Evaluation of the biodegradability of organic waste by the means of impedance analysis

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Abstract

The biodegradability and consequently the stabilization degree of biologically treated waste is a required parameter to provide the evidence of the fulfillment for the German Waste Storage Ordinance (AbfAblV, 2002). The in appendix 2, AbfAblV recommended test procedures RA_4 (Respiration Activity over 4 days) and GF_{21} (Gas Formation over 21 days) takes at least 4 or 21 days respectively. Moreover, despite uniform regulation, obtained analytical results show a strong dispersion of the values particularly with regard to different laboratories.

Within this work basics for a new microbiological approach, the impedance analysis, are examined for the evaluation of the biodegradability. A clear correlation resulted in the case of impedance measurement and biodegradability. In addition the impedance values can be converted with appropriate regression equations into the standard parameters RA_4 and GF_{21}. Hence, it seems suitable, that organic waste samples may be controlled within a day on their depositing ability according to AbfAblV or the efficiency of the biological treatment processes could be examined by impedance analysis.

Keywords

Biodegradability, Composting, Municipal Solid Waste, Impedance, Microbial Population Dynamic, RA_4, GF_{21}. MBT

1 Introduction

In the course of the past ten years, stricter ecological requirements became effective to national and European regulations concerning the disposal of wastes.

Since January 2004 in Austria and, June 2005 in Germany the deposition of untreated waste is not allowed by law. Wastes for deposition must be pre-treated thermally or mechanical-biologically and have to fulfil the stability criteria of the Waste Storage Ordinance (AbfAblV, 2002). Hence this decreases the volume of the deposited waste, the biological activity in the organic portion as well as the quantity of gas emissions and landfill leachate.

An important and essential parameter for verification of the deposits ability is the biodegradability of the waste treatment output material.

In practice, the estimation of the biodegradability, determined by RA_4 or GF_{21} is associated with uncertainties and discomfort. Firstly, their long test duration: RA_4 takes at least four and GF_{21} up to 21 days. Secondly, the margin of errors is high. In interlaboratory tests it was determined that significant fluctuations, impede their experiences or quality standards (Bockreis, 2006).

Both methods RA_4 and GF_{21} essentially cause concern on the indirect determination of the microbial activity. In order to establish a new method, which reduces the test duration time and the error sources, the impedance analysis is investigated in this work. To be able to better explain the impedimetric results, the classical germ number determination was carried out too.

2 Background

Numerous studies describe the cell number of different microorganisms during the rotting process. There are many involved and cultivatable microorganisms known and in the newer development microorganisms are identified with molecular-biological methods (Ryckeboer, et al., 2003). Some authors appraise the development of microorganism's population to the biodegradability (Herrmann, et al., 1997); this work will prove these theses.

The classical cultivation methods for germ number counting are economical from the expenditure for material and supplies point of view, but not suitable due to the time expenditure. Molecular-biological methods are however cost-intensive and only feasible under trained laboratory personnel. An alternative method for the estimation of the stability of organic material on basis of microbiological populations should be more economical, more simple and faster than the standard methods RA_4 and GF_{21}.

Impedance analysis is an economical and fast microbiological method for germ number counting. This method is used particularly for sterility controls and germ number counting in the foodstuffs industry and in health care for drinking water quality control (Futschik, et al., 1995). Isolated applications within the range of the wastewater and/or sludge characterization are known likewise (Weichgrebe, et al., 2004).

The impedance measurement is an automated method with an increasing application in various fields of the biology (Cady, et al., 1978). It is generally recommended as a high-speed method for estimation of microbial contamination. In contrast to classical cultivation procedures, it is not necessary to wait for the appearance of a macroscopic visible colony. The germ number can be derived from the electro-chemical changes in the nutrient solution that is involved with microbiological metabolism. The online determination of this measurable signal shortens the analysis duration to a few hours.

An impedance-measuring instrument detects the change in the conductivity of the nutrient solution, which is caused by growth of the microorganisms. The theoretical relation of the electrode-electrolyte interface during bacterial growth is shown below:

$$\left|Z_{1,2}\right| = \sqrt{\left(G_m + 2G_i\right)^2 + \left(1/\pi \bullet f \bullet C_1\right)^2} \quad (1)$$

Electrical circuit equivalence between two electrodes. G_m – medium conductance, G_i – interface conductance, C_i – capacitance of each electrode, f - frequency (Guan, et al., 2004).

At the two electrodes, which are immersed into a nutrient solution, an alternating current (AC) is applied. Metabolic products created during the bacterial growth modify the ionic concentration, which, in turn, results in conductivity changes of the nutrient solution. Such modification is proportional to the concentration of viable microorganisms (Guan, et al., 2004). The recording and evaluation of the measured values occur through a computer with specific software. The conductivity represents as function of the incubation durance, the media impedance curve. This curve, resulted from the metabolic activity of the microorganisms, is very similar to the normal, bacterial growth curve.

According to the manufacturer of the impedance measurement device (SY-LAB Geräte GmbH, Neupurkersdorf / Austria), the parameter Impedance Detection Time (IDT) is used for the evaluation of the impedance measurement. IDT corresponds to the point of the beginning of the exponential growth in the normal growth curve of the microorganisms. With appropriate calibration, IDT is also used for rapid determination of the germ number.

3 Research Objectives

The decomposition of organic substance is a very complex microbiological process. Today there are numerous investigations over the composition of the microbial communities in solid waste or compost (Ryckeboer, et al., 2003), (Harutaa, et al., 2005). However, the function of individual species, populations and their contribution to the process of decomposition, are not well known. Moreover, in the most works data are achieved with classical, cultivate-based methods, where the difference is observed only between mesophilic and thermophilic microorganisms. The examined groups of microorganisms are mostly limited to total cell count, fungi and actinomycetes. The comparison between the results of different research groups is often difficult, because no standardized investigation methods were used in their experiments.

Several microorganism groups were suggested to be suitable an indicator for biodegradability of organic materials. Although we can certainly assign specific microorganisms to different degrees of decomposition, en suitable method to determinate the biodegradability could not be developed.

One aim of this investigation was to study the microbial population dynamics during composting and determining the stability level of the product by microbiological approaches.

In the first part of this work, all samples were examined simultaneously with standard methods to determine the biodegradability (RA_4, GF_{21}, organic dry matter (ODM) and self-heating) and microbial methods in order to evaluate correlations between the stabilization degree and the microbial population dynamics. Investigations on changes in the germ number of different microbial groups were accomplished during organic waste (OW) composting. The dependence was examined between germ number and the stabilization of the organic material. Further, the suitability of impedance analytics was examined as a high-speed method. Appropriate growth media for impedance analytics were tested.

In the second part of the work, the data was transferred to residual waste (RW) from the Mechanical-Biological waste Treatment. The impedimetric approach could be used for the examination of the deposit ability according to AbfAblV with appropriate calibration. The calibration was carried out with material from a full-scale MBT-facility.

4 Methodology

4.1 Treatment Process and Sampling

Actual OW was taken from a full-scale composting facility (aha, Lahe). It consists of a mix of organic waste (kitchen and garden waste) and a small amount of horse manure and wood shavings. The total duration of the composting amounts to 13 weeks, with 6 weeks of intensive-rotting (with aeration) and 7 weeks maturation.

RW was taken from a full-scale MBT facility (RABA, Bassum) for municipal solid waste. The input for the plant consists of household similar trading waste and municipal solid waste. In the mechanical waste treatment iron and non-ferrous metals are sorted out. In the following rotary sieve drum, the material is separated into 40 and 60 mm fractions. The fine fraction of 0 to 40 mm is stabilized in a wet fermentation process. The 40 to 60 mm fraction is treated for 8 weeks along with the fermentation residues aerobically by an intensive rotting and 6 weeks maturation afterwards.

Three samples of about 3 kg were taken from the middle and the sides of the pile, every week after turning the material. For analysis, the samples were mixed and briefly hand sorted to remove large inert material, such as metal and glass. According to the ASA Standard, the samples were milled up to 10 mm (Rohring, et al., 2007). For the microbiological analyses eluates were made from the solid material. Therefore, 50 g of the ma-

terial was made up to 1 L with physiological saline solution and suspended for 1 h in an overhead shaker.

4.2 Selective Media and Incubations Conditions

For the investigation of individual microorganism groups, selective growth media were used. Total germ count: Nutrient Broth, Difco (NB) and SY-LAB 001B (SY); Gram-positive: Phenylethyl Alkohol Agar, BBL (GP); Gram-negative: NB-Medium with SDS (GP); Actinobacteria: Actinomycete Isolation Agar, Difco (AI); *Arthrobacter:* CT-Medium according to Tanaka (CT); Lactobacillales: MRS-Agar, Fluka (MRS); Cellolytic group: CMC-Medium according to Ryckeboer (CMC); Fungi: Sabouraud Pepton-Agar (SAB). The selective growth media were used without changes for the impedanceanalytic and plate count.

The incubation occurred in the mesophilic range at 30°C. Duration of incubation varied depending on the microorganisms group for the plate count between 2 to 5 days and for the impedance-analytic between 1 to 10 hours.

5 Results and Discussion

5.1 Plate Count

The partial results of the germ counting are shown in Figure 1. In comparison to the determination of the germ number the simultaneously analyzed Biodegradability (RA_4) is shown.

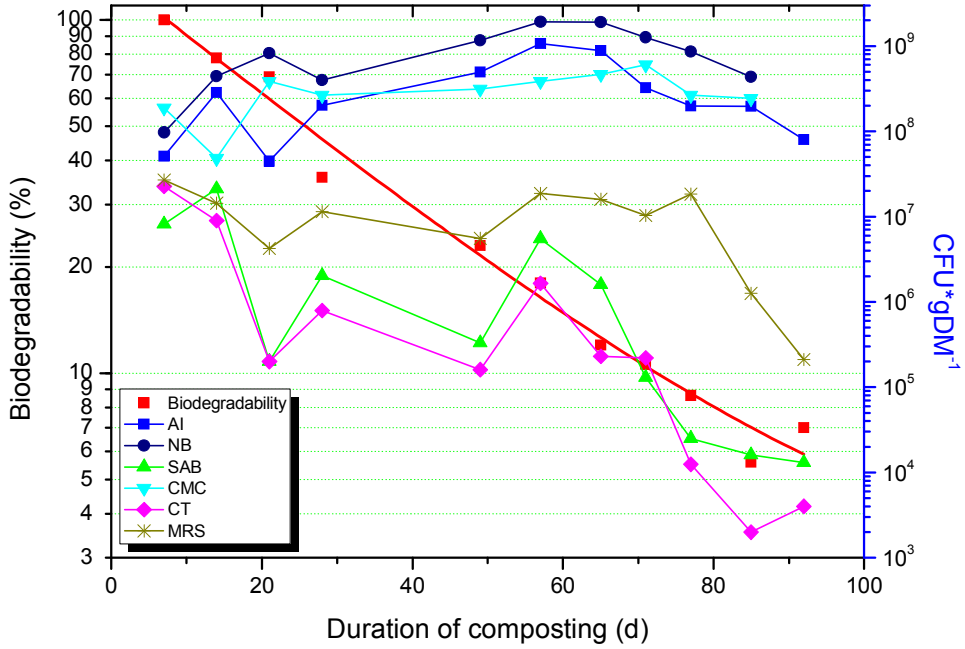

Figure 1: example for Germ count biodegradability (RA_4) AI – Actinomycetes, NB – total germ count, SAB - Fungi, CMC – Cellolytic MO´s, CT – Arthrobacter, MRS – Lactobacillales.

The thermophilic phase last from day 3 to 25, with temperature until 70°C. For all investigated microbial groups the effect of the temperature is stronger than influence of the biodegradability.

None of the tested microorganism groups show a suitable correlation with the biodegradability (measured by RA_4). Similar results also arise for the correlation with parameter GF_{21} (data not shown). A weak correlation is present by the Lactobacillales, fungi and *Arthrobacter* group. Only in the last phase of composting, the germ number could be an indicator for biodegradability.

Due to the strong heterogeneous microorganism's community in solid waste, only a weak correlation was observed between the results of germ count and impedimetric approach (data not shown).

5.2 Impedimetric Approach

For the impedimetric approach, the same selective growth media were used. The results are shown in Table 1.

Table 1: Established correlations between IDT and biodegradability, by screened groups of microorganisms. Key: strong – R^2 > 0,8; present R^2 0,8-0,5; absent R^2 < 0,5.

Group of microorganisms	**Correlation of IDT and biodegradability**	
	OW	**RW**
Total germ count	strong	present
Gram-positive	not tested	strong
Gram-negative	not tested	strong
Actinomycetes	strong	present
Arthrobacter	strong	not tested
Lactobacillales	present	strong
Cellolytic microrganisms	absent	not tested
Fungi	strong	present

A strong correlation of IDT and biodegradability show the groups of actinomycetes, *Arthrobacter* and fungi in OW, and Gram-positive, Gram-negative and Lactobacillales in RW. The growth media with a strong correlation may be used to evaluate the biodegradability of the dry residue according to AbfAblV. Just as well to estimate the compost maturity.

The relation of the IDT-value (total germ count) to RA_4 and GF_{21} is shown in Figure 2.

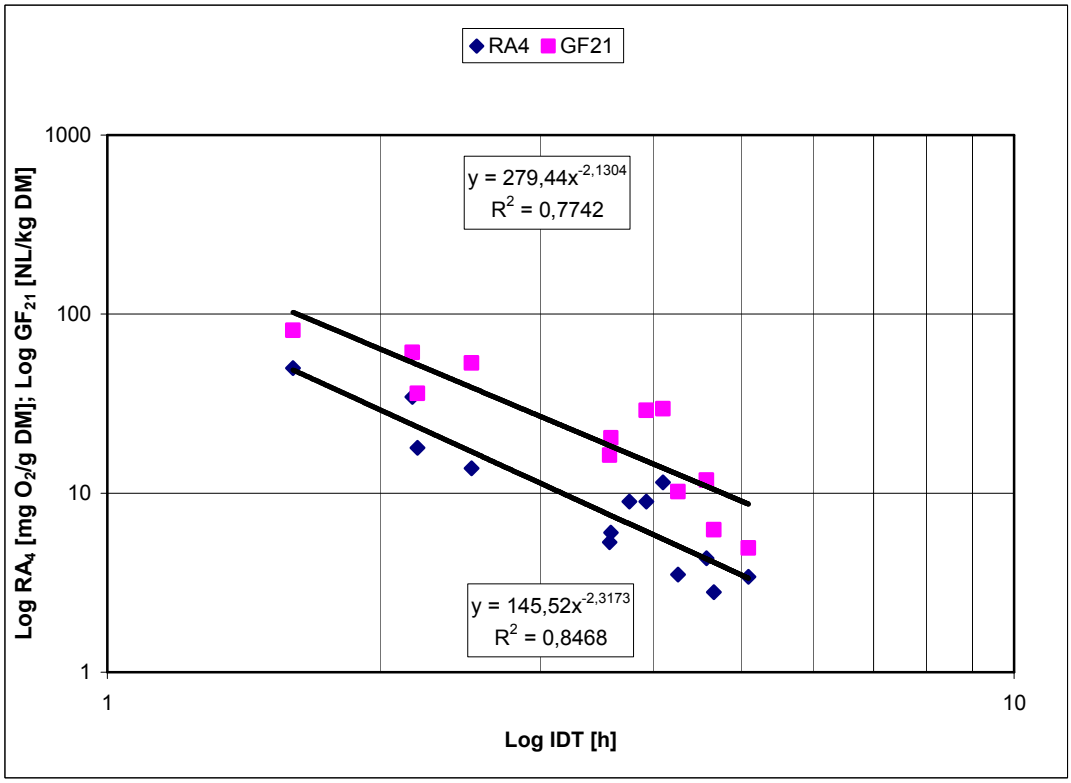

Figure 2: IDT in correlation with RA_4 and GF_{21} (organic waste). Growth media for total germ count used.

IDT can be converted as follows into the RA_4:

$$RA_4[mgO_2/gDM]=141{,}52 \bullet IDT[h]^{-2{,}3173} \quad (2)$$

GF_{21} can be estimated with the following equation:

$$GF_{21}=[NL/kgDM]=279{,}44 \bullet IDT[h]^{-2{,}1304} \quad (3)$$

6 Conclusions

The use of impedance analysis provides a method to define microbial activity during waste treatment processes. In this study, samples of a composting plant and of a waste treatment process on a full-scale facility were examined by impedance analysis along the process operation. For this organic waste (OW) and residual waste (RW) were investigated in particular.

As expected rapid changes in germ number were observed during the waste treatment. According to other works different microbial groups are related to different stages of degradation. Nevertheless, no clear correlation between the germ number and the biodegradability was determined. The germ count is not suitable to determine the biodegradability clearly, because it is primarily dependent on the rotting temperature of the

organic material. Only in the last phase of rotting, where no more self heating is observed, the germ number can be used as an indicator for the biodegradability.

On the other hand, a clear correlation resulted in the case of impedance and biodegradability. We suppose that the impedimetric signal is primarily dependent on the activity of the microorganisms and the composition of the microbial community in the waste sample, but further investigations are necessary.

Impedimetric analysis of stabilised composts may provide a method for evaluation maturity and stabilisation of varied composts. However, more important is the application for RW. The feasibility of evaluating the biodegradability and stabilisation degree of a waste sample with impedance analytics is shown. The analysis is suitable for aerobically or anaerobically treated wastes. Full stream fermentation was not examined so far. With the regression equation, it is possible to convert the IDT values into RA_4 and GF_{21}. The period to obtain the analytical results by the means of impedance analytics shortens to 1-24 hours in contrast to RA_4 and GF_{21} with 4 and 21 days respectively. The definite duration time depends on the activity of the sample.

IDT seems to be an attractive alternative against RA_4 and GF_{21}, which helps the operator to control and to observe the waste treatment process quickly and easily. Nevertheless, to establish such a method, further investigations are necessary and are under progress.

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