Investigations on the Separability of Dynamically Dried Municipal Solid Waste – First Results

B. Bartha, J. Brummack

Institut für Verfahrenstechnik und Umwelttechnik, Technische Universität Dresden

Untersuchungen zur Trennbarkeit von dynamisch getrockneten Restabfällen - erste Ergebnisse

Abstract

The physical properties of the output of biological drying of municipal solid waste (MSW) in a rotary drum reactor have been analysed. It could be shown, that the determined combination of biological and mechanical processes within the reactor can lead to output qualities that with state-of-the-art static reactors can not be reached or a complex post treatment (bulking, post-crushing) is necessary for that. By sieving and manual sorting in substance classes (fibrous, plastic, miscellaneous) the individual product fractions could be described in detail very good. The results can be the basis of the further development for separation of MSW.

Keywords

biological drying, MSW, rotary drum reactor, dynamic treating, separability

1 Introduction

For six years the authors of this paper have dealt with the aerobic treatment of municipal solid waste (MSW) in a dynamic reactor. The results of these investigations have among others been extensively published in (BARTHA ET AL., 2003), (BARTHA ET AL., 2006).

From a processual point of view the aerobic treatment of solid waste constitutes a three-phase-system which is characterised by its utter complexity. The static aerobic fixed film process is dominant in practice today although for biogenic waste or waste with biogenic components this process is, from a chemical-physical point of view, only partially controllable. In a static heap a rapid development of inhomogenities, caused by different material systems, which intensify further during the process, is characteristic of these processes. Yet the almost exclusive use of the static aerobic fixed film process is justified by the fact that processes in static reactors (boxes, tunnels) can technically and economically be put into practice rather easily.

Dynamic reactors, especially rotary drum reactors, are hardly used in every day practice even though they allow a cyclic decomposition of the more critical gradients in the fixed film. Reasons for this apart from higher investment costs are the so far bad experience with the use of so-called composting drums in composting. The treatment of wet and structurally poor biowaste, which is in principle unsuitable for a treatment in fixed film, indicates the lack of knowledge of the mechanic and biological processes running parallel in the rotary drum reactor.

With the introduction of more complex automatic sorting techniques as they are known from DSD-sorting more recyclable flows, for example different types of plastic or paper, could be made from MSW. The successful automatic sorting presupposes a pourable and in reference to the different fractions homogenous input material. With increasing heterogeneity of the material flow to be separated (bonds, adhesions) the energetic and mechanic effort increases or respectively the product quality decreases. Especially with adhesions on flat plastic fractions (foils, bags) the product's worth is decreased significantly.

2 Biological Municipal Solid Waste Conditioning in the Rotary Drum

2.1 Biological Processes in the Municipal Solid Waste Treatment

The changes in the statutory framework for landfilling and the rethinking in the working with MSW made the mechanical-biological waste processing an essential part of waste disposal and use in Germany.

In all mechanical-biological processings the biochemical conversion of the material is the single most important part of the process. The preceding und succeeding mechanical steps are either used for adapting the material's features to the requirements of the biological process or they are necessary for the further processing of the output of the biological step. Two chief purposes are distinguished in aerobic process concepts (BRUMMACK ET AL., 2005):

- biological stabilisation through quantitative degradation of native carbon compounds for the production of a storable high calorific fraction through mechanical-biological processing (**MBP**) and
- dry stabilisation through biologically supported water extraction and subsequent material flow separation without production of disposable fractions (**MBS**).

The main plant concepts are illustrated in fig. 1

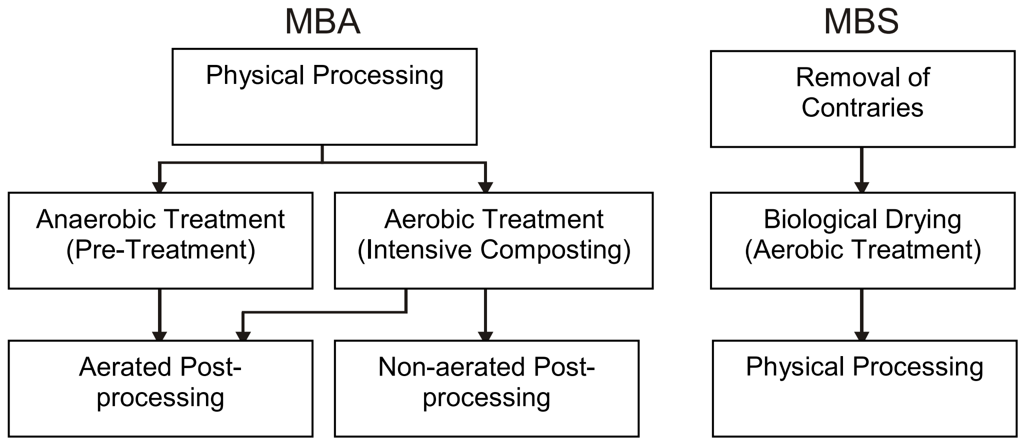

Figure 1 Biological process concepts for MSW treatment

Of the 5.2 Mio. mg/a plant capacity in biological municipal solid waste treatment plants authorized in 2007, about 4.0 Mio. mg/a are allotted to MBP-plants and 1.2 Mio. mg/a to MBS-plants (BMU, 2006). The majority of the implemented processes requires an aerobic treatment during the biological step. The few anaerobic concepts also require a second, then aerobic step for the follow-up treatment of the fermenting residuals. Thus, the aerobic treatment has a key function in all mechanical-biological conditioning processes.

In the *MBP-processes* a major part of the organic components has to be degraded in the waste for the production of disposable materials to avoid later undesired biological processes in the landfill body. The demands for the features of the rot output (landfill material) are prescribed by the Ordinance on Environmentally Compatible Storage of Waste from Human Settlements and on Biological Waste-Treatment Facilities (2001).

In the *MBS-processes* on the other hand, only as much degradation performance is necessary as energy for the evaporation of water from the material until its dry stabilisation is needed. This can be achieved with an intensive process, the operating period of which is about one unit shorter than the time necessary for the biological stabilisation of MBP-processes. A modification of the physical features is achieved by drying. This enables the recovery of a pollutant-free high calorific fraction and fuel features as well as more recyclable fractions (metals, minerals) through well-known physical separation processes (sieving, sifting, magnetic separation).

Another major difference between MBP- and MBS-concepts is the way the material is guided before and after the biological treatment (see fig. 2). MBP-plants are usually constructed as *part flow plants*. This means that after the pre-crushing but before the biological treatment a material flow separation is carried out. One or more high calorific fractions as well as metals or foreign material are separated from the total flow. The waste organics yet to be biologically treated are concentrated in the remaining flow. Waste organics are understood to be the bio-degradable part of the waste. The remaining flow is conditioned before the biological treatment step (homogenised, humidified). Seemingly for process economic reasons the material to be biologically treated is reduced, yet at the same time the profound knowledge of the ideal conditions of a rot is ignored. For detailed descriptions of this problem and its consequences see BRUMMACK ET AL. (2005).

In MBS-concepts the material flow separation is obligatory after biological drying; an exception is a possible foreign material separation. Such plants work in *full flow mode*.

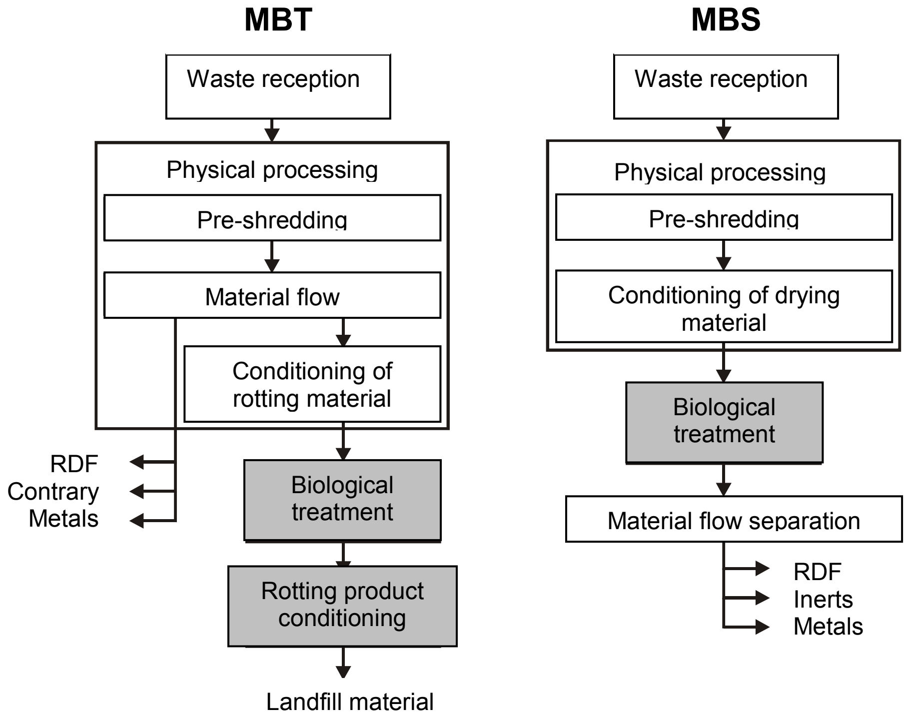

Figure 2 Schematic process flow in MBP- and MBS-plants

If and how effective a material flow separation before the biological step really is, depends mainly on the resultant water content of the input material. Is it higher than 40 m.-% which is typical for medium-sized and big cities in Germany and comparable countries and rather independent of an implemented separate biowaste collection system, a physical material flow separation before a biological treatment requires a high instrumental and energetic effort due to limited separability. Badly separable mixtures generally lead to an increased wear and tear of equipment with according consequences on the effective maintenance costs as well as the availability of the plants.

In the aerobic MBP- as well as in the aerobic MBS-technology statically working reactors such as rotting tunnels and composting boxes as well as other variations not deviating from the basic principle are used for the biological intensive step. The use of static reactors presupposes that all mechanical process steps be realised either before or after the biological treatment. The consequence of this sequential process flow is that the physical and chemical features of the substrate, which are ideal for the biological treatment, must be achieved before the biological process. There are no defined possibilities to influence the most important heap parameters during the running biological process in the static reactor. It is only by rearranging the material that parameter gradients can temporarily be cancelled out. For moist MSW the use of dynamic reactors therefore is interesting as they allow a coupling of biological and mechanical processes, in other words, reactors that run the biological treatment and the mechanical digestion both at the same time.

2.2 Investigations on the Treatment of Municipal Solid Waste in the Rotary Drum Reactor

During a running promotion process at the University of Technology in Dresden, a fully automatically working test-rotary drum has been developed and realised on a pilot scale for the dynamic treatment of waste with organic parts. Within the scope of three test series with up to 1000 kg per test, the following essential connections could be verified:

- The flexibility of the rotary drum as opposed to the varying input qualities could be proved through a broad range of the used input material (MSW in its original condition, fine fraction of mechanically pretreated MSW from a MBP-plant, sorting residuals from a sorting plant for packaging waste).
- Neither pre- nor post-crushing was necessary.
- Due to parallel realisable mechanical and biochemical sub-processes the combination of process and reactor shows the best possible prerequisite for the implementation of surface processes in structurally inhomogeneous fixed films. Due to the cyclic reproduction of the process-relevant propelling force the drop of the process speed, which is unavoidable in static reactors with their unchangeable surface structures in the heaps, is opposed in a way that ideal conditions for a biological degradation are practically given at all times.
- It could be shown that already a rotary time share of 1-2 % of the total in-process time is sufficient for reaching the theoretically justifiable limits of the biological drying as well as for guaranteeing the desired mechanical digestion.
- Only the dynamic reactor enables an ideal utilisation of the aeration air and therefore a minimisation of the fed amount of fresh air and resulting amounts of exhaust gas. If this option is projected onto actual operated plants, with this alone great savings can be predicted regarding the energy demand for the moving of the air, but above all the operation of the exhaust gas cleaning systems.

- Due to air circulation, which is customary also in static reactors and which enables an orderly degradation process in the rotary drum even with an extremely low oxygen concentration in the incoming air of up to 3 vol.-% and with it an ideal heat release, a further reduction of the amount of exhaust gas yet to be treated is possible. Thermal-regenerative exhaust gas cleaning systems therefore require clearly less auxiliary energy. There is less exhaust gas to treat and it has a considerably higher calorific value.

At present, there are no operating rotary drum reactors in MBP-/MBS-plants for the biological treatment step in Germany. However, the findings can be considered fundamental for the future economic evaluation and for the possibilities of applying the dynamic process in practice.

3 Investigations on the Product Quality after the Dynamic Treatment

3.1 Influence of the Dynamic Treatment on the Product Quality

The dynamic waste treatment is characterised by the moving of the solid material during the treatment. Especially the mixture of materials of differing density and form stability leads to a shredding which mainly affects the softer parts. The shear and compressive forces developing in this process are considerably smaller than in the comminution aggregates.

The shredding of MSW in rotary drums is *autogenous* because the pulverising and specifically heavy parts are included in the material system. This leads to the fact that pulverisation is:

- *gentle* because problematic material, e.g. bottles or batteries, are not destroyed and
- *selective* because only the soft parts (vegetables) are pulverised and fibre compounds such as paper, cardboard and tiles dissolve only partially.

At the same time the mechanic influence causes the digestion of ever new surfaces of the biogenous parts that up to this point have been inaccessible to aerobic degradation. From a biological process point of view this equals a regular feeding of degradable substrates in an extreme case up to their complete consumption.

During the dynamic biological drying process the physical features of the material change. The decreasing water content and the change of the particle size distribution have an effect on the shredding. It is expected that the shredding effort decreases according to the in-process time. In the last process phase the mutual friction of the dry material leads to a cleaning of the surfaces.

According to these reflections, a product from a rotary drum reactor is expected which can directly and without further post-pulverisation be separated into different material flows. This would lead to an important advantage over the state-of-the-art MBS-plants because there, apart from a comminution, a decompaction of dried agglomerates sticking together in the output is necessary.

3.2 Test Results

At the end of every test, which was conducted with original solid waste from a big city, the results of the treatment in the rotary drum reactor were evaluated according to qualitative as well as quantitative parameters.

a) qualitative parameters

Figure 3 shows the opened reactor at the end of the test.

Figure 3 Open reactor at end of test (input material: unshredded solid waste)

The output material was loose and pourable with a high percentage of light and fluffy components which mainly consisted of frayed paper and cardboard. The sticking together of dried material as it is inevitable in static reactors could generally not be witnessed. An entanglement of the material could also not be discovered in spite of the use of real solid waste. The dried MSW had an excellent separability by sieving after the treatment.

b) quantitative parameters

For the evaluation of the drying results a representative sample of 60-70 kg was taken from the product. The sample was put onto five screens with square openings and classed manually into six fractions. The sieve fractions were then brought together into three groups:

- The *coarse fraction* > 50 mm consisted mainly of plastic foils and bottles, textiles and wood.
- The *intermediate fraction* 20-50 mm contained frayed paper and smaller plastic parts.
- The *fine fraction* < 20 mm contained beside paper fibre smaller stones and refuse glass.

Figure 4 shows the sieve fractions.

Figure 4 Sieve fractions (fine, intermediate, coarse) after dynamic treatment (input material: unshredded solid waste)

Figure 5 (left) shows the composition of each of the samples from the coarse, intermediate and fine fraction for the solid waste tests. For the following treatment steps the water content of the product is important. Figure 5 (right) shows the water content of these fractions.

The tests were conducted according to activity and chosen strategy and not until a certain water content was reached. Therefore, a further analysis of the output is only partially possible. On the basis of only eight evaluated tests a quantitative statement on the water distribution in the fractions can therefore not be made.

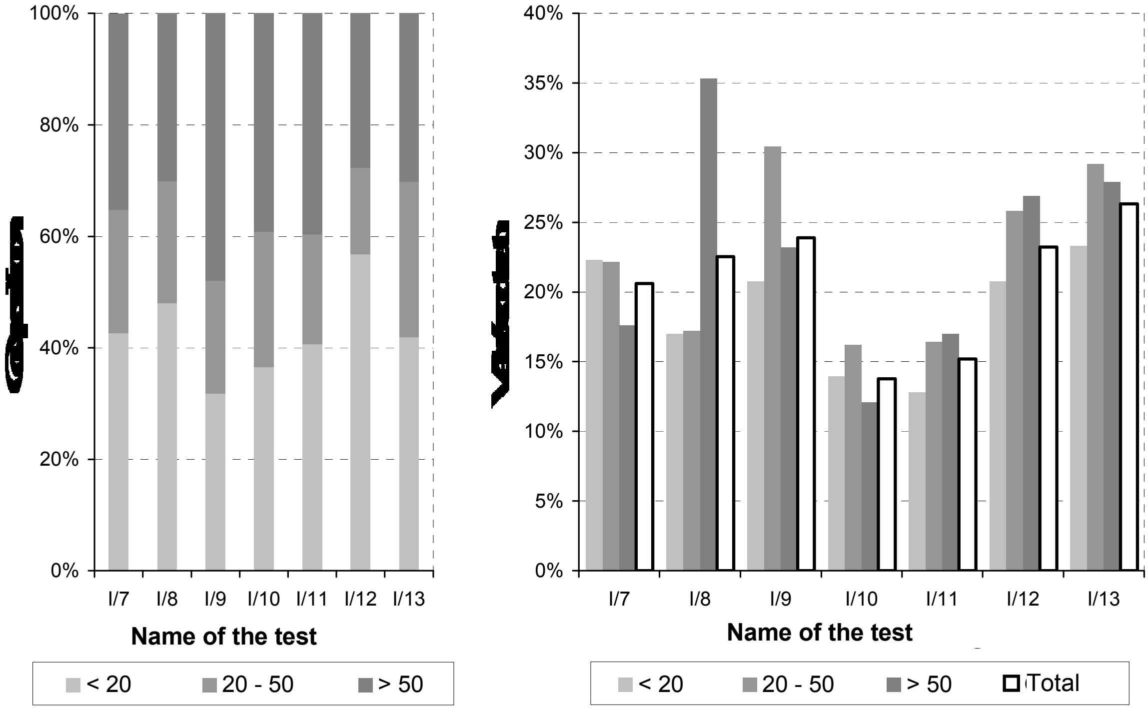

Figure 5 Mass percent and water content of fractions of output of several tests after dynamic treatment (input material: unshredded solid waste).

However, it can already be seen that the material fractions show similar water contents as is expected from a dynamic process. This is especially noticeable in tests I/10 and I/11, which were run until a low final moisture content was reached.

In another step the composition of the material was analysed. For this, the sieve fractions were divided manually into the following material groups:

- frayed (textiles, paper/card board)
- plastics
- miscellaneous (stones, ceramic, metals, glass)

Figure 6 shows examples for this in the intermediate fraction 20-50 mm

Figure 6 Material groups from intermediate fraction after manual sorting (input material: unshredded solid waste).

Proof for the outstanding selectivity of the shredding in the desired direction were the mainly unbroken glass bottles and undamaged batteries which could be found. A most impressive example is the undestroyed light bulb in figure 6, right picture top middle. In how far an undesired destruction of components took place at all could only have been determined by a complete sorting of the input charges with a weight of each up to a 1000 kg before the treatment, which was impossible for hygienic reasons.

4 Summary

Within the scope of investigations on the process modelling and control of the biological drying of MSW in a rotary drum reactor, the physical features of the output were also analysed and evaluated. It could be demonstrated that with a calculated use of combinations of biological and mechanical processes an output quality can be reached which in state-of-the-art static reactors is either not at all accomplishable – the cleanliness of surfaces – or only with costly post-treatment, such as decompacting or post-pulverisation. By sieving and manual sorting of material groups different product fractions could be described precisely. The results obtained so far present a stable foundation for a future strategy for the development of a material flow separability which is adjusted to dynamically produced output material.

5 Literature

Bartha, B. et al.	2002	Steuerung eines Reaktors zur Aufbereitung von Abfällen mit biogenen Bestandteilen. Abschlussbericht zum DBU-Projekt 14736.
Bartha, B. et al.	2006	Entwicklung einer Steuerungsstrategie für biotechnologische Prozesse in der Abfallbehandlung, in: Abfallforschungstage 2006. Cuvillier Verlag, Göttingen, ISBN 3-86537-863-3.

Federal Ministry for the Environment, Nature Conservation and Nuclear Safety BMU	2006	Municipal Solid Waste Management in Germany 2006. Published under: http://www.bmu.de/abfallwirtschaft/doc/37876.php
Brummack, J. et al	2005	Ertüchtigung der Nachrotte in MBA´s durch das Dombelüftungsverfahren (DBV), in: International Symposium MBT 2005. Cuvillier Verlag, Göttingen, ISBN 3-86537-665-7.

Authors' Addresses

Dipl.-Ing. B. Bartha
Technische Universität Dresden, Institut für Verfahrenstechnik und Umwelttechnik
D-01062 Dresden
Phone: +49 351 46332045
Email: Bela.Bartha@mailbox.tu-dresden.de
Website: http://www.tvt-uvt.tu-dresden.de/

Dr.-Ing. Joachim Brummack
Technische Universität Dresden, Institut für Verfahrenstechnik und Umwelttechnik
D-01062 Dresden
Phone: +49 351 46334430
Email: Joachim.Brummack@tu-dresden.de
Website: http://www.tvt-uvt.tu-dresden.de/