The situation of Austrian MBT-plants – a synopsis of data originating from a research project

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Die Situation der österreichischen MBA-Anlagen – eine Zusammenschau von Daten aus einem Forschungsprojekt

Abstract

The target of the FWF-research project (January 2007 to September 2009) is the development of prediction models for the determination of time consuming parameters. Respiration activity, gas generation sum and calorific value have to comply with the limit values of the Austrian Landfill ordinance before landfilling. The prediction models are based on infrared spectral and thermal analyses (differential scanning calorimetry DSC) and multivariate statistics. Due to many advantages these methods are promising tools for the application in waste management practice in the future. In the course of the project many data of all Austrian MBT-plants were generated using conventional and innovative methods. This study gives a short synopsis of the results obtained to date. Similarities and differences between the plants depending on input materials and process operation are presented. Variations of processes in the same plant due to changing operation conditions are visualized by FTIR spectroscopy, thermal analysis and by conventional parameters.

Inhaltsangabe

Das Ziel des FWF-Forschungsprojektes (Januar 2007 bis September 2009) ist die Entwicklung von Vorhersagemodellen zur Bestimmung zeitaufwändiger Parameter. Atmungsaktivität, Gasbildungspotenzial und Brennwert müssen vor der Ablagerung des behandelten Abfalls die Grenzwerte der österreichischen Deponieverordnung einhalten. Die entwickelten Vorhersagemodelle basieren auf infrarotspektroskopischen und thermoanalytischen Untersuchungen (Dynamische Differenzkalorimetrie). Aufgrund ihrer Vorteile sind diese Methoden Erfolg versprechend für die zukünftige Anwendung in der abfallwirtschaftlichen Praxis. Im Zuge des Projektes wurden viele Daten aller österreichischen MBA-Anlagen generiert. Diese Studie gibt eine kurze Zusammenschau der bisher verfügbaren Ergebnisse. Ähnlichkeiten und Unterschiede zwischen den Anlagen in Abhängigkeit von Input-Material und Prozessführung werden gezeigt. Unterschiede der Prozesse innerhalb einer Anlage durch Veränderungen des Prozessablaufes werden durch die neuen Methoden und durch konventionelle Parameter dargestellt.

Keywords

Austrian MBT-plants, material characterization, processes, data evaluation

Österreichische MBA-Anlagen, Materialcharakteristik, Prozesse, Datenauswertung

1 Introduction

1.1 Objectives

Since 2004 pretreatment of municipal solid waste and compliance with limit values according to the Austrian Landfill Ordinance has been required. In terms of reactivity and gas forming potential biological parameters are in the focus of interest. The calorific value provides information on careful separation of plastics and additionally on progressing degradation. The research project (1/2007-9/2009) concentrates on the development of prediction models for the time-consuming biological parameters (respiration activity and gas generation sum) and for the determination of the calorific value. The models are based on infrared spectroscopic and thermo-analytical investigations in association with multivariate statistics (Partial least squares regression). During the project approximately 300 samples originating from the 16 Austrian MBT-plants were collected. Apart from spectral and thermal analyses and the corresponding reference tests samples were additionally characterized by conventional parameters to complete the data set and to give a comprehensive survey of Austrian MBT-plants.

The huge data pool provides a basis for the assessment of process operation and of input materials. Due to the detailed insight weaknesses can be revealed.

1.2 Sampling and Applied Methods

The sample pool comprises materials of different degradation stages, from input materials to landfilled MBT-waste. Sampling took place several times over a period of one year to get information on seasonal variations. Samples and plants are marked by capital letters.

At the beginning several months were spent on sample preparation. The small sample amount for spectral and thermal analyses requires particle sizes <0,2 mm. Several steps of chopping, cutting and milling were necessary to obtain representative residue-free samples and reproducible results.

Conventional analyses such as water content, loss on ignition, total carbon, total nitrogen, NH_4-N and NO_3-N, carboxylic acids (C2-C5), pH and electrical conductivity were determined according to Austrian Standards. Biological tests (respiration activity and gas generation sum) were carried out from the fresh sample (BINNER et al. 1998). Humic acid extraction was performed according to GERZABEK et al. (1993). FTIR spectra were recorded in the mid-infrared range (4000-400 cm^{-1}) using the KBr pellet technique (MEISSL et al. 2008). Thermal analysis was carried out according to SMIDT and TINTNER (2007). Data evaluation was supported by multivariate statistical methods (Brereton 2002) using the Unscrambler Camo 9.2 software.

2 Results and Discussion

2.1 Characterization by conventional parameters

Figure 1 (a, b, c and d) illustrates the box plots of data obtained from all Austrian MBT-plants. The box plots indicate the minimum, the maximum, the median and the 25% and 75% quantile of the measured parameters. Abbreviations: TN = total nitrogen (% DM), EC = electrical conductivity (mS cm^{-1}), LOI = loss on ignition (% DM), TOC = total organic carbon (% DM), RA_4 = respiration activity within 4 days (mg O_2 g^{-1} DM), GS_{21} = gas generation sum/ 21 days (NL kg^{-1} DM); WC = water content (% WM), C2-C5 = sum of carboxylic acids, HAc = acetic acid only. The parameters WC, LOI, TOC, TN, pH and RA_4 comprise 280 to 300 samples, the other ones 100 samples, EC: 45 samples.

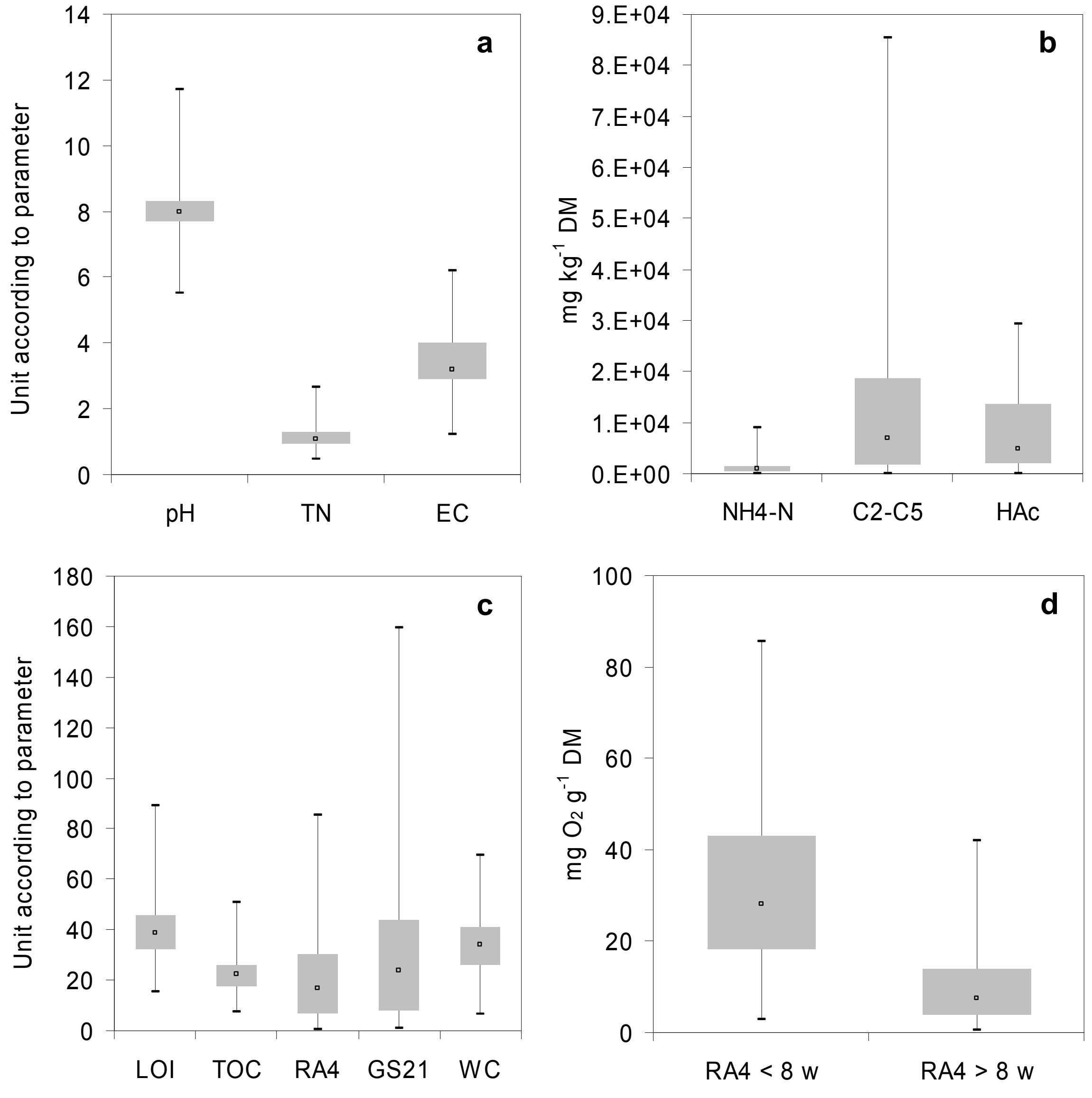

Figure 1 Box plots indicating the minimum, the maximum, the median and the 25 % and 75 % quantile of the measured parameters

The box plots visualize the range of the determined parameters from initial to final MBT-waste. Although carboxylic acids and NH_4-N are in general early metabolic products they were also found at later states of the biological treatment with high variability in the same plant. An unequivocal reason such as changes of material composition, could not be identified. Acetic acid contributed most to the sum of carboxylic acids (C2-C5). Figure 1d displays the range of respiration activities depending on the duration of biological treatment (< 8 weeks and > 8 weeks). It is clearly visible that most of the materials shift to respiration activities < 14 mg O_2 g^{-1} DM after 8 weeks. After an 8-week-treatment 12 materials reached the limit value of 7 mg O_2 g^{-1} DM.

2.2 Development of the loss on ignition and respiration activity during the biological treatment

The most noticeable decrease of the loss on ignition took place within the first 4 weeks, then it decreased continuously up to approximately 20 % DM (minimum: 15.4 %). Figure 2 demonstrates the development within the most intensive rotting phase. It has to be emphasized that the development is assembled by samples from different charges.

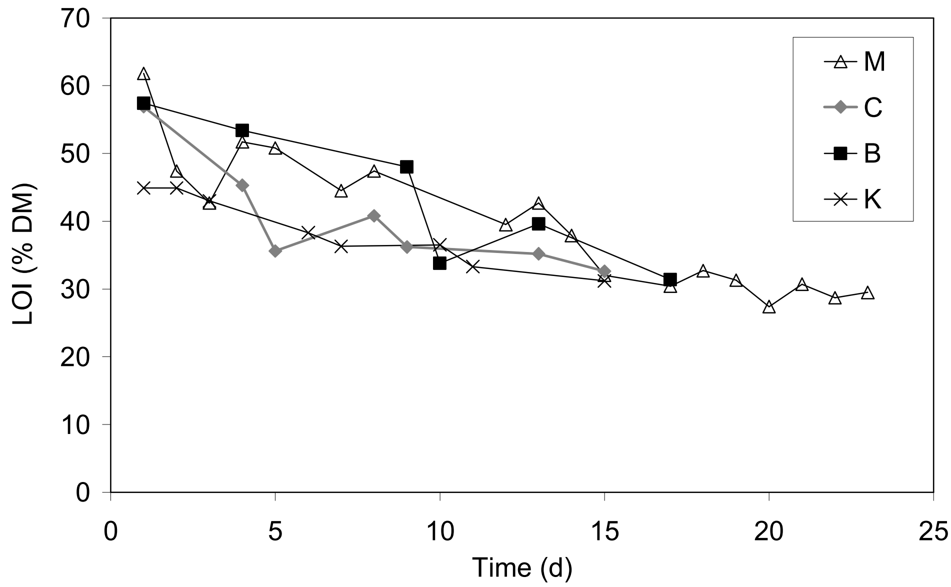

Figure 2 Development of the loss on ignition (LOI) in several selected MBT-plants

Compared to the loss on ignition (Figure 2) and the TOC (not shown), the gradient of the decreasing respiration activity is stronger. After two weeks microbial activity became weaker causing the curve to flatten. The subsequent decrease of respiration activity proceeded slowly. Figure 3 illustrates the particular decline of respiration activities depending on process operation. Plant "O" features a steep decrease due to strong aeration during 3 weeks. After 3 weeks the heavy fraction is separated from the light fraction. The light fraction comprises a considerable amount of organic matter that is combusted. The heavy fraction is landfilled.

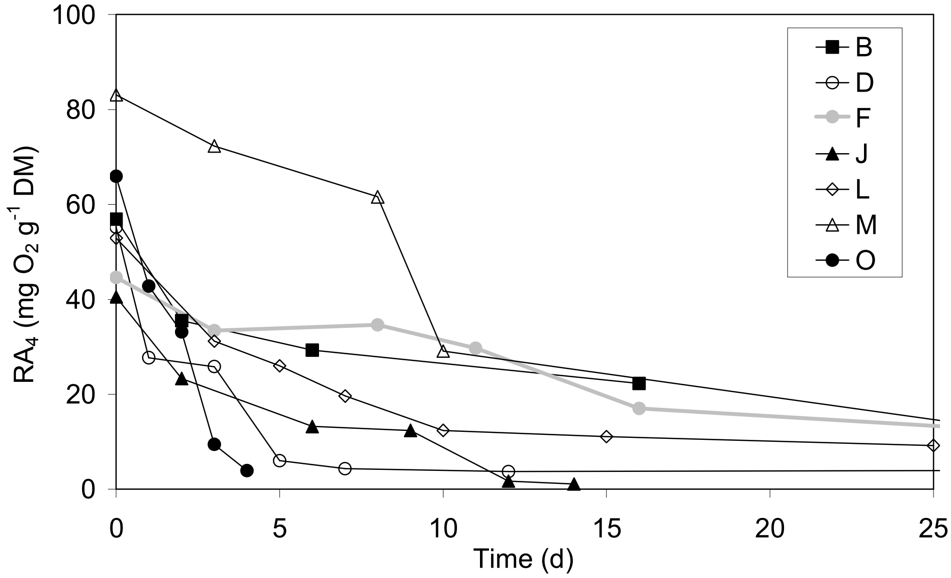

Figure 3 Development of respiration activities in several selected MBT-plants

2.3 Comparison of “landfill fractions”

Comparison of final materials intended for landfilling reveals the variability between different MBT-plants and between charges of the same plant. Data presented in Figures 4 and 5 (TOC and respiration activities) of the MBT-plants “F” and “O” visualize the differences. In general process conditions affected material properties more than seasonal diversity of input materials.

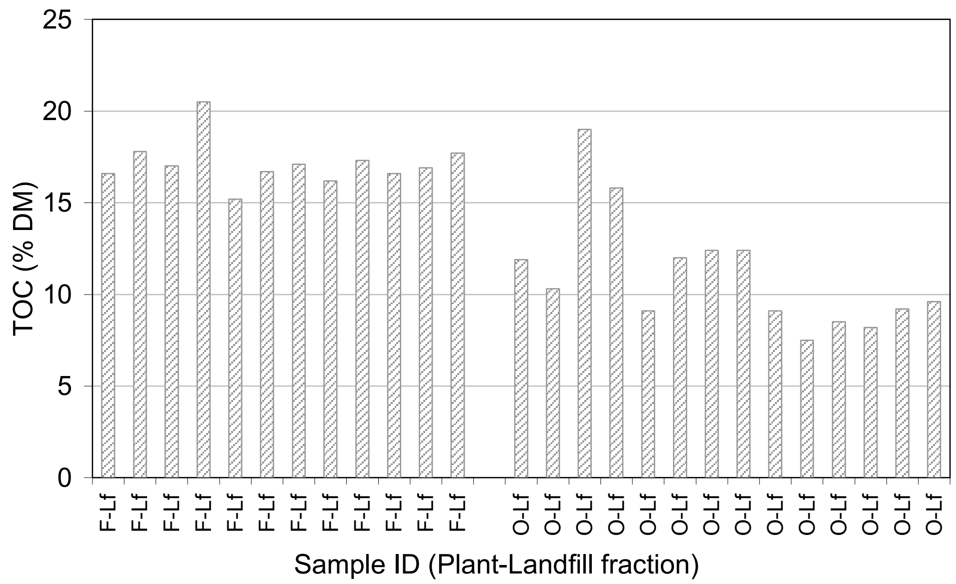

Figure 4 Variability of TOC in „landfill fractions“ from two MBT-plants (F-Lf and O-Lf)

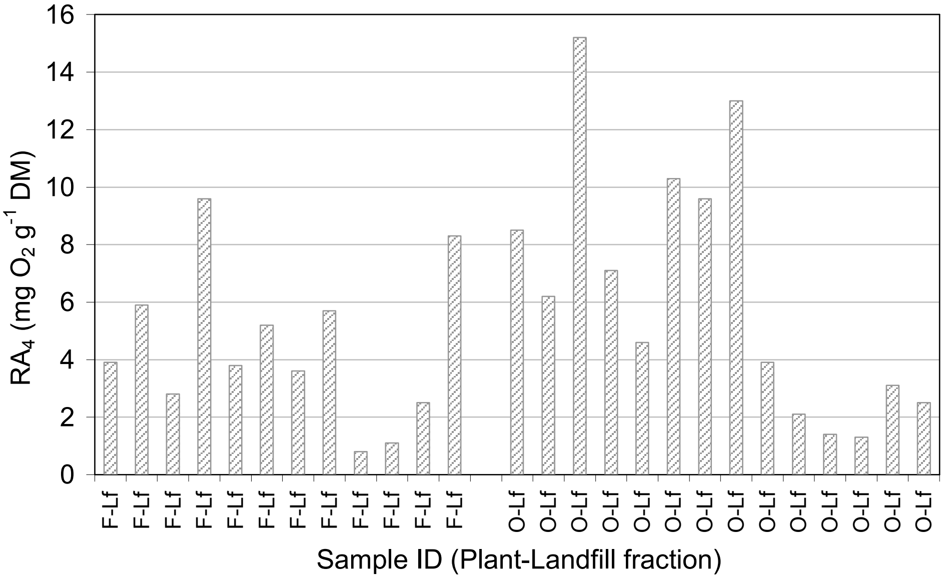

Figure 5 Variability of respiration activity (RA_4) in „landfill fractions“ from two MBT-plants (F-Lf and O-Lf)

In some cases the limit value of respiration activity (7 mg O_2 g^{-1} DM) was exceeded which led to closer inspection of process operation and process conditions.

2.4 Correlation of conventional parameters - evaluation

Parameters that were determined for all samples (LOI, TOC, TN, RA_4, pH, calorific value) were subjected to a principal component analysis to find out the relation among each other. The correlation loadings plot indicated a correlation between LOI and respiration activity. The calorific value was closer to the TOC than to the LOI. No correlation was found between LOI and TN, and all parameters and the pH.

Usually applied sum parameters such as LOI and TOC provide a rough estimation of a progressing process. They are less appropriate to compare different processes.

Considerable humification took place if the biogenic fraction was processed with MBT-waste. Biogenic materials contribute appropriate ingredients and therefore support humic acid formation. Stabilized MBT-materials feature in general humic acid contents of 10 to 12 % ODM. Humic acid contents of 28 % and 29 % were determined in MBT-waste “M” and “P” where biogenic waste is not separated. MBT-waste “M” additionally comprises sewage sludge. This fact confirms the hypothesis that biogenic materials contribute significantly to humic acid formation.

Determination of parameters such as NH_4-N, NO_3-N and carboxylic acids that is based on elution of the solid fresh sample are sensitive in terms of reproducibility. Composition and texture affect the elution behavior considerably.

2.5 Process conditions

The progress of the biological stabilization process depends on inherent properties of the material and process conditions. Material properties can be marginally influenced. Therefore attention is primarily paid to process conditions that need adaptation to specific requirements of the treated material in order to effectuate well running processes. Figure 6 displays data of gas measurements in the heap of two MBT-plants "F" and "G" (CO_2, CH_4 and O_2). Methane and CO_2 were still present in aged materials. Oxygen was missing in most cases.

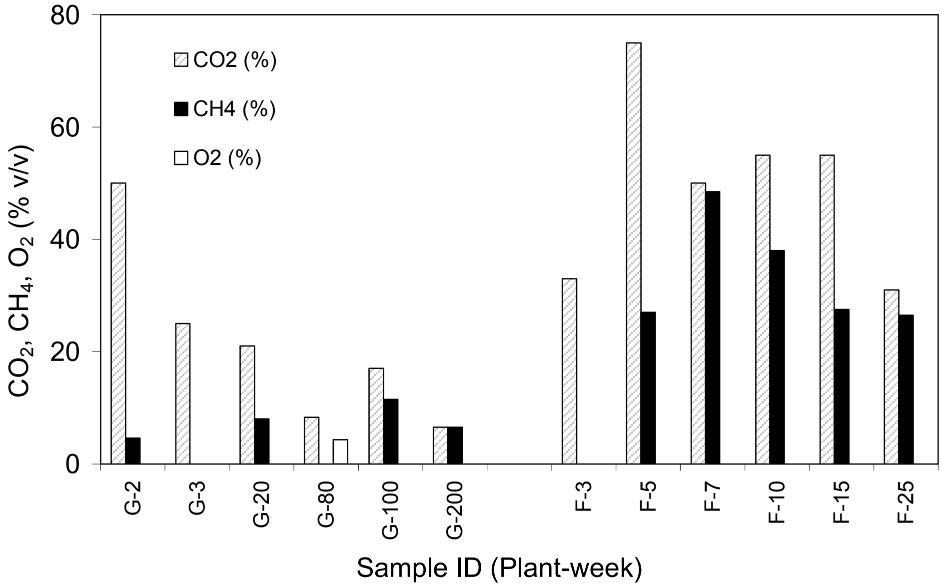

Figure 6 Measurement of gas composition in the heap at different stages of the biological treatment (MBT-plants "F" and "G")I

In most cases inadequate air and water supply are responsible for retardation of the biological process and odor nuisance. Clogging of holes in the aeration system often prevent sufficient aeration. Water deficiency leads to weight saving, which might be preferable sometimes. However, dryness pretends stability that is disproved by biological tests.

2.6 Application of FTIR spectroscopy and thermal analysis

2.6.1 Characterization of MBT-waste by the spectral and thermal pattern

FTIR spectroscopy and thermal analysis provide comprehensive information on waste materials due to many data points that characterize the material. A principal component analysis (PCA) based on spectral and thermal data of all samples revealed that MBT-waste in Austria is not as different that it can be unequivocally assigned to each MBT-plant. The variety due to different degradation stages is more significant than the variety caused by different input mixtures. Nevertheless, specific features influence the position of samples in the scores plot. Figures 7 a and b show the PCA of (a) spectral and (b) thermal data (heat flow profiles). Clustering of samples is obvious. Samples „D“ represent the material of the typical MBT-plant (municipal solid waste being partly rid of biogenic waste). In plant „M“ municipal solid waste is processed with the biogenic fraction and sewage sludge. Plant “O” processes the typical MBT-waste, but applies a special technique as described in section 2.2. Fresh materials are located in the right corner. Progressing stabilization causes samples to shift to the left side as indicated by the arrow. Samples “O” are similar to samples “D” at the beginning. After separation of the “light” fraction samples are primarily located in the left corner.

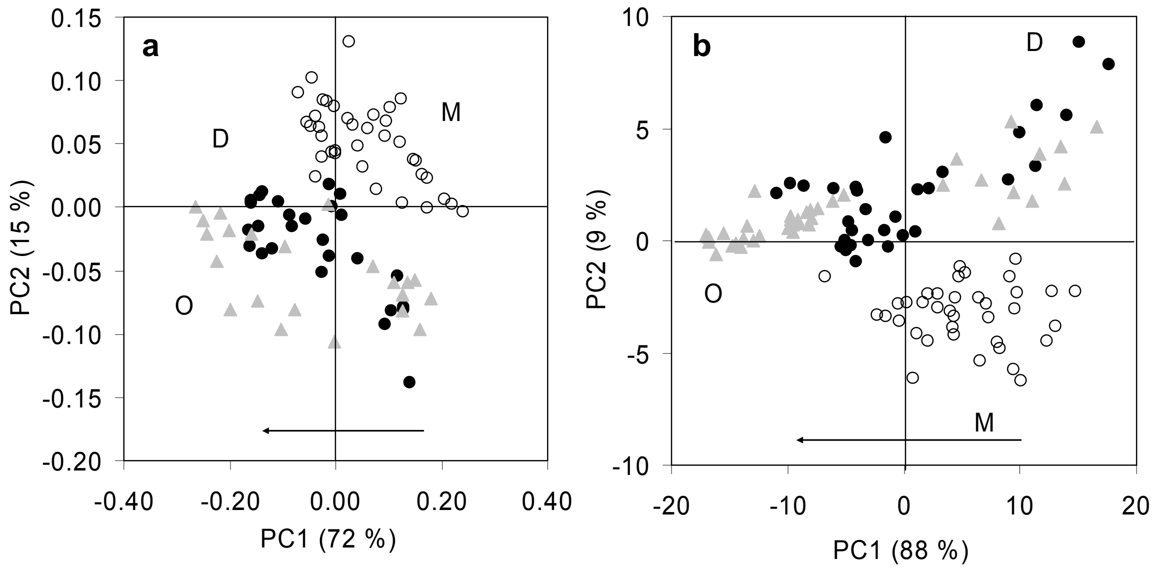

Figure 7 PCA based on (a) spectral and (b) thermal data of three MBT-plants (D, M, O)

2.6.2 Prediction of respiration activity, gas generation sum and calorific values

Multivariate statistical methods are helpful tools to evaluate huge data pools. Partial least squares regression has been used to develop prediction models of respiration activity, gas generation sum and the calorific value. These parameters are reflected by the infrared spectrum and the heat flow profile respectively. The development of prediction models is based on this correlation and requires large data pools. Model validation is performed by independent data sets to guarantee the validity of the model for all defined MBT-materials. Figure 8 demonstrates the correlation between the heat flow profiles and the calorific value that is a precondition within the scope of the preparatory work.

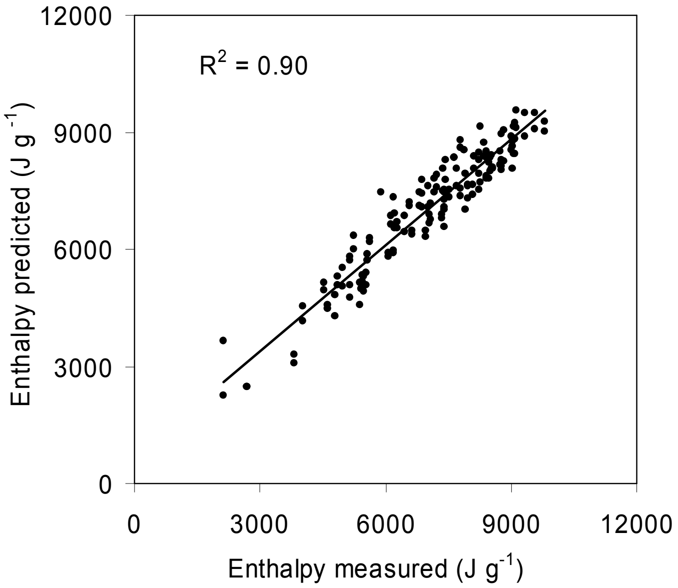

Figure 8 Correlation between the calorific value determined by the bomb calorimeter and by the heat flow profile

2.6.3 MBT-landfills as carbon sinks

Based on the data obtained the role of landfilled MBT-waste as carbon sink is assessed. For this purpose the determination of TOC is not sufficient. Due to diverse aspects of organic matter stability the term needs specification. The thermal behavior of materials seems to be a reliable indicator of stability. A current research topic focuses on the definition of "internal" stability that is an inherent property of waste and less dependant on environmental conditions. The correlation between decreasing enthalpy in the whole system, increasing enthalpy of remaining organic matter and bioavailability will be elucidated in future projects. Table 1 compiles data of enthalpies referring to dry matter (DM) and organic dry matter (ODM) of MBT-waste (3 weeks, 12 weeks, 120 weeks), landfilled municipal solid waste (MSW, 30 years) and an agricultural soil.

Table 1 Enthalpies of MBT-materials referring to dry matter (DM) and organic dry matter (ODM); w = week, y = year

Enthalpy	MBT 3 w	MBT 12 w	MBT 120 w	MSW 30 y	Soil
J g^{-1} (DM)	6,892	4,966	4,333	3,627	3,532
J g^{-1} (ODM)	14,733	21,286	24,718	33,245	48,920

3 Conclusion

So far the largest part of the project has been carried out. As shown by principal component analysis the composition of municipal solid waste in Austria does not differ considerably, neither by regional nor seasonal factors. Addition of sewage sludge or special treatment procedures cause a specific pattern that is identified by infrared spectroscopic and thermal analyses. Difficulties of biological treatment are primarily caused by unfavorable conditions for microbial activity, especially missing air and water supply. There is a potential of optimization in some cases. The development of adequate analytical methods that are fast and easy to handle is a crucial target to support process control. FTIR spectroscopy and thermal analysis are promising tools to achieve this purpose. They could replace several time consuming and error-prone parameters. The sampling procedure and sample preparation are still current topics to get reliable results.

It can be assumed that the improvement of separation technologies leads to a more homogenous organic fraction that is transformed to stable organic matter by biological processes. Optimization of internal stability is a target to be reached by appropriate process operation. In association with mineral compounds MBT-landfills will represent substantial carbon sinks in the future.

4 References

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