Weak-point Analysis: Example MBT Wilsum

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Schwachstellenanalyse am Beispiel der MBA Wilsum

Abstract

A material flow analysis of two different input flows was carried out at the MBT Wilsum on the basis of technical criteria. In the district of Leer the “Sack + Sack” system of collection is used and in the Grafschaft Bentheim district the MGB-system without bio-waste collection (experiment “GB”). The results of the analysis showed that there are differences in the per-capita amounts of the different components, as well as in the composition and decay tendencies. In contrast to the usual method (experiment “business”) of the separation of a fraction larger than 100 mm in the waste incineration plant, a separation at 60 mm and later at 25 mm took place in the course of the decay process. With the data it is possible to depict the current situation and possible procedural variations in a simulation model. The secondary decay of a fine pile 0-25 mm took very long (270 days), due to low oxygen content, until the landfill criteria had been met. Especially the TOC in the eluate was difficult to reach. An acceleration is possible here through an improved hydration. The examination of the usual piles 0-100 mm shows that there the oxygen supply and moisture retention is better. Therefore, it’s recommended to remove the energy-rich components after the decay process. The organisation analysis led to improvement suggestions (landfill material, need for personnel) and the process-cost analysis shows that at around 107 euros per Mg input the MBT-process including deposit in a landfill and aftercare is able to compete with waste incineration.

Keywords

Sampling, waste composition, decay, balance, landfill material, density of waste, process costs, process variations

1 Problem definition and realisation

The storage of waste looks back on a longstanding tradition and has many local supporters regarding its decentralised implementation. Waste incineration requires high amounts of waste, a large service area and considerable investment costs. Both methods compete with separate collection and materials recycling. It has taken more than 20 years to put an end to the environmentally unsound waste storage and to start primarily collecting and treating waste separately before it is disposed or recycled. In the Grafschaft Bentheim district, a simple concept was realised like was intended when first thoughts were directed at an improvement of waste management.[1] In the context of a

[1] Baienfurt (1982) in Scheffold: Getrennte Sammlung und Kompostierung, GML Versuch (1991)

project conducted with the help of students from the of environmental protection course at the FH Bingen, a weak-point analysis was realised, supported by the district.

With the legal deadline set to 31 Mai 2005, it became obvious that it would not be possible to immediately meet the theoretically established requirements on MBT technology and on the quality of the produced amount of landfill material. The shortage of incineration capacities especially for commercial waste caused problems. For the first time, the financial consequences became apparent leading to a considerable increase in charges. The base data were uncertain and there was a large lack of confidence. With the help of the ***LeanManagementMethod***[2], it was possible to convince the political decision makers of the further course of action and to support them. There is no economic alternative to the continued operation of the landfill and the MBT. An increase of the capacity utilisation leads to relative cost reductions for the debtors of charges. To this effect, a well-functioning and efficiently sized plant is necessary.

For the evaluation of the plant, two large-scale experiments were conducted to make up the balance of the processes with separate treatment of the amounts of incoming waste depending on the area of origin (Leer dc., Grafschaft Bentheim dc.). After sieving (100 mm) and homogenisation and before feed into intensive composting, random samples are taken and manually sorted to determine their composition. After the first phase of intensive composting, a sieving (60 mm) was realised to reduce the amounts to be composted. At the end of intensive composting, the material is sieved at 25 millimetres. For comparison, a composting windrow with 0-100 mm grain-size out of the usual input mixture was set up and optimally pre-treated in 3 intensive composting phases. The different fractions are treated in separate biological post processing windrows and samples are taken on a regular basis. Thus, the biological composting progress becomes visible. The parameters in accordance with the AbfAblV (Waste Storage Ordinance) are analysed by the laboratory Wessling, Altenberge. At the FH Bingen, parallel samples are dried, sieved, sorted and the ignition loss of components and of the entire samples is determined. For some components, also the calorific value and the TOC is identified.

2 Results of the material flow analysis

2.1 Sampling

The sampling out of 240 litres MGB from the continuous sieve overflow has proved to be relatively unproblematic and representative. However, taking samples from the windrows was more difficult. The windrows 0-25 mm were digged up and a bucket with 11

[2] What would be the consequences if the district had all waste thermally treated (external service)?

litres capacity was randomly filled by shovel with material from an undisturbed area. This amount allowed to gather representative information for this particular grain-size. From the windrow 0-100 mm, this method cannot be applied successfully. Either a separation is done on a screen grate so that a larger sample amount can be processed or a larger sample amount (MGB240) has to be extracted and completely treated. For comparison, a conventional plant windrow was sieved at 25 mm and the sieve underflow and overflow were taken samples from. All mobile windrows were measured and the apparent density in the 240 liters-container and the water content were determined.

Results

The sample amount and the sampling method have to be modified depending on the grain-size of the windrows. The cumulated landfill material quantity of 2,000 Mg before storage cannot be representatively described with a sample. In this case, either material has to be extracted from the area with the shortest composting duration to reliably meet the criteria, or separate samples from sampling points along the whole length of the windrow have to be taken and separately analysed. Automatic sampling devices for the production of mixed samples during the shifting process are preferable.

The analysis results are not insignificantly influenced by the sampling method, sample amount, sample treatment and organisational realisation.

2.2 Air supply and water content of the windrows

After mechanical treatment, the waste is optimally prepared for biological treatment. The experiments have shown that the sieve overflow is biologically too dry. Vice versa, the fine windrows dry up when they are not enough irrigated and the oxygen content of the windrows is too low without artificial aeration. The coarse windrow (0-100 mm) decomposes faster because of the better natural aeration.

The homogenisation drum influences the consistency of the rotting material and is, as a test, bypassed in a further experiment. As the water content in the intensive composting input (0-100 mm) is optimal already due to its origin, homogenisation is not absolutely necessary.

2.3 Composting drum and screening rasp as alternative

The treatment duration in the homogenisation drum is too short to achieve an autogenous grinding which would be advantageous for an optimal separation of the high calorific fraction from the disposable fraction as our earlier experiments in Bach Kreuznach (1990) have shown. At present, potentially compostable and inert matter get into the material flow to waste incineration (high calorific value). Due to the existing landfill capacities, the aim is to maximise storage quantities and minimise the amount of fractions to be incinerated.

The possibility of shredding, then intensive composting and afterwards sieving still has to be examined. Regarding the existing plant layout, it should be considered to partly transfer the intensive composting into a prior composting drum.

At present, the production of refuse-derived fuel is not an economic alternative. The disposal and energy recovery in a WTE-plant is much more cost-effective. For the next 12 years, additional payments of more than 75 Euros per Mg are not an alternative due to the particular situation. Commercial waste is not treated in Wilsum.

2.4 Composting process and decomposition

2.4.1 Intensive Composting

2.4.1.1 System influences

The feeding by wheel loader, the cleaning of the vent holes in the ground, the filling level, the recirculation air conduction, the irrigation etc. influence the composting process. The experiment quantities were produced over 3 days and stored intermediately. The analysis parameters and the process variables indicate that this might have a negative influence on the reduction of TOC in the eluate. In the comparative windrow NEU (0-100 mm), it was possible to optimally control the process in the intensive composting tunnel. After 4 weeks, the parameters were met, allowing a non-aerated biological post processing in an open hall. In the mobile windrow, a repeated augmentation of the parameter values can be detected and the decomposition process has to be described by another function (discontinuity due to system change). In summer, the missing air cooling in the recirculation air conduction into the intensive composting may lead to problems. During this period, the heat cannot be completely discharged from the system.

2.4.1.2 Aeration and de-aeration

In the experiments, air amounts usually used by the operator of ca. 2,800 m^3/h were applied (ca. 9,800 litres of air / kg rotting material or 15.6 l/kg/h or 59 m^3/kg decomposed substrate).

2.4.1.3 Decomposition

The decomposition measured as respiration activity is supposed to follow the function

AT_4 [mgO_2/g DM] = 80.444 exp (-0.0701 composting duration [d]) in the intensive composting and

AT_4 [mgO_2/g DM] = 52.628 -10.273 Ln (composting duration [d]) in the biological post processing

as function of time. According to this, a value of 20 mg after 20 days and of 5 mg after 100 days treatment duration in the system should be reached. This normative function derived from literature serves as measuring scale for the proceedings in plant evaluation and can point out optimisation potential in concrete cases.

Table 1 Example for normative-actual value comparison for the parameter AT_4 in mg O_2/g DM in experiments

	Intensive composting		biological post processing		
	normative	experiment	normative	exp. L	control exp.
composting duration [d]					
20	19.8		21.9	54	
26	13	20.1±5.7	19.2	48	33.75
42	4.2		14.2	36	
65			9.7	24	13.6 ±4
80			7.6	18	12.3 ±10.6
93			6.1	15	
105			4.8	12	

The grain-size distribution and the aeration of the windrows have a considerable influence, as table 1, experiment L shows in comparison with the control experiment and the normative function.

2.4.2 Biological Post processing and mobile windrows

2.4.2.1 Windrow cross section

The experimental windrows have a trapezoidal section of 5 to 7 m², ca. 2 m height and lengths of 11 to 20 meters, The initial volume is reduced from ca. 90 m³ to 50 m³ due to the composting procedure. These windrows have to be compared to the plant windrows with a section of 7.3 ± 1.7 m^2 with a height of ca. 2 ±0,2 m and a length of 66-74 m.

2.4.2.2 Biological post processing area

The present biological post processing area is not optimal for operation and too small. With the change from hipped windrows to triangle windrows, the cross-section area was reduced from 7.3 m² to 4.6 m² and the oxygen supply was improved. With volume adjustment management, the treatment duration can be maintained and the decomposition can be accelerated by optimised aeration and irrigation during shifting process. To avoid shifting on days of unfavourable weather conditions, the biological post processing area will be enlarged, e.g. by relocation of the storage facilities. Before acceleration of the decomposition, a treatment duration which was longer by 17% was necessary to ensure that the limit value of 5 mgO_2/g DM is not exceeded. The base width of the triangle windrow is 4.60 m at a dumping height of 2 ±0.2 m and 6 ±0.45 m for a hipped windrow.

2.4.2.3 Shifting

From a practical point of view, the shifting of the experimental windrows was mostly effected by wheel loader and just twice by a turner. The efficiency of the turner amounts to 300 – 350 cubic meters per hour.

2.4.2.4 Irrigation

The irrigation was partly realised by using a slotted sprinkling hose and cannot be considered as optimal. The water content in the windrows was temporarily rather too low and decreased from initially 50 % FM to about 33 (24 to 43) % FM being much higher in the compostable components.

2.4.2.5 Temperature

The temperature in the windrows was permanently high and only decreased after 20 weeks to less than 40°C.

2.4.3 Decomposition

About 43 percent of the input (FM) can be classified as belonging to the category "compostable" which means ca. 111 Mg DM in the windrow Leer. With ignition of the components, 70.9 Mg organic dry matter (oDM) can be found which potentially is to be biodegraded.

Table 2: Example for balancing experiment Leer regarding compostable material

	Start	Phase A	Phase B	Phase C	Phase D
composting duration days	0	10	28	100	270
compostable oDM Mg	70.90 100%	39.95 56%	25.82 36%	21.42 30%	12.83 18%

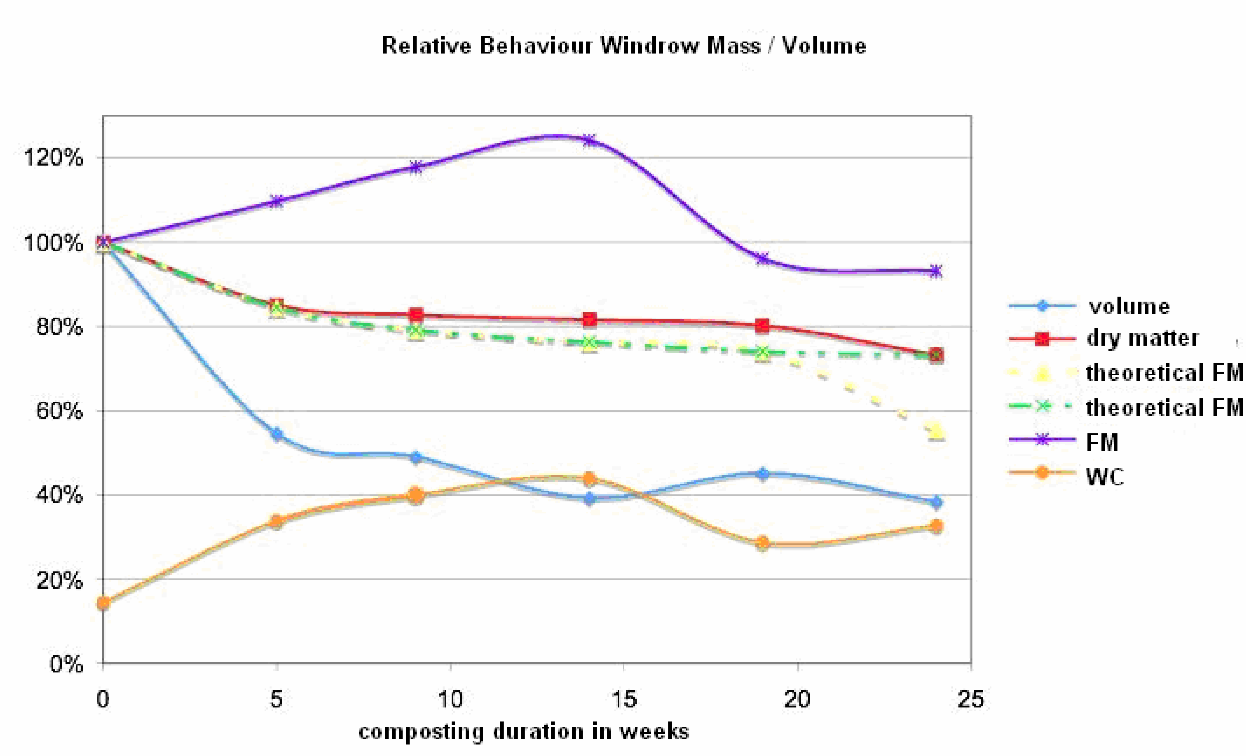

Figure 1 Behaviour of wet and dry matter, volume and water content in the windrow „ffc“ which originated from the high calorific sieve overflow 25-60 mm after drying

2.4.4 Respiration activity

The initial value in the windrow “Leer“ of 63 mg O_2/g DM is much lower than in the windrow “GB” with 102 mg O_2/g DM. With 34 mg O_2/g DM, the initial value for the biological post processing windrow “fine from coarse” (ffc) is lower due to experiment conditions. After intensive composting, the respiration activity rose again and then fell from the new level.

The time course with AT_4 (GB_D) = 101.78 e $^{-0.0195\ \text{composting duration}}$ totally deviates from the expectation AT_4 (literature) = 80.344 e $^{-0.0701\ \text{composting duration}}$. According to the latter, it can be expected that the limit value of 5 mg O_2/g DM is reached after about 40 days in intensive composting (cf. also table 1).

A reason for the long-lasting decomposition phase is the oxygen supply (natural aeration of a fine grain windrow). The “fine from coarse” windrows have a smaller cross-section and are better aerated. Nevertheless, only in the beginning there is a very large difference regarding respiration activity.

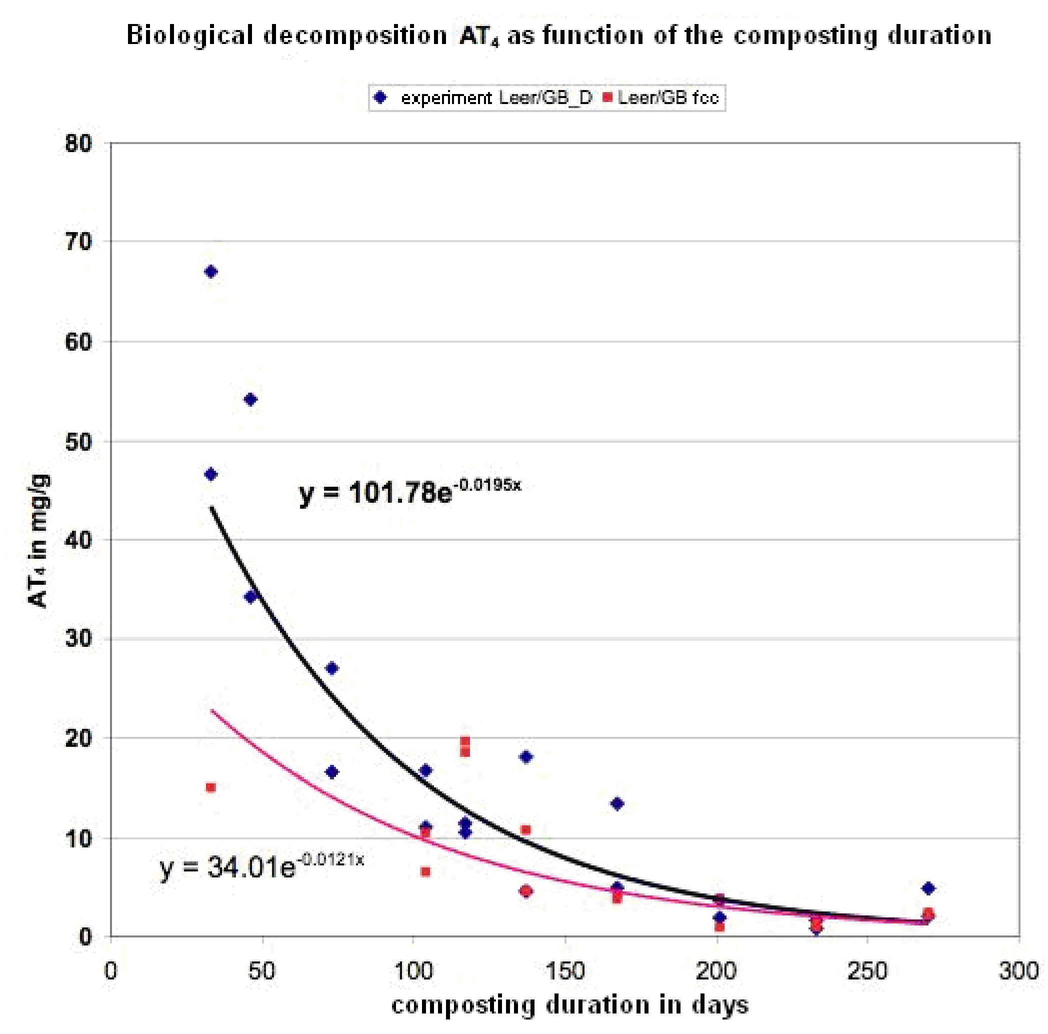

Figure 2 Course of the respiration activity in 4 experimental windrows with fine-grain landfill material 0-25 mm from two areas of origin

After composting for 75 days, the analysis KW 10 has shown a point which lies in the range of the behaviour of the windrow "fcc" and would afterwards need 158 days to reach the limit value. It seems as if the decomposition simply needs enough time (at a coarse windrow structure without artificial aeration 110 – 160 days ?). This should be analysed in greater detail and reproducibly.

2.4.5 Ignition loss

The ignition loss can be easily and well reproducibly determined in the laboratory. The landfill material consists of inert/mineral components (ashes) and the "organic components" carbon, hydrogen, oxygen, nitrogen, phosphorus and sulphur, chlorine etc. as long as they are emitted at 550°C.

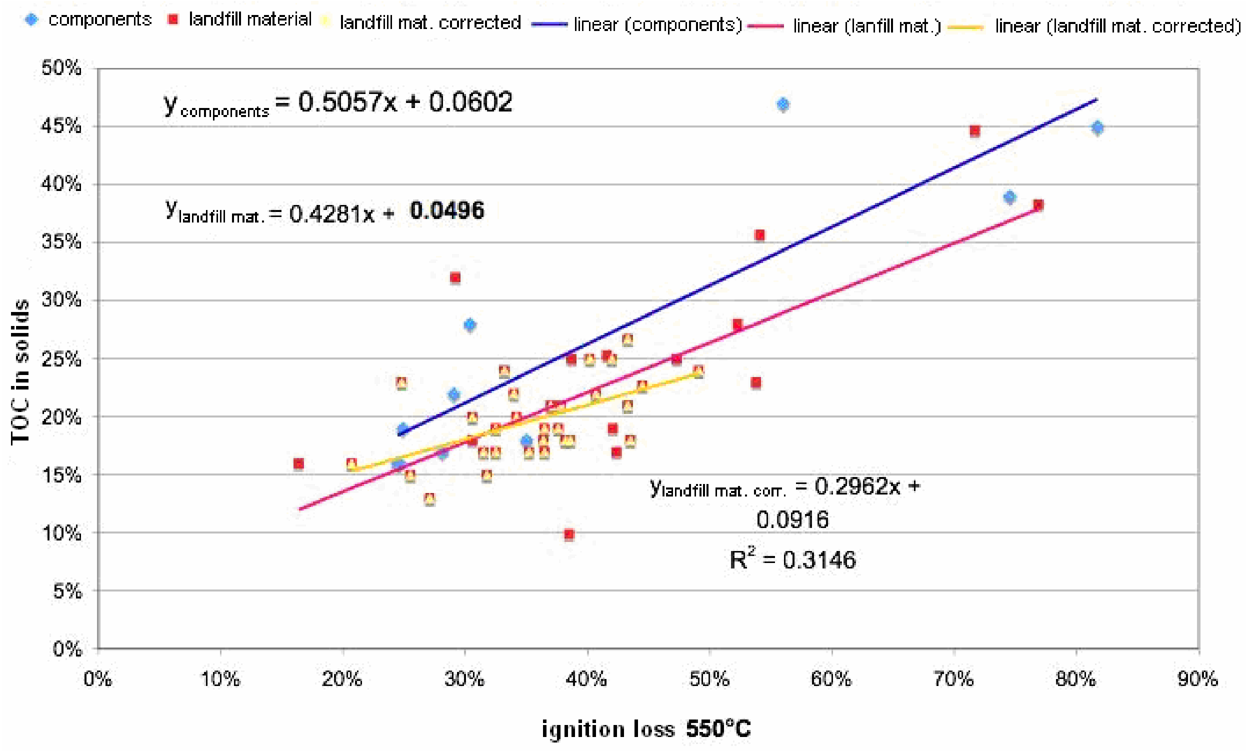

Figure 3 Correlation between ignition loss and TOC

Occasionally, the analytical laboratory detected more carbon than was altogether emitted as ignition loss. Surprisingly, the ignition loss was for all plastic samples under the expected 85-95 %. This illustrates the negative alteration that the plastics' quality suffers in "mixed waste collection" and shows that a materials recycling for the system "Yellow in Gray" is not recommendable. The biological decomposition process can be very well traced with the help of the ignition loss. For the windrow GB, the ignition loss (IL) developed e.g. according to the equation

$$IL = 0.5972\, e^{-0.0032 \times \text{composting duration}}$$

(composting duration 30 to 270 days). The windrow "GB fcc" shows the same behaviour, whereas the windrows Leer show a considerably greater decrease at the beginning. It must be noted that the ignition loss is at about 55 DM.-% at the beginning and at between 20 and 35 DM-% at the end.

2.4.6 Carbon content and calorific value

The inventory of the input and output flows in the composting experiments is balanced. The energy content and the carbon content in the storage product are determined by the treatment process. The correlation of the values for the individual components (plastics, wood, paper, fine-grain matter) corresponds to the correlation of the many values for the landfill material condition (cf. fig. 4).

Table 3 Development ignition loss, carbon (TOC in solids) and calorific value of components

	IL	TOC i. s.	CV	
plastics	81.8%	47.7%	25,900	20.3 – 29.6 MJ/kg
fibrous	61.4%	36.0%	17,325	14.9 – 21.2 MJ/kg
wood	75.1%	42.0%	17,400	16.1 – 18.7 MJ/kg
FINE [116d]	33.6%	24.0%	11,770	9.8 – 13.5 MJ/kg
FINE [270d]	26.9%	19.7%	7,767	7.1 – 7.9 MJ/kg

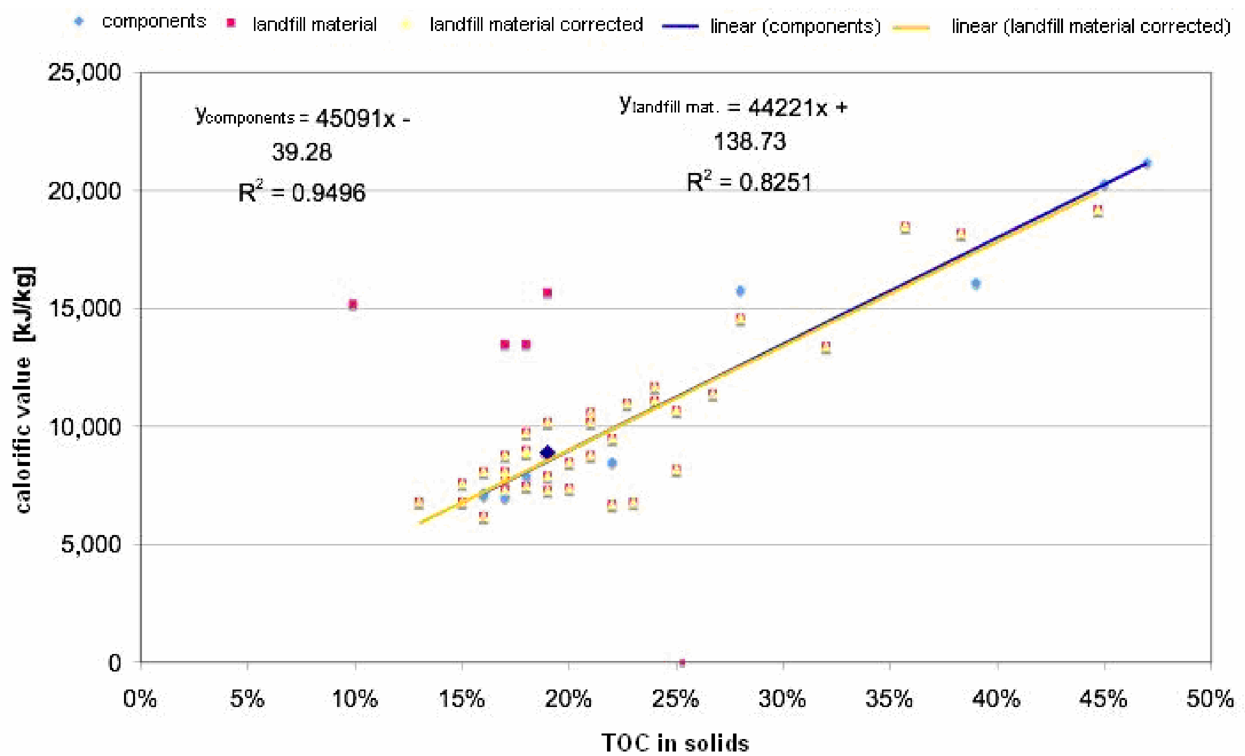

Figure 4 Correlation between carbon content and calorific value of individual components and of landfill material in the rotting process as result of the laboratory analyses for experimental windrows

As a result, it has to be noted that the final product from composting has a calorific value of more than 7 MJ/kg even after 270 days. So it is only possible to meet the limit value of 6,000 kJ/kg with the help of inert components such as glass and KSP (ceramics / stones / porcelain). Plastics disproportionately increase the carbon content in the landfill material but probably behave like inert material on the landfill. The detection of the periods of time in which plastics are decomposed biologically and which emissions result from this are not available to the author. In table 3, some parameter developments necessary for the simulation are listed.

2.4.7 TOC in the eluate

The practical experience with MBT technology shows that it is difficult in pure composting systems to reach the limit value of 300 mg/litre within a short period of time. After intensive composting, an increase sets in which is only slowly reduced depending on the decomposition. The fine windrows show that with an improved aeration, a lower level of 210 or 310 is reached. Also here, the time demand for decomposition and the necessity of a systematic mass screening over the process becomes evident.

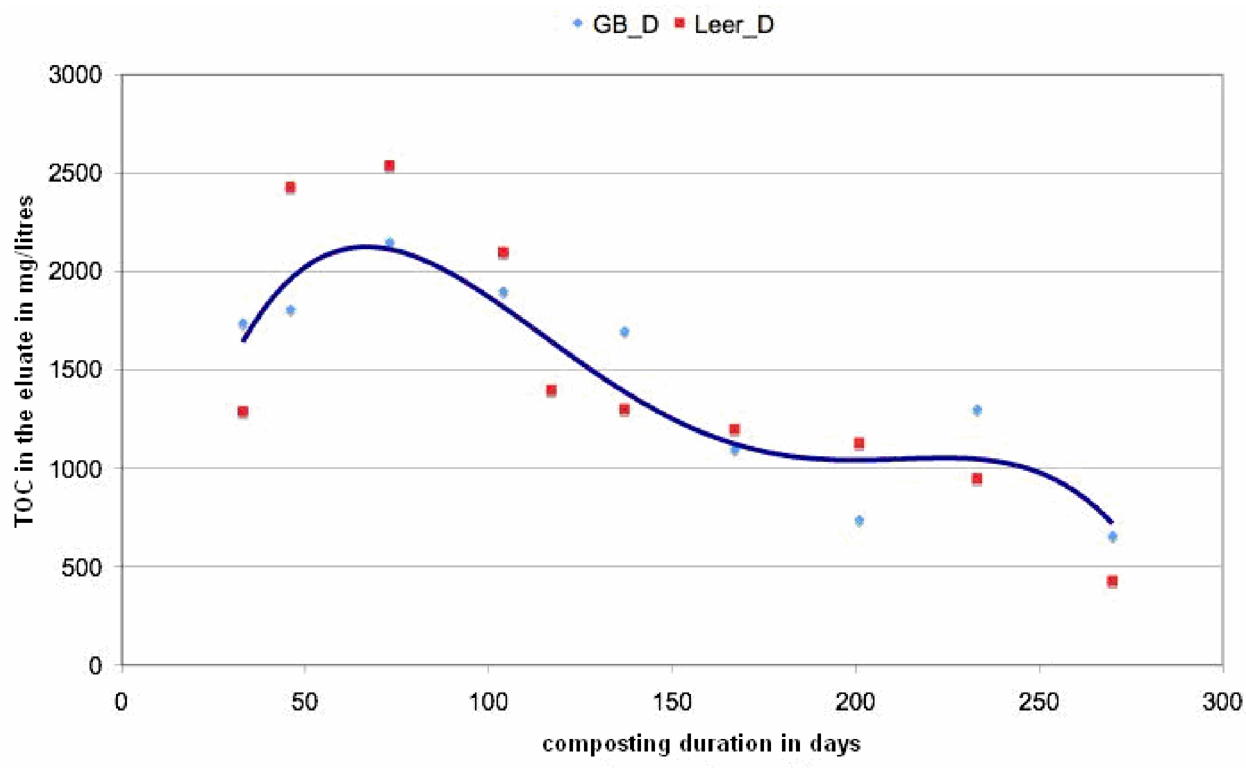

Figure 5 Correlation between composting duration [d] and TOC in the eluate [mg/l] for two windrows of different origin and differently treated

Theory: The dewatering of thermally disintegrated waste sludge at temperatures > 55°C is relatively difficult.[3] In windrows, high temperatures of about 50°C arose over long periods of time. On the fine-grain surfaces, there are adherences of microorganisms (MO) and decomposition products which are detached through shear forces during the elution process. It takes very long until all these substances are decomposed or they have to be so tightly connected to the fine-grain by adsorption forces that they cannot be detached during elution process. Also the content of inorganic carbon influences the value level. In anaerobic processes, considerably lower TOC values are detected in the eluate. As in this case, the temperature conditions are different and no thermal adhesions take place, the substances seem to be more susceptible for decomposition in

[3] Experiences from waste sludge analysis, see Diplomarbeit Kessler, FH Bingen (2007)

the aqueous phase. To what extent the elevated eluate values of the composting are linked to environmental impacts and how this “caking process” can be avoided has in my opinion not been analysed for this matrix.

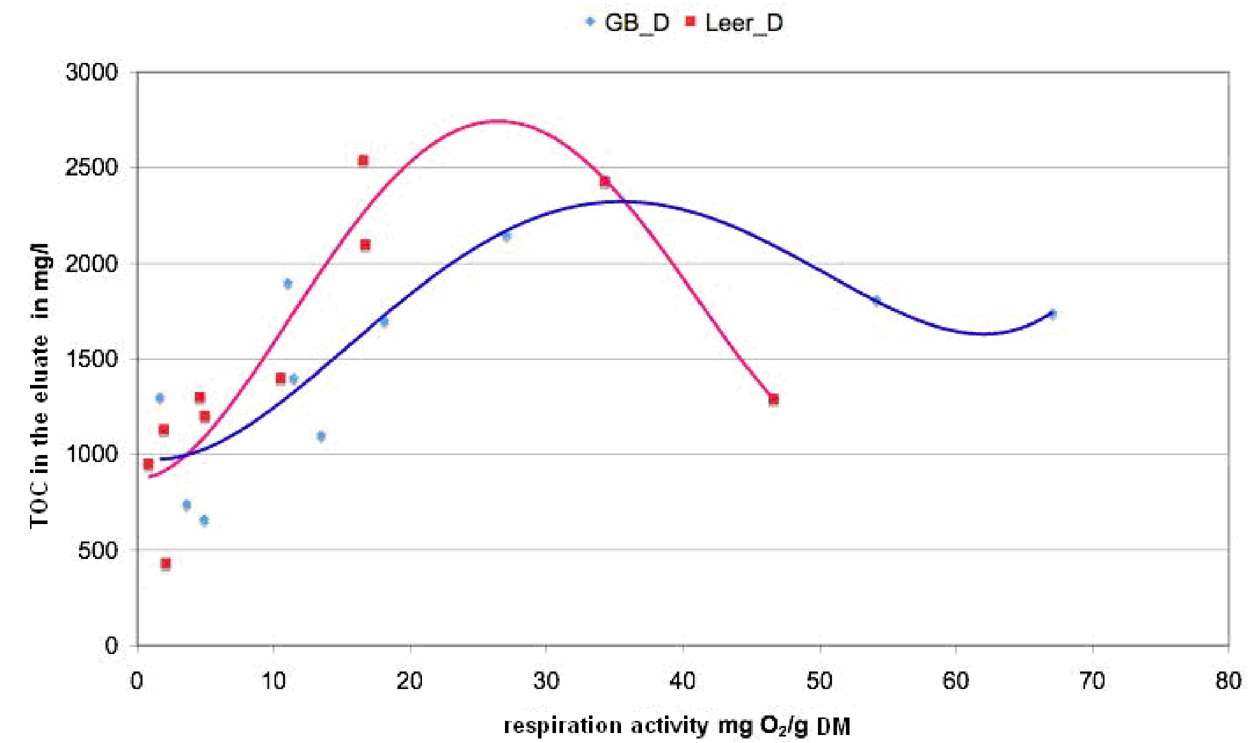

Figure 6 Correlation between respiration activity [mg O_2/g TM] and TOC in the eluate [mg/l] for two experimental windrows from 257 Mg and 156 Mg input

3 Material flow

3.1 Balance

In the presentation, a Sankey diagram is shown illustrating the material flow.[4]

About 111 Mg (43 % FM input) were detected as compostable, of which ca. 71 Mg are degradable oDM that is readily degradable to two thirds. We find 6.7 Mg of this matter in the landfill material. The ash content in the compostables of 39.9 Mg is passed on by 21.3 Mg to the WI-plant (high calorific) and by 18.6 Mg to the landfill material. 18.6 + 6.7 = 25.3 Mg referred to FM input amount to 9.8 % compostables in the landfill material (cf. table 4). As composting loss, 42.5 Mg oDM, i.e. 16.5 % of the FM input escaped. Regarding water, 47.2 Mg (48.3 %) plus 49.8 Mg supplied from outside, adding up to 97 Mg were discharged over the air path.

[4] Can on request be provided by the author.

Table 4 Substantial material flows windrow Leer referred to FM input 257.4 Mg

DM	inerts	high cal.	compostable	water	FM	DM
INPUT	6.2%	12.8%	43.0%	38.0%	100%	62.0%
WI high cal.	3.5%	12.2%	16.7%	12.8%	45.2%	32.4%
landfill material	2.7%	0.6%	9.8%	6.8%	20.0%	13.2%
composting loss	0%	0%	16.5%	18.3%	34.8%	16.5%
rel. CL			38.4%	48.3%		

The waste "Leer" consists of ca. 25 % ashes, 37 % organic matter and 38 % water. Only 7.7 Mg or 3 % of the input or 8.1 % of the organic matter can be found in the thus treated landfill material. Too much inorganic matter is passed on to the high calorific fraction which should rather be landfilled. Therefore, the extraction of the high calorific fraction has to be optimised.

Biologically degraded are renewable carbon-containing components. Therefore, an optimal process management does not influence the carbon dioxide balance on a sustainable basis. What is important, is that the fossil, carbon-containing components are used for energy recovery and not for landfilling.

3.2 Grain-size distribution and composition

The wet samples were sieved on a double deck screening machine in fine (0-5 mm), medium-sized (5-15 mm) and coarse (> coarse), afterwards dried at 105°C and fractioned on a sieve tower with 10 sieves. Each fraction was separately sorted.

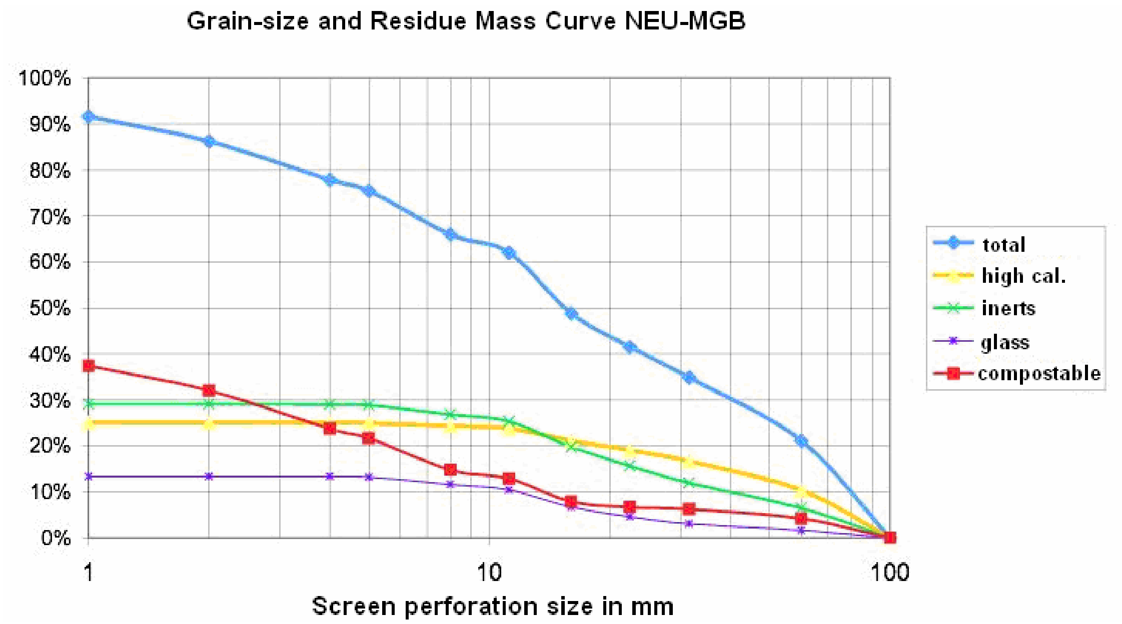

Figure 7 Example of grain-size distribution of a plant windrow

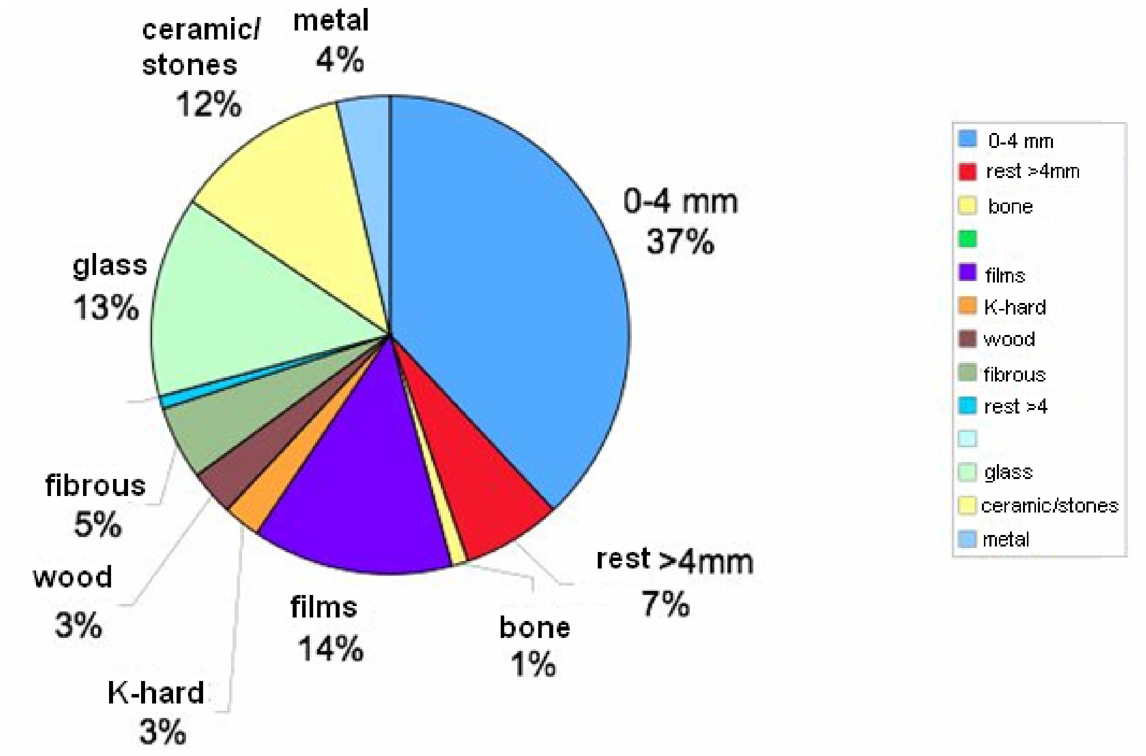

Figure 8 Example composition of an operation windrow dry matter

Regarding the samples from the plant windrows, before fed to the double deck screen, a fraction 31.5 to 60 mm and a second fraction > 60 mm was sorted and then the components which have been sorted out were dried. While a sample from the fine grain windrows (0-25 mm) came up to 9 kg, from the operation windrows ca. 100 kg per sample had to be treated.

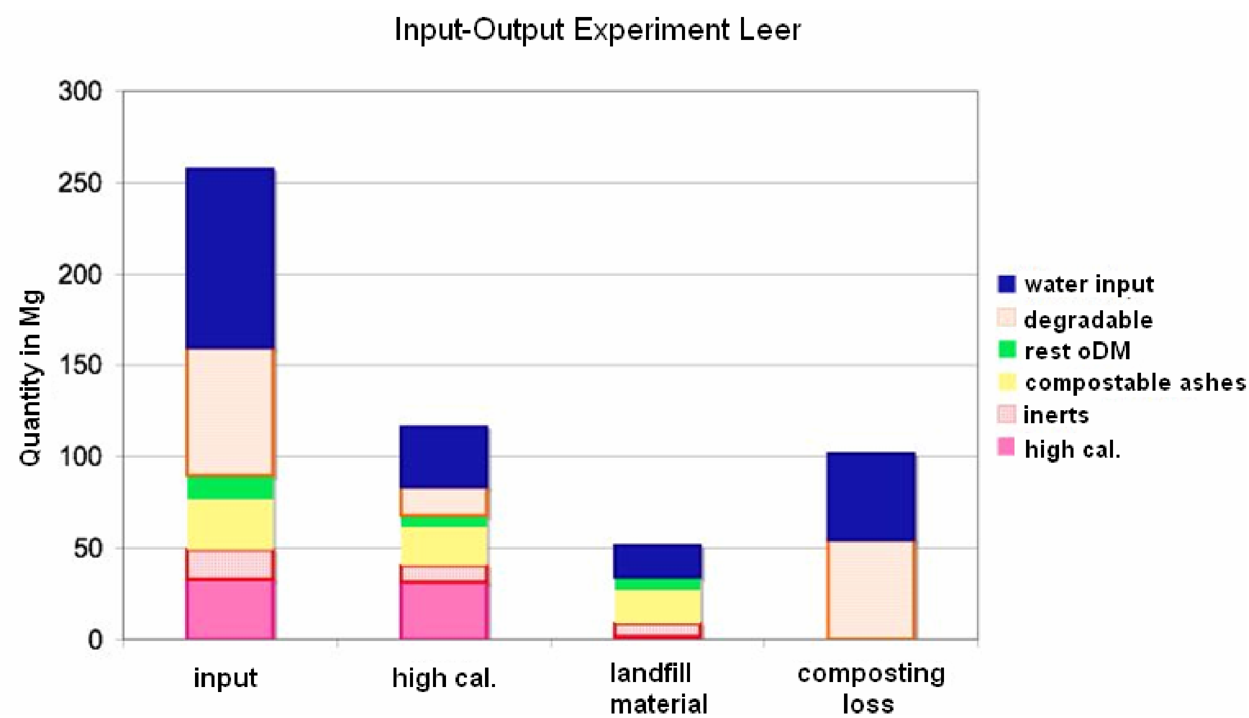

Figure 10 Balance of the „compostable“ components experiment Leer

3.3 Simulation of the process

The results allow to establish a simulation model which can be used to examine the influence of the input composition, the variation of the process parameters and the extraction of high calorific components on the landfill material quality.

The emplacement density FM based on composition and compaction densities is calculated at 1.34 to 1.46 Mg/m³ and pretty much corresponds to the laboratory results of Dr. Entenmann, IGB Oldenburg who has measured dry densities between 0.78 and 0.86 Mg/m³ for the conventional landfill material from Wilsum.

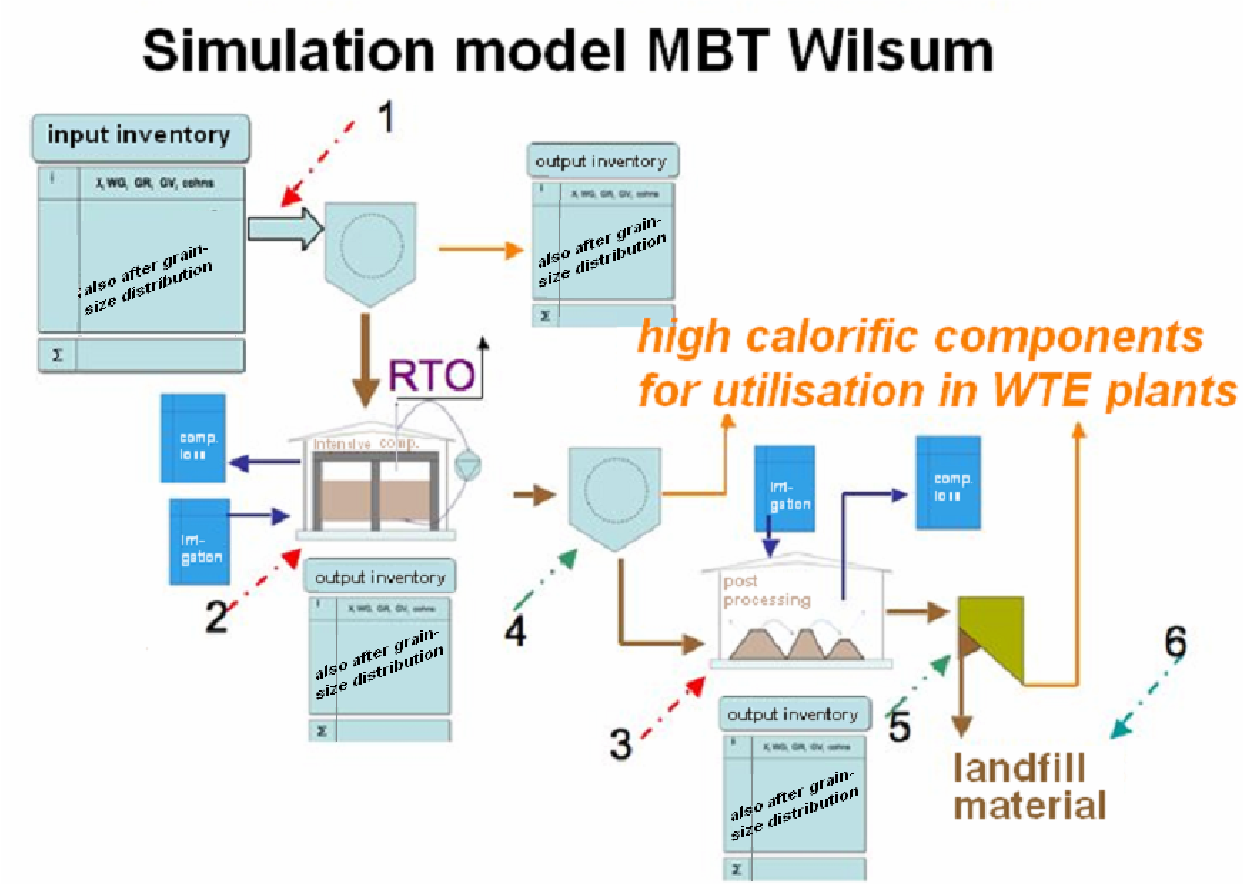

Figure 11 Scheme of the implemented simulation model on Excel

4 System evaluation

Considering the experiences made in Wilsum in connection with a reasonable price for the disposal of the sieve overflows, a processing into refuse-derived fuels does not seem to be economically sound. The compliance with the storage criteria requires a sufficiently large-sized intensive composting and enough roofed biological post processing areas. For the latter, it should be considered that shifting is only possible under suitable wind conditions, to not disturb the neighbourhood. The sieve overflow for the WTE-plant contains many inert substances and the landfill material contains too many high calorific components. The shredding must selectively crush hard inert matter, plastics have to remain as large-sized as possible. In the first separation stage one sieving is at considerably more than 100 mm, but after composting plastic films and high calorific components have to be separated by sieve/classifier combinations. In intensive composting, there is no possibility to cool the recirculation air. In biological post processing, there is no efficient irrigation system. The rotting process can be improved.

The economic analysis shows that the existing residual landfill volumes at the site Wilsum and the missing recovery does not allow an alternative to the present operation. Any further optimisation measure such as the installation of a digestion stage can only be justified if the throughput amounts are thus augmented and additional external quantities can be acquired and bound by contract.

5 Summary

The comparison of waste incineration (e.g. visit of the plant Mainz) to MBT by the students has led to the common consent that the incineration solution is the most convincing. 10 years ago, the opinion of the students was exactly the opposite. Especially the working conditions in MBT-plants are seen as critical. Simple efficient and reliable systems are required. The MBT technology can be justified for rural areas with sufficient landfill capacities as long as they are considerably more cost-effective than waste incineration.

The necessity of the homogenisation drum in the mechanism in Wilsum could not be proved and the drum is now switched off. The compliance with the storage criteria requires careful working; to this effect, an irrigation system was installed in the biological post processing unit. The coarse sieve cut at 100 mm has proved advantageous for the air supply of the windrows. Additional composting capacities are necessary to avoid disagreements with neighbours and to optimally operate the rotting process. The optimisation of the separation of high calorific components seems to be necessary. The sampling and sample pre-treatment out of coarse-grain piles has to be adjusted accordingly. To this effect, experiments are conducted at present. The monitoring of the storage quality can in the medium term be considerably facilitated for the corresponding facility allowing to thus safe 1.5 Euros per ton. This sum added up over 15 years could be “more sustainably” invested for plant improvement. Also necessary is the further analysis and evaluation of the air conduction and exhaust gas treatment.

The operation of a fine-grain table windrow 0-25 mm with natural aeration has turned out to be difficult regarding air supply. Only 3-5 vol.-% of oxygen were determined in the windrow. The decomposition took much too long with 270 days. Based on sieve and sorting analysis over the whole composting process, the material flow can be reproducibly traced. Of originally 54 Mg carbon in the input of the windrow Leer, 6 Mg are at the end still in the landfill material, about 36 Mg in the WTE-plant and the rest (34 Mg) has emitted into the atmosphere as carbon dioxide. Of 27 kg/E/a glass, 20 kg/E/a are collected separately; 7 kg are in the residual household waste from Leer, 4 kg are passed on the landfill and 3 kg go to the WTE-plant. The separate collection of voluminous plastics and paper is sustainable and relieves the MBT. The portion of non-degradable plastics and similar high calorific components is considerable with about 15 % in the DM which is 30 kg/E/a from the Leer district. The calorific value of the waste is calculated with 8.2 MJ/kg.

6 Literature

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