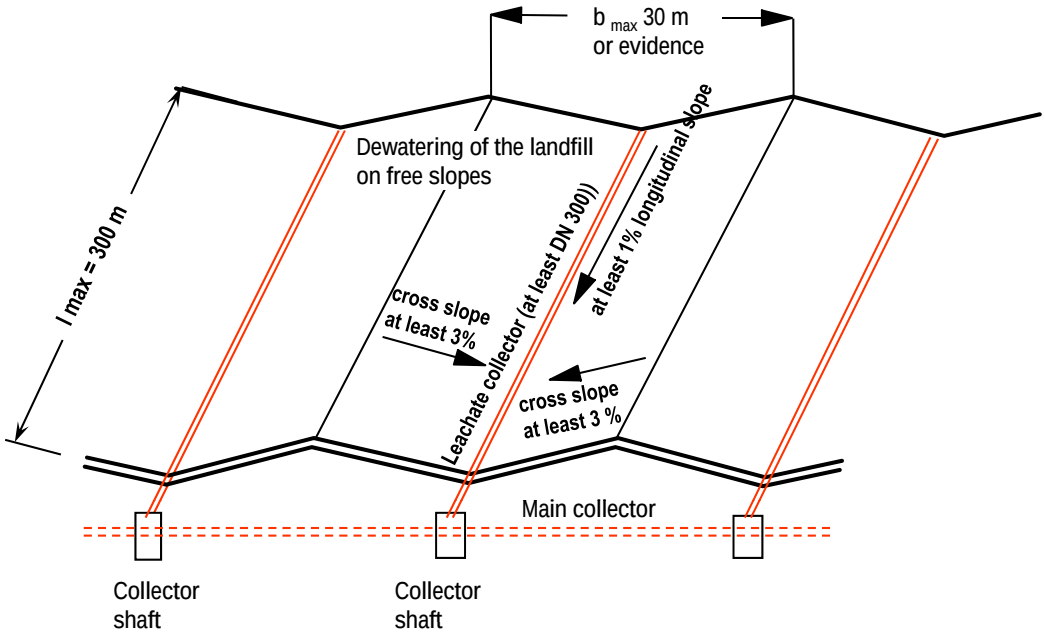
Task 3: Landfill Gas Calculation

Landfill Gas Production

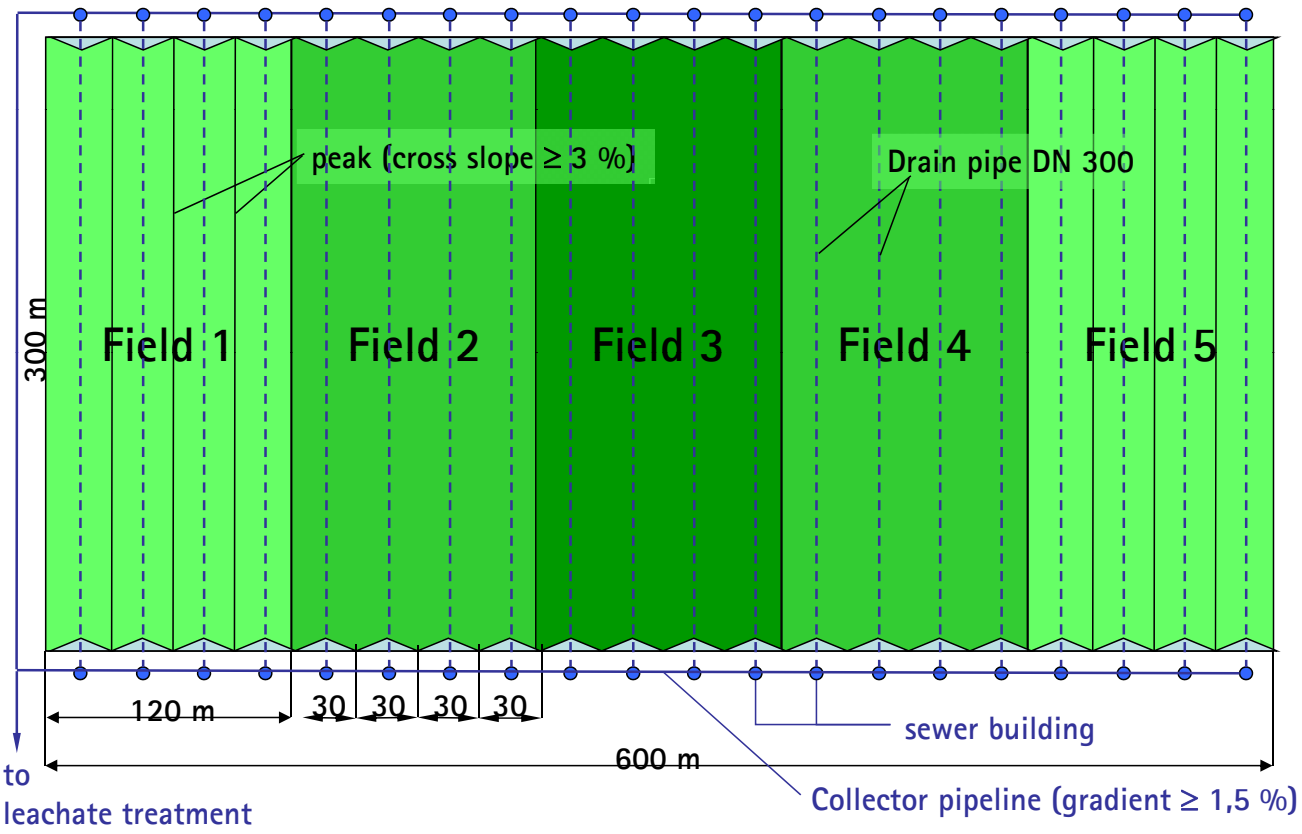


Task 4: Drainage System

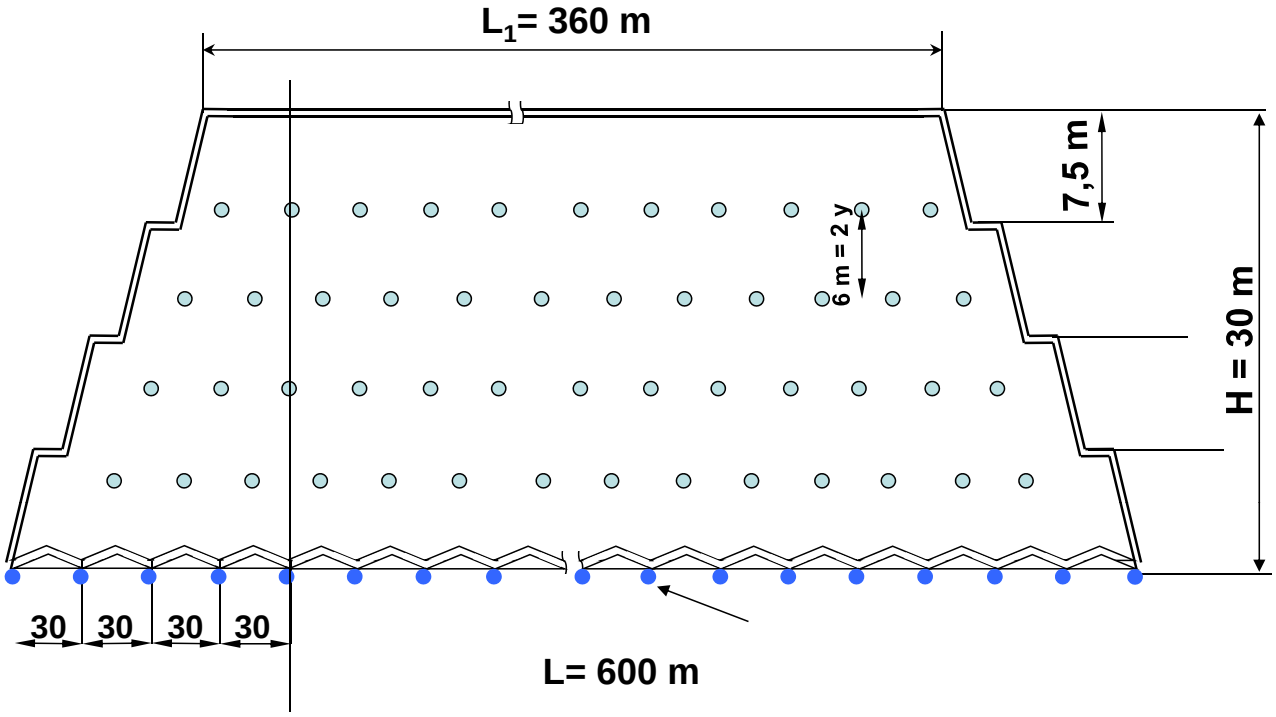
Landfill Drainage System



Task 4: Drainage System



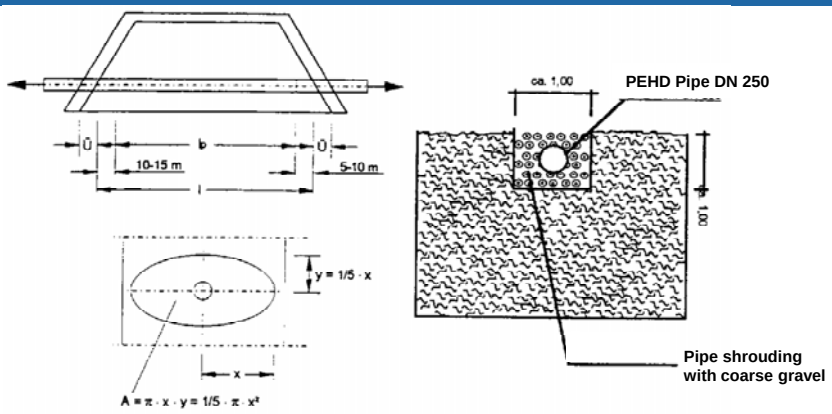
Task 5: Degassing System

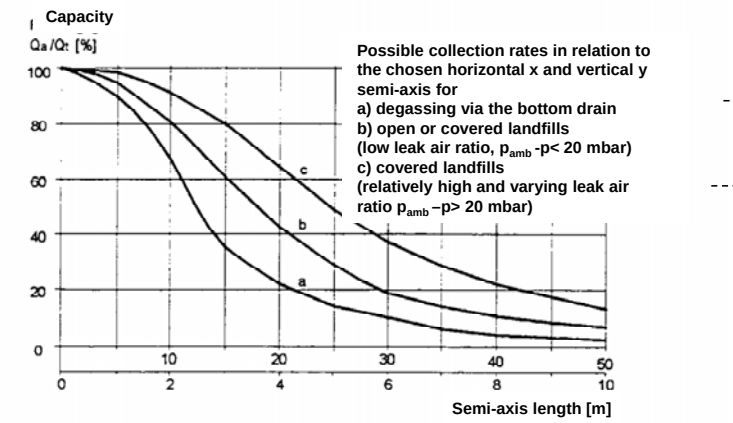


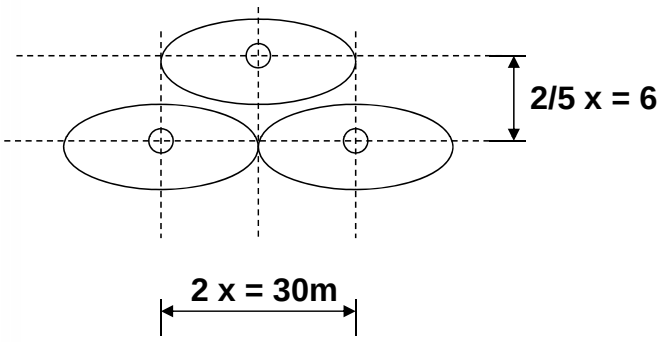
Task 5: Degassing System

Degassing Capacity		
height H	m	30
length L	m	600
number of terraces		4
H_1	m	
L_1	m	
distance degassing layers	m	6
elliptic axis of degassing area x	m	
elliptic axis of degassing area y	m	
degassing area A	m^2	
capacity Q_a/Q_t	%	

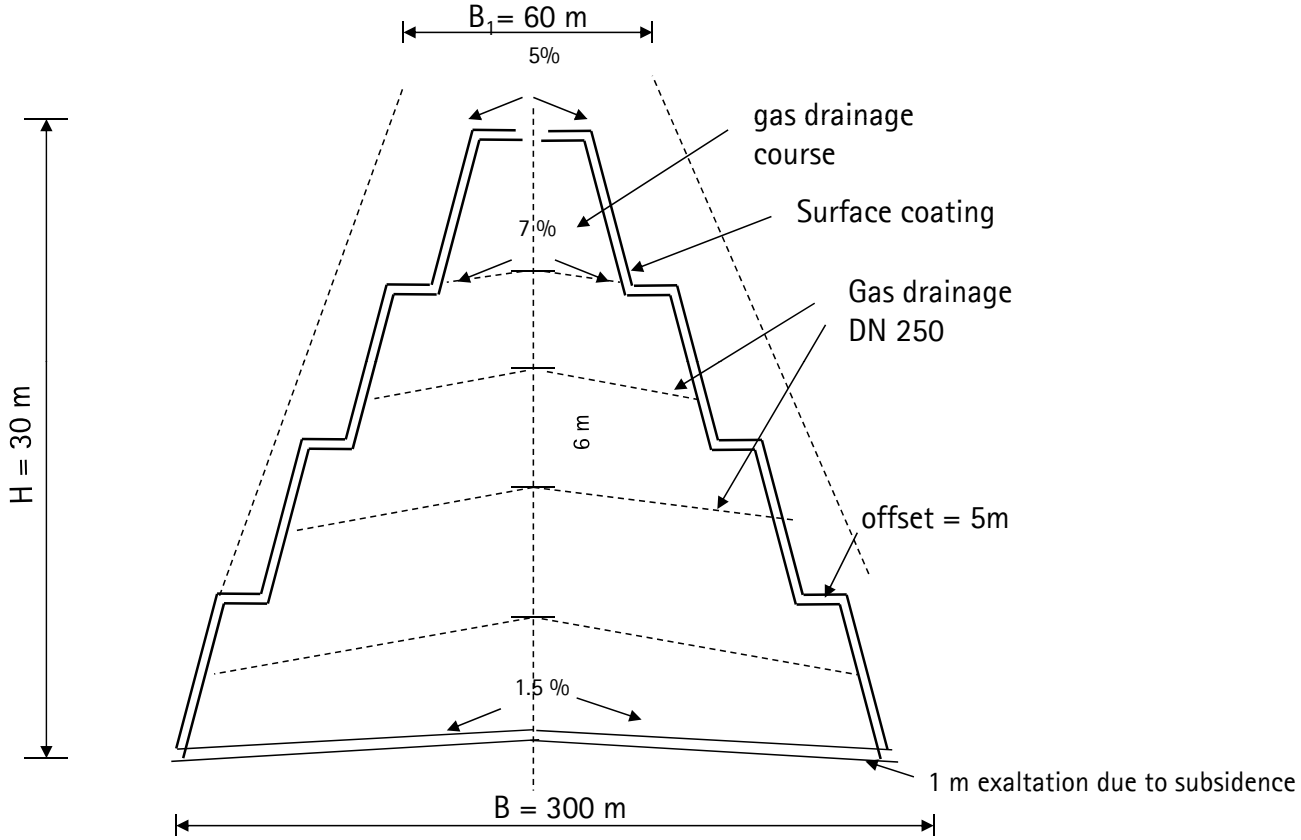
Task 5: Degassing System







Info: Effect of a Complete Enclosure of Landfills



Info: Effect of a Complete Enclosure of Landfills

- The leachate amount and landfill gas amount will be reduced with an intact surface sealing.
- Constructions for leachate and gas treatment can be less dimensioned
- Lower costs of the treatment plants for investments and ongoing maintenance measures
- Better stability
- Lower environmental harm by uncontrolled emergent leachate and landfill gas
- Reform of the flora growth conditions above the sealing. Because of the flora damages emissions of landfill gas has to be stopped.
- Better oxygen supply for the flora
- Lower emissions of smell
- Better collection and alternative usages of the landfill gas
- Biological degradation processes will be disrupted by missing water inflow,
  i.e. reduced inertisation of the waste (-> long maintenance) and
  artificial moisturisation for gas formation
- Continuous potential of gas and eluation over a longer period. Possible mobilisation by degradation of sealing properties.
- Plastic liner (PL) is like a baffle
  -> unhindered heat transport goes to seasoning of surface soil
  -> seasoning of vegetation layer (-> bad vegetation)
  -> danger by slipping of surface soil at the plastic liner in the berm
- Higher investment and maintenance costs

Task 5: Degassing System

Degassing Capacity		
height H	m	30
length L	m	600
number of terraces		4
H_1	m	7.5
L_1	m	360
distance degassing layers	m	6
elliptic axis of degassing area x	m	15
elliptic axis of degassing area y	m	3
degassing area A	m^2	141.37
capacity Q_a/Q_t	%	60

Task 6: Leachate amounts

Landfill Leachate

treatment capacitiy
60 m^3/d

plant availability
80 %

operating time
12 months/year

month	leachate amount Q_t [m^3/month]	sum of influent ΣQ_z [m^3]	sum of effluent ΣQ_S [m^3]	storage capacity [m^3]
January	6.230	6.230		
February	2.540	8.770		
March	3.290	12.060		
April	1.200	13.260		
May	35	13.295		
June	290	13.585		
July	410	13.995		
August	725	14.720		
September	530	15.250		
October	640	15.890		
November	2.356	18.246		
December	3.210	21.456		

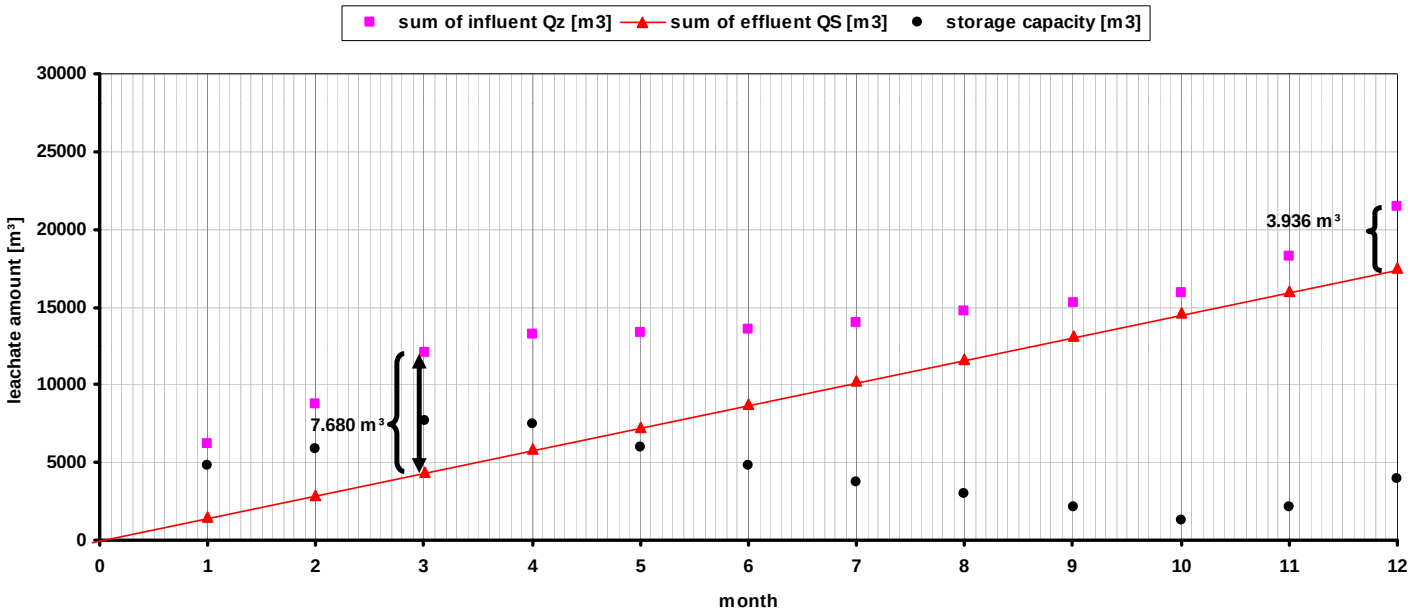
Leachate influent and effluent

month	leachate amount Q_t [m^3/month]	sum of influent ΣQ_z [m^3]	sum of effluent ΣQ_S [m^3]	storage capacity [m^3]
January	6.230	6.230	1.460	
February	2.540	8.770	2.920	
March	3.290	12.060	4.380	
April	1.200	13.260	5.840	
May	35	13.295	7.300	
June	290	13.585	8.760	
July	410	13.995	10.220	
August	725	14.720	11.680	
September	530	15.250	13.140	
October	640	15.890	14.600	
November	2.356	18.246	16.060	
December	3.210	21.456	17.520	

Leachate influent and effluent

month	leachate amount Q_t [m^3/month]	sum of influent ΣQ_z [m^3]	sum of effluent ΣQ_S [m^3]	storage capacity [m^3]
January	6.230	6.230	1.460	4.770
February	2.540	8.770	2.920	5.850
March	3.290	12.060	4.380	**7.680**
April	1.200	13.260	5.840	7.420
May	35	13.295	7.300	5.995
June	290	13.585	8.760	4.825
July	410	13.995	10.220	3.775
August	725	14.720	11.680	3.040
September	530	15.250	13.140	2.110
October	640	15.890	14.600	1.290
November	2.356	18.246	16.060	2.186
December	3.210	21.456	17.520	3.936

Determination of leachate storage capacity



Reduction of the storage volume at 3.000 m³

(max. leachate amount – storage volume) / number of month

(12.060 m³ - 3.000 m³) / 3 month = 3.020 m³/month => 99,29 m³/d

-> magnification of leachate treatment plant about 99,29/(60 · 0,8) ·100% = ca. 206,8 %

Dead time of the leachate treatment plant
- biological treatment: reduction of the efficiency factor
- membrane: conservation
- thermal treatement: energy loss

recommissioning costs, amortisation calculation

Leachate influent and effluent

month	leachate amount Q_t [m^3/month]	sum of influent ΣQ_z [m^3]	sum of effluent ΣQ_S [m^3]	storage capacity [m^3]
January	6.230	6.230	3.019	3.211
February	2.540	8.770	6.039	2.731
March	3.290	12.060	9.058	**3.002**
April	1.200	13.260	12.077	1.183
May	35	13.295	12.077	1.218
June	290	13.585	12.077	1.508
July	410	13.995	12.077	1.918
August	725	14.720	12.077	2.643
September	530	15.250	12.077	3.173
October	640	15.890	15.096	794
November	2.356	18.246	18.116	130
December	3.210	21.456	21.135	321

Reduction of the storage volume at 3.000 m³