Solid Waste Management SS 2012

Exercise 1

Designing a Composting Plant

Task 1: calculation of the essential biowaste container volume

Area Structure	Inhabitant per container location	Average garden size m^2 container	for calculation
I	30 to 100	-	
II	10 to 50	-	
III	**5 to 20**	**0 – 100**	**selected**
IV	2 to 8	100 – 500	
V	2 to 4	200 - 1000	

Task 1: calculation of the essential biowaste container volume

Task 1: Bio-waste container volume			
collection period			every 2nd week
collected kitchen waste per Inhabitant	kg/(inh*a)		50
inhabitant per container	inh/container		13
bulk density kitchen waste	kg/m³	250 – 350	261
safety factor kitchen waste	-	1.1	1.1
amount of specific garden waste	kg/(m²*a)		1.5
operated garden waste per container	m²/container		50
bulk density garden waste	kg/m³	150 – 250	161
safety factor garden waste	-	1.8	1.8
essential bio-waste container volume	L/(container*a)		3,578
essential bio-waste container volume	L/((container*2 weeks)		138
chosen container volume acc. Standard	-		
standardized container	L	120 / 240 or 360 L	240

$$V_{C,min}[L/(a*hh)] = \frac{\text{compostable kitchen waste}\left[\frac{kg}{inh*a}\right]}{\text{bulk density}\left[\frac{kg}{m^2}\right]} \cdot \frac{\text{inhabitant}}{\text{household}} \cdot \text{safety factor}_{\text{kitchen}}$$

$$+ \frac{\text{garden waste}\left[\frac{kg}{m^2*a}\right]}{\text{bulk density}\left[\frac{kg}{m^3}\right]} \cdot \frac{\text{operated garden}}{\text{household}} \cdot \text{safety factor}_{\text{garden}}$$

Task 2: Calculation of delivery and input amounts

Task 2: Calculation of input amounts					
connected residents in catchment area	inh	140,000			
participation quota inh_P for bio-waste	inh	87 %			
Raw material		**bio-waste**	**green waste**	**prod. spec. waste**	**total**
$M_{raw,Inh,a}$	kg/(inh*a)	150	42		
$M_{raw,a}$	t/a	18,270	5,880	5,200	29,350
$M_{raw,d,average}$ for 250 d/a	t/d	73.08	23.52	20.8	117.4
Safety factor $M_{raw,d,max}$ / $M_{raw,d,average}$	-	1.5	3.0	1.5	
$M_{raw,d,delivery\ max.}$	t/d	109.62	70.56	31.2	211.38
Safety factor for processing	-	1.5	1.0	1.5	
$M_{raw,d,processing\ max.}$	t/d	109.62	23.52	31.2	164.34
$M_{raw,week,delivery\ max.}$	t/week	548.1	352.8	156	1056.9
$M_{raw,week,processing\ max.}$	t/week	548.1	117.6	156	821.7

Task 2: Calculation of delivery and input amounts

Impurities					
Impurity ratio common range Impur%	% M_{raw}	1-10 %	0.5-3%	0-1%	
Impurity ratio Impur%	% M_{raw}	2.8 %	1.1%	0.0 %	1.96%
Impurities $M_{Impur,a}$	t/a	511.56	64.68	0	576.24

Task 2: Calculation of delivery and input amounts

Water content WC					
Delivery WC_0 common range	%	55-60 %	30-40 %	30-90 %	
Delivery WC_0	%	58 %	36 %	85 %	58.38%
Water content $WC_{Intens,0}$	%				58.38%
Water content $WC_{second,0}$	%				50 %
Water content $WC_{second,e}$	%				35 %

Task 2: Calculation of delivery and input amounts

Ignition loss IL					
Delivery common range $IL_{Intens,0}$	weight % DM	60-80 %	60-75 %	50-95 %	
Delivery=Input intensive rotting $IL_{Intens,0}$	weight % DM	72 %	70 %	90 %	72.41%
$IL_{Intens,e} = IL_{second,0}$	weight % DM	$oDM_{Intens,t,max}/(oDM_{Intens,t,max}+mDM_{max,0})$ with $oDM_{Intens,t,max} = oDM_{Intens,0,max} * e^{-kIntens * tIntens}$			
$IL_{second,e}$ = Input compost store	weight % DM	test result			42 %

for calculation of $I_{LIntens,e}$ the
degradation kinetics have to be calculated
task 5 in short

Task 5: Calculation of degradation kinetics

referred to oDM_0 =				1,000 kg				
Rotting period	time	e^{-k*t}	oDM_t	DM_t	mDM_t	oDM-degradation	DM-degradation	IL_t
weeks	a		kg	kg	kg	%	%	
0	0.00							
1	0.02							
2	0.04							
3	0.06							
4	0.08							
5	0.10							
6	0.12							
7	0.13							
8	0.15							
9	0.17							
10	0.19							42.0 %

$$time = \frac{\text{rott. period}}{52\ \text{weeks}/\text{year}}$$

Task 5: Calculation of degradation kinetics

referred to oDM_0 =				1,000 kg				
Rotting period	time	e^{-k*t}	oDM_t	DM_t	mDM_t	oDM-degradation	DM-degradation	IL_t
weeks	a		kg	kg	kg	%	%	
0	0.00	1.00						
1	0.02	0.85						
2	0.04	0.73						
3	0.06	0.62						
4	0.08	0.53						
5	0.10	0.47						
6	0.12	0.42						
7	0.13	0.38						
8	0.15	0.34						
9	0.17	0.31						
10	0.19	0.28						42.0 %

$$e^{-kt} = e^{-k_{intens} \cdot t} \quad \text{for intensive rotting}$$

$$e^{-kt} = e^{\left(-k_{intens,e} \cdot t_{intens,e} - (t - t_{intens,e}) \cdot k_{second}\right)} \quad \text{for secondary rotting}$$

Task 5: Calculation of degradation kinetics

referred to oDM_0 =				1,000 kg				
Rotting period	time	e^{-k*t}	oDM_t	DM_t	mDM_t	oDM-degradation	DM-degradation	IL_t
weeks	a		kg	kg	kg	%	%	
0	0.00	1.00	1,000	1381	381			
1	0.02	0.85	851	1232	381			
2	0.04	0.73	725	1106	381			
3	0.06	0.62	617	998	381			
4	0.08	0.53	525	906	381			
5	0.10	0.47	472	853	381			
6	0.12	0.42	424	805	381			
7	0.13	0.38	381	762	381			
8	0.15	0.34	342	723	381			
9	0.17	0.31	307	688	381			
10	0.19	0.28	276	657	381			42.0 %

$$oDM_t = oDM_0 \cdot e^{-kt}$$

$$mDM_t = oDM_0 \cdot \frac{1 - IL_{Intens,0}}{IL_{Intens,0}}$$

$$DM_0 = {}^{oDM_0}/_{IL_{Intens,0}} \qquad for\ t \neq 0 \qquad DM_t = oDM_t + mDM_t$$

Task 5: Calculation of degradation kinetics

referred to oDM_0 =				1,000 kg				
Rotting period	time	e^{-k*t}	oDM_t	DM_t	mDM_t	oDM-degradation	DM-degradation	IL_t
weeks	a		kg	kg	kg	%	%	
0	0.00	1.00	1,000	1381	381	0 %	0 %	72.41 %
1	0.02	0.85	851	1232	381	15 %	11 %	69.08 %
2	0.04	0.73	725	1106	381	28 %	20 %	65.54 %
3	0.06	0.62	617	998	381	38 %	28 %	61.82 %
4	0.08	0.53	525	906	381	47 %	34 %	57.96 %
5	0.10	0.47	472	853	381	53 %	38 %	55.32 %
6	0.12	0.42	424	805	381	58 %	42 %	52.66 %
7	0.13	0.38	381	762	381	62 %	45 %	49.98 %
8	0.15	0.34	342	723	381	66 %	48 %	47.30 %
9	0.17	0.31	307	688	381	69 %	50 %	44.63 %
10	0.19	0.28	276	657	381	72 %	52 %	42.0 %

$$\Delta oDM = 1 - \frac{oDM_t}{oDM_0}$$

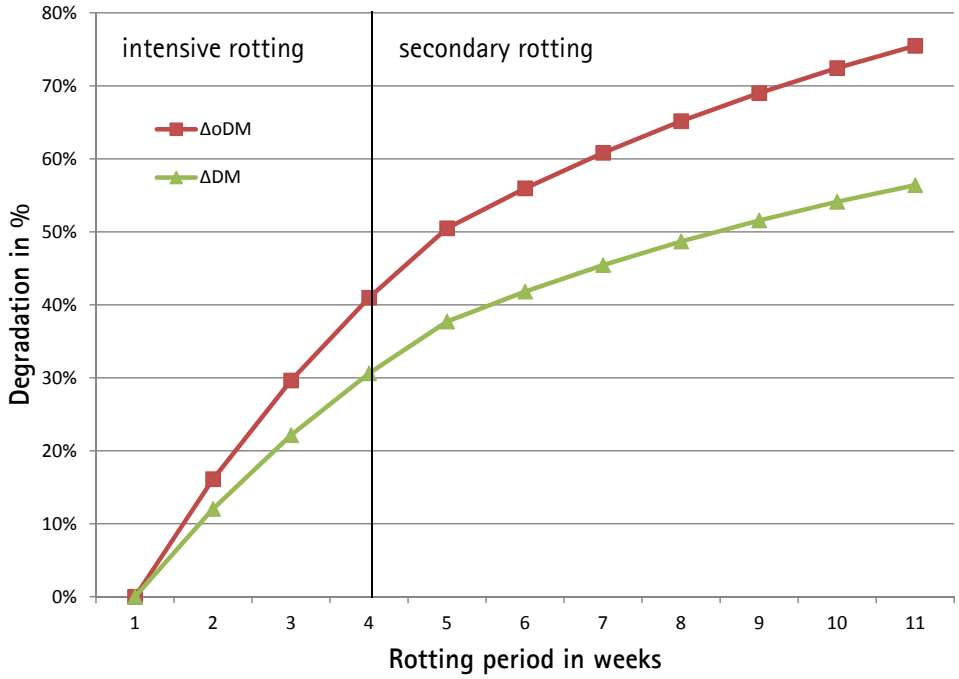
$$\Delta DM = 1 - \frac{DM_t}{DM_{0_t}}$$

$$IL_t = \frac{oDM_t}{DM_t}$$

Task 5: Calculation of degradation kinetics

referred to task $oDM_{Intens.0.a}$ =				8947.62 t/a				
Rotting period	time	e^{-k*t}	oDM_t	DM_t	mDM_t	oDM-degradation	DM-degradation	IL_t
weeks	a		kg	kg	kg	%	%	
0	0.00	1.00	8672	11977	3304	0%	0%	72.41%
1	0.02	0.85	7383	10687	3304	15%	11%	69.08%
2	0.04	0.73	6285	9590	3304	28%	20%	65.54%
3	0.06	0.62	5351	8655	3304	38%	28%	61.82%
4	0.08	0.53	4555	7860	3304	47%	34%	57.96%
5	0.10	0.47	4092	7396	3304	53%	38%	55.32%
6	0.12	0.42	3676	6980	3304	58%	42%	52.66%
7	0.13	0.38	3302	6606	3304	62%	45%	49.98%
8	0.15	0.34	2966	6270	3304	66%	48%	47.30%
9	0.17	0.31	2664	5968	3304	69%	50%	44.63%
10	0.19	0.28	2393	5697	3304	72.41%	52%	42.00%

Task 5: Calculation of degradation kinetics



Task 2: Calculation of delivery and input amounts

Ignition loss IL					
Delivery common range $IL_{Intens,0}$	weight % DM	60-80 %	60-75 %	50-95 %	
Delivery=Input intensive rotting $IL_{Intens,0}$	weight % DM	72 %	70 %	90 %	72.41%
$IL_{Intens,e} = IL_{second,0}$	weight % DM	$oDM_{Intens,t,max}/(oDM_{Intens,t,max}+mDM_{max,0})$ with $oDM_{Intens,t,max} = oDM_{Intens,0,max} * e^{-kIntens * tIntens}$			57.96%
$IL_{second,e}$ = Input compost store	weight % DM	test result			42 %

Task 2: Calculation of delivery and input amounts

Pouring weights					
Delivery common range ρ_{an}	kg/m³	250-350	150-250	300-500	
Delivery ρ_{an}	kg/m³	316	216	416	
Compacting factor through processing	-	1.1	1.2	1.05	
Density input intensive rotting $\rho_{Intens,0}$	kg/m³	347.6	259.2	436.8	345.69
Density input secondary rotting $\rho_{second,0}$	kg/m³	$\rho_{Intens,0}$ * 1.3			449.40
Density output sec. rotting $\rho_{second,e}$	kg/m³	$\rho_{Intens,0}$ * 1.6			553.11
Density compost storage ρ_{comp}	kg/m³	$\rho_{Intens,0}$ * 1.7			587.68

Task 3: Licensing procedure

Throughput capacity of the composting plant	Licensing/Notification	Participation of the Public	Decision period after submission of the complete application	EIA Duty cf. Appendix § 3 EIAA and amendment to the Appendix
> 10 t/ h (> 87,600 t/a)	Approval according to § 10 BImschG and Section 8.5 of the 4th BImschV	public advertising and display; date for the hearing of objections	7 Months	yes, for waste plants with public participation (i.e. also for landfills)
>0.75 - < 10 t/h; simplified method	Approval according to § 19 BImschG and Section 8.5 of the 4th BimschV	None	3 Months	no
< 0.75 t/h (< 6,570 t/a) *(< 1,000 t/a used material)*	notifiable according to the 4th BImschV *notifiable according to Section 8.5 of a draft for a BimSchV for notifiable plants*	none	not applicable	no

$M_{raw,d,processing,max}$ = 164.34 t/d
= 6.85 t/h

0.75 t/h < 6.85 t/h < 10 t/h

Task 4: Dimensioning of the composting

Task 4a: Dimensioning of the intensive rotting						
Amounts, Volume during the operation						
Input intensive rotting	t/a	$M_{raw,a}$ - $M_{Impur,a}$				
Input Intensive rotting $M_{Intens,0,a}$	t/a	17,758.44	5,815.32	5,200		28,773.76
DM-Input Intensive rotting $DM_{Intens,0,a}$	t/a	$M_{Intens,0,a}$*(1-WC_0)				11,976
$oDM_{Intens,0,a}$	t/a	$DM_{Intens,0,a}$*$IL_{Intens,0,a}$				8,672
Moist matter Input $MM_{Intens,0,max}$	t/week	$M_{raw,d,processing,max}$*5*(1-M_{Impur})				805
$mDM_{max,0}$	t/week	$MM_{Intens,0,max}$*(1-$IL_{Intens,0}$)*(1-WC_0)				92.51
$oDM_{Intens,0,max}$	t/week	$MM_{Intens,0,max}$* (1-WC_0) *$IL_{Intens,0}$				242.8
$oDM_{second,e}$ = $oDM_{compost}$	t/week	$mDM_{max,0}$*$IL_{second,e}$ / (1-$IL_{second,e}$)				66.99
$mDM_{compost}$ = Input min DM	t/a	$M_{Intens,0,a}$*(1-WC_0)*(1-$IL_{Intens,0}$)				3,304.4
$oDM_{second,e}$ = $oDM_{compost}$	t/a	$mDM_{compost}$*$IL_{second,e}$ / (1-$IL_{second,e}$)				2,392.8
DM Output second rotting $DM_{compost}$	t/a	$mDM_{compost}$+$oDM_{compost}$				5,697.22
Moist matter output secondary rotting MMcompost	t/a	$DM_{compost}$/(1-$WC_{second,e}$)				8,764.96

Task 4: Dimensioning of the composting

Dry matter reduction total ΔDM	%	$1-\frac{1-IL_{Intens,0}}{1-IL_{second,e}}$	52.43 %
		control	52.43 %
Original substance reduction total ΔMM	%	$1-\frac{(1-WC_0)*(1-IL_{Intens,0})}{(1-WC_{second,e})*(1-IL_{second,e})}$	69.54 %
		control	69.54 %
organic dry matter degradation total ΔoDM	%	$1-\frac{IL_{second,e}*(1-IL_{Intens,0})}{IL_{Intens,0}*(1-IL_{second,e})}$	72.41 %
		control	72.41 %
concentrating of contaminats concDM	%	$\frac{1}{1-\Delta DM}$	210.22 %

Task 4: Dimensioning of the composting

Intensive rotting			
$DM_{second,0,w,max}$	t/week	$mDM_{max} + oDM_{Intens,0,max} * e^{-kIntens * tIntens}$	220.05
$oDM_{second,0,w,max}$	t/week	$DM_{second,0,w,max} * IL_{second,0}$	127.54
$MM_{second,0,w,max}$	t/week	$DM_{second,0,w,max}/(1-WC_{second,0})$	440.09
Duration time of intensive rotting	week		4
essential windrow volume for 4 W intensive rotting V_{Intens}	m^3	$0.5*4*(MM_{Intens,0,w} + MM_{second,0,w})/(0.5*(\rho_{Intens,0}+\rho_{second,0}))$	6,266.72
windrow height Intensive rotting h_{Intens}	m		2.5
essential windrow aera intensive rotting A_{Intens}	m^2	V_{Intens}/h_{Intens}	2,506.69
chosen windrow width b_{Intens}	m	width b_{Intens} + ca. 4m = hall width	21
windrow length intensive rotting L_{Intens}	m	A_{Intens}/b_{Intens}	119.37

Task 4: Dimensioning of the composting

Calculation of intensive rotting aeration			
Respiartion activity $RA_{4,0}$	mg O_2/(g oDM*4d)		90
Respiartion activity $RA_{4,28}$	mg O_2/(g oDM*4d)		40
spec. O_2-need intensive rotting	mg O_2/(g oDM*4d)	$0.5*(RA_{4,0}+RA_{4,e})*(1-WC_0)*IL_{Intens,0}*28/4$	137.14
O_2-need intensive rotting O_2-need Intens	kg O_2/4 weeks	$0.25*(oDM_{Intens,0,max}+oDM_{second,0,W,max})*4*(RA_{4,0}+RA_{4,e})*28/4$	337,002
Rest-O_2 in exhaust air O_2-RestVol%	Vol.-% O_2	usually 12 to > 20	16
essential standard volume $SAir_{intens}$	Nm^3	$O_2\text{-need}_{Intens}*21\% / ((21\%-O_2\text{-RestVol\%})*0.21*32/22.4)$	4,718,025
ess. aeration intensive rotting $SAir_{Intens,h}$	Nm^3/h	$SAir_{Intens}$ / duration intensive rotting	7020.87
Exhaust air by 40°C $Q_{Exhaust,Intens,h,40}$	m^3/h	$SAir_{Intens,h}*(273+40)/273$	8049.57

Task 4: Dimensioning of the composting

Task 4b: Dimensioning of the secondary rotting and composting			
Secondary rotting			
DM max after secondary rotting $DM_{second,e,W,max}$	t/week	$mDM_{max,0} + oDM_0 * e^{-k*t}$	159.5
MM max after second rotting $MM_{second,e,W,max}$	t/week	$DM_{second,e,W,max}/(1-WC_{second,e})$	245.39
duration secondary rotting	week		6
essent. windrow volume for 6 weeks sec. rott. V_{second}	m^3	$0.5*6*(MM_{second,0,W}+MM_{second,e,W,max}) /(0.5*(\rho_{second,0}+\rho_{second,e}))$	4102.6
chosen windrow height sec. rotting h_{second}	m		2.2
chosen windrow basis width sec.rotting a_{second}	m		5.0
windrow head width sec. rotting b_{second}	m	$a_{second}-2* h_{second}*\tan 30°$	2.46
essential windrow length L_{second}	m	$V_{second}/(h_{second}*0.5*(a_{second}+b_{second}))$	500
way width between the windrows $c_{way,second}$	m		1.25
essential canopied area for sec. rotting A_{second}	m^2	$L_{second}*(a_{second}+c_{way,second})$	3,124.83

Task 6: Dimensioning of the biofilter

Task 6: Bio filter				
ess. ventilation intensive rotting $SAir_{Intens,h}$	m^3_n/h	cf. task 4		7020.87
exhaust air flowrate (40°C $Q_{exhaust,Intens,h,40}$)	m^3/h	cf. task 4		8049.57
gas retention time in the biofilter design basis $t_{filter,design}$	s	>15 to 20		28
gas retention time in the biof. t_{filter}	s	selected		26
selected filter material		free selectable		root wood
pore volume selected ε_{filter}	%	free selectable, 55-75 %		70 %
max. valid biofilter volume rate $q_{biof,V,h,max}$	$m^3/(m^3*h)$	$3600*\varepsilon_{filter}/t_{filter}$		96.92
biofilter volume loading $q_{biof,V,h}$ chosen	$m^3/(m^3*h)$	selected, dependend on $q_{biof,V,h,max}$	**ok**	90
filter height normal average h_{biof}	m	per layer 0.7 to 1.5 m		1
biofilter surface flow rate $q_{biof,A,h}$	$m^3/(m^2/h)$	$q_{biof,V,h} * h_{biof}$		90
ess. biofilter volume V_{biof}	m^3	$Q_{exhaust,Intens,h,40} / q_{biof,V,h}$		89.44
ess. biofilter surface A_{biof}	m^2	$Q_{exhaust,Intens,h,40} / q_{biof,A,h}$		89.44