MATERIAL FLUX MANAGEMENT OF WASTE BY MECHANICAL-BIOLOGICAL PRE-TREATMENT

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SUMMARY: After the European landfill order, a pre-treatment of MSW before deposition is necessary. In Germany as a specific technology the mechanical-biological pre-treatment (MBP) is applied. It has been ruled by specific ordinances since 2001, which demands for a material management to separate special substances, as plastics with a high heating value (limiting value: 6000 kJ/kg). This supports the tendency of MPB to become a technology for material flux management. This also includes the gas management, which is ruled by an extra ordinance (30. BImSchV). In modern MBP plants 40–50% of the input are processed to Refuse Derived Fuel (RDF fraction), which sum up to about 1,5-4 millions tons p.a. in Germany only. For the RDF production, mechanical processes have to be optimised with reference to both total energy content and calorific value. Alternative processes as waste extrusion are available. To improve the overall process ecology, the toxic waste substances must be directed after ecological criteria. Overall ecological benefits of regenerative thermal oxidation of waste gas are low in some cases and can be improved by a design considering the whole process.

1. INTRODUCTION

Mechanical-biological treatment of municipal solid waste (MBP) is defined as the processing or conversion of waste from human settlements, which include biologically degradable components, by a combination of mechanical processes (e. g. crushing, sorting, screening) with biological processes (aerobic "rotting", anaerobic fermentation) (BMU, 2001).

At the beginning of the development of MBP, it was applied as a pre-treatment technology for residual waste before landfill (hence the common abbreviation "MBP"). It aimed primarily at the reduction of the mass, volume, toxicity and biological reactivity of the waste, in order to minimise environmental impacts from waste deposition. Here, MBP competed with waste incineration. The recovery of re-usable waste components such as metals and plastics then was only a side effect of the minimisation of the waste amounts.

In recent years, the recovery of waste components for industrial re-use has become an integral part in the development of MBP, especially with the production of refuse derived fuels (RDF). Thus, MBP is now an integrated technology for the material flow management of MSW, where almost half of the input flow is recovered for industrial re-use, and only one third remains for

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deposition (see Figure 1). Further 20% are process losses in the biological stage, respectively. converted into bio-gas in the case of an anaerobic process.

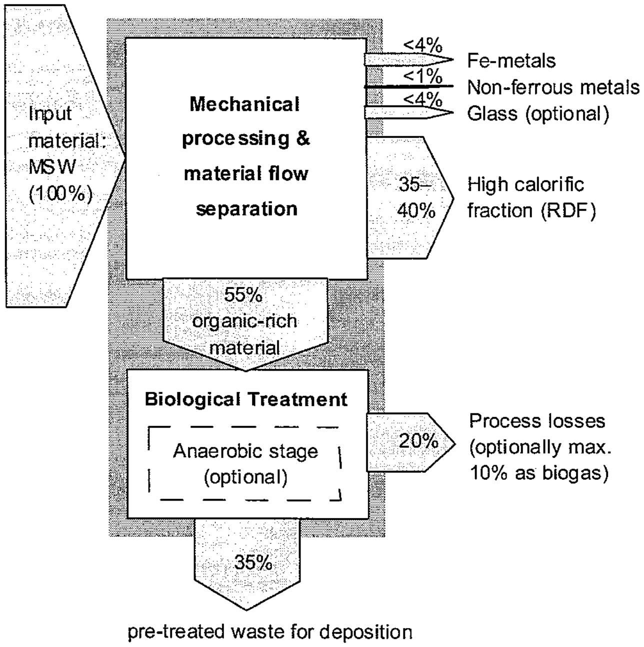

Figure 1- Principal material flow diagram of a MBP plant.

Since March 1st 2001, the application of MBP in Germany has been ruled by the German Ordinance on Environmentally Compatible Storage of Waste from Human Settlements (BMU 2001). It defines quality limits for the pre-treated waste, e. g. limit values for heavy metals, AOX and the reactive organics. Standards for the process emissions are ruled by the 30th Ordinance on Execution of the Federal Immission Control Act: Ordinance on Facilities for Biological Treatment of Waste (30. BImSchV).

2. MATERIAL SEPARATION BY MECHANICAL PROCESSES

For the material flow management, demanding limit values are defined for TOC and the upper thermal value of the output material for deposition (18% respectively. 6000 kJ/kg). To meet these requirements, all MBP facilities in Germany have to separate out a considerable fraction of high calorific waste components, which is then predominantly utilised as RDF. Thus, the new ordinances corroborate the development of MBP from a waste disposal technology towards a technology for material flow management.

For this aim, MBP comprises several mechanical and biological process steps and combinations thereof. The mechanical step is important for the pre-processing of the material before the biological step, but its main task is the separation of the material streams. The biological step mostly determines the residual organic content and thus the landfill behaviour, but may also influence the separation behaviour of the material. Hence, there is not necessarily a strict sequence between the mechanical and the biological stage. Part of the mechanical processing may take place after or even within the biological step, e. g. the separation of metals from the output material or the removal of heavy, mineral-like substances at the bottom of a biogas reactor.

2.1 Compromise decisions in material management

In general, the mechanical processing inside an MBP plant has the following functions:

- Removal of contaminants and components, which impede the mechanical or biological processes,
- Adjustment of the particle size distribution for the subsequent processes,
- Recovery of waste components for physical recycling such as ferrous and non-ferrous metals, optionally glass and plastics,
- Recovery and processing of a high calorific fraction destined for energy recovery as refuse derived fuel (RDF),
- Pre-processing of the remaining material for the biological treatment, e. g. homogenisation and adjustment of the material's water content.

To fulfil these tasks, a combination of various mechanical processing devices is applied in MBP plants, mainly crushing and screening units, that are used also in traditional waste processing. Special properties of MSW are partly considered, but there is still a big potential for the optimisation of mechanical units used for MBP.

As MSW is a very inhomogeneous and complex mixture of both organic-rich, high calorific, metal and mineral-like components, the separation of material fractions in generally object to compromise decisions between maximum output flows and high product qualities. Thus, an optimisation has to be made for each mechanical step, according to the individual waste composition and the quality demands for the products recovered.

The separation of a high-calorific or organic-rich fraction is even more complicated, because neither the calorific value nor the organic content is a suitable property for material separation (in contrary e.g. to magnetism, which is a unique property for the separation of ferrous metals). Thus, only secondary material properties like particle size and density or a different crushing behaviour can be used for physical separation, but this causes a low selectivity. In addition to this, the separation effect of technical screening units is significantly worse than in laboratory, especially when the throughput is close to the machine's capacity.

Another compromise situation is given by the fact, that the organic-rich components also contribute to the waste's calorific value. Hence a maximum output of the energy content on one hand, and a maximum organic load in the remaining material on the other, are also conflicting goals. As the purpose of the biological treatment is to reduce the input of reactive organic components into the landfill, the organic load of this fraction does not necessarily be maximised. However, the portion of total organic load in the remaining fraction also has to be considered to ensure an optimal material flow separation.

2.2 Separation of RDF by a two-step mechanical process

Figure 2 exemplifies a compromise situation for a simple two-step mechanical separation of RDF from the input material for the biological step in the MBP plant in Quarzbichl, Germany (Fricke, 1999). In this case, a compromise has to be found between the conflicting goals of a) a maximum transfer of the waste's energy content into the coarse-grained fraction for energy recovery, and b) a maximum calorific value of this fraction.

In Figure 2, the assumed quality demand for RDF due to market reasons is a calorific value of 15,000 kJ/kg (see vertical dashed line; the minimum for energy recovery according to German law is 11,000). As no screen fraction of the non-crushed material reaches this value (see the leftist graph), crushing the waste is indispensable to produce RDF. The highest calorific values are reached by the hammermill or the roll crusher, when screened at 150 mm (points 'A' and 'B'). In order to choose an optimally suited crushing device, the portion of total energy in the RDF output has to be considered: At the points 'A' and 'B', only 7% resp. 16% of the waste's total energy are recovered. When crushed by a revolving composting drum, the portion of total energy in the RDF output rises up to 31% in the case of the 80 mm screen overflow (point 'C'). The 40 mm screen overflow (point 'D') even contains 48%, while its calorific value is only slightly below 15,000 kJ/kg.

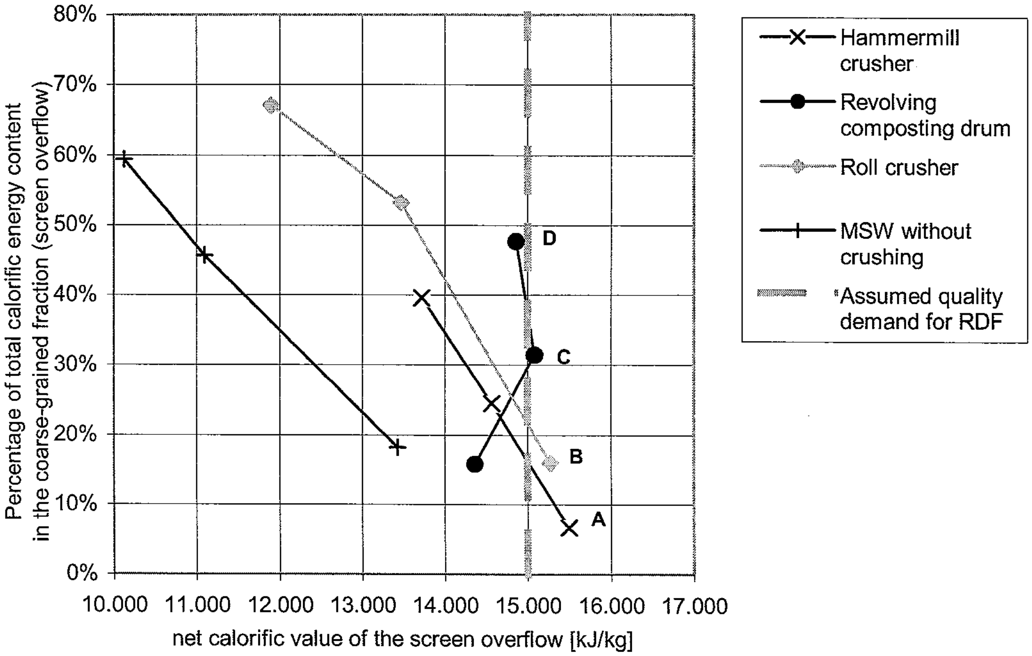

Figure 2 - Effects of crushing devices and screening sizes on the calorific value of the screen overflow and on the total calorific energy recovered as RDF (data points on each graph represent – from top to bottom – the screen overflows at 40, 80 and 150 mm) (Soyez, 2002).

Concerning the organic load in the remaining fraction, the combination of a revolving composting drum and a 40 mm screening device is as well acceptable, as it almost doubles the organic load in the 40 mm screen underflow compared with non-crushed MSW (determined as organic dry matter from biological origin). A higher accumulation of reactive organics in the underflow is only reached by the hammermill crusher, but the difference in the 40 mm screen underflow is negligible compared to the big difference in the RDF output.

Under real conditions, the demands on both product and separation quality are more critical, thus requiring a more sophisticated system for mechanical processing and separation. Naturally, the optimisation of such a complex system is much more demanding than the example given here, especially as the process expenditures also have to be considered, both economically and ecologically.

2.3 Material flow management by the 'dry stabilate' process

Another approach to material flow management by mechanical-biological processes is the 'dry stabilate' process developed by the Herhof Company, applied (or planned) in 9 facilities in Germany as well as in Italy and in Belgium with a capacity of 75 to 220,000 tons, each. The goal of this process is to make a maximum percentage of waste available for industrial re-use, thus minimising the amounts for deposition to a very low degree.

To achieve this, the entire waste is brought into the biological stage, where it is dried by physical and biological processes for 7 days under high aeration rates. Within this process, the organic content is reduced only slightly, and the separation behaviour is improved significantly. This is followed by a separation into a heavy and a light fraction. The light fraction is used as RDF after a further separation of metals. The heavy fraction (about 15%) is separated into metals, glasses, batteries, and mineral components.

Table 1 shows, that in this process more than two thirds of the input flow are recovered for industrial re-use, while only 4% remain for a direct waste disposal. The rest is lost in the process and stripped out with the process air, which is purified by a sophisticated regenerative incineration technology (see 3.2).

Table 1 - Output flows of the 'dry stabilate' process.

Output fractions		% of total input
Fractions for industrial re-use:		
RDF (calorific value: 15–18 MJ/kg)		53%
Ferrous metals		4%
Non-ferrous metals		1%
Batteries		0,05%
White glass		3%
Brown glass		0,5%
Green glass		0,5%
Minerals		4%
	Total	66,05%
Others:		
Fine grain and dust		4%

2.4 Material separation by high pressure extrusion

The spectrum of apparatus for the mechanical treatment is relatively small; only a few are practically applied. A potential is seen in the combination of the apparatus available (see 3.1.). But also, earlier developments of waste treatment should be re-established in modern versions.

An example is an Italian technology, which is based on an extruder compactor for compaction and inertisation of municipal solid waste and production of an organic rich component and a refuse-derived fuel (VMpress, 2003). In the process, the metals are separated first to an amount of about 3 % of the total mass. After that, the iron free material is disrupted under high pressure and separated into two phases by extrusion. About 65% form a dry phase, and 32% a wet phase.

The dry phase consists of the pressure resistant components of the waste, as plastics, wood, paper and cardboard, which obviously build a RDF fraction. The heating value is about 15,000 kJ/kg. The wet phase mainly consists of organic components with low quantities of various fibres, plastic materials and inert bodies. The physical appearance is that of a semi-fluid, fine-grain paste. In particular, the low quantities of glass and ceramics have a granulometric grade which is not too fine and therefore can be easily eliminated via screening. The moisture is about 50%.

The wet fraction is applied to the biological degradation. The process is positively influenced by the mechanical pre-processing and the rise of temperature during pressing. According to the material properties of the organic fraction, the application of the process seems useful in the case of an anaerobic treatment of the waste. A direct application of the residual product as a fertilizer, as is proposed by the producer of the technology, seems but impossible, e.g. after German soil protection act.

2.5 Potentials of RDF-production

As was given in Figure 1, about 35-40% of the waste in a modern MBP plant will be processed into a RDF fraction, in the case of the dry stabilate production even more than 50% result. Thus, if we consider a total of waste treated in MPB facilities between 3,5 to 7,5 millions of tons in Germany in 2005, than a RDF capacity of about 1,5 to 4 millions of tons results. In Europe, predictions come down with a total of 10 millions of tons.

This amount has to be considered in relation to the other secondary fuels, as business waste, wood and timber, plastics and gums, textiles, shredder material, used oils, lubricants, solvents, etc (see Table 2). The total is 22 to 27 millions of tons per year. On the other hand, there are limited capacities for the use of these materials as a substitute for regular fuels, especially in cement kilns, in coal power stations, in blast furnaces, foundries, lime stone industry, and brick production (see Table 2) The total of fuels, which can be substituted in these industries, is about 21 millions of tons per year.

After these numbers, supply and demand seem to be in relatively good accordance. But we have to consider, that the secondary fuels probably really will occur, but the number of the demand is quite risky, for it depends on market conditions, as the price of coal, as well as on the technology of the processes applied, which may change.

To improve the chances of RDF, it seems necessary to improve the quality of the product and to establish a quality management. Consequently, some efforts for a standardisation of the quality were made in different countries, as in Germany (RAL quality label 724) and in Switzerland (BUWAL). But there are different approaches: The German proposal defines the qualities of the RDF after practical results in operating MBP facilities, whereas the BUWAL proposal is related to the pollutants of the fuels to be replaced, i.e. the regular fuels. For these two approaches, limiting values differ. Higher values are accepted by the BUWAL proposal in the case of Cd, As, Pb, and V, lower values for Hg, Sb, Cu, and Zn. It is to be expected, that under market conditions the cheaper version will dominate, which has negative consequences for the ecological situation. A proper EU regulation is prepared therefore by CEN, which will take into consideration both economic and ecological effects.

Table 2 - Offer and demand of secondary fuels in Germany.

Potential offer		Application potential	
Origin	[Mio. t/a]	Industrial process	[Mio. t/a]
MBP (2,5–7,5 Mio t/a waste)	1,5–4	Cements kilns (substitution rate* 50%)	2,8
Business waste	8–10	Coal power stations (subst. rate 10%)	15,2
Production specific waste		Blast furnaces	2,5
• Used wood and timber	10,4	Foundries	?
• plastics and gums	0,9	Asphalt mixing facilities	0,2
• Paper production residues	0,7	Lime stone production	?
• Textiles	0,5	Brick production	?
• Shredder light fraction	0,4		
• Used oils and lubricants	?		
• Solvents	k. A.		
• Other production residues	?		
Sum	21,9–26,9	Sum	20,7

* Substitution rate relating to the energy content of regular fuels

3. ECOLOGICAL EFFECTS OF MATERIAL FLUX MANAGEMENT

Every measure of the material management is connected with ecological effects, due to the input of energy and material, but also with respect to the application of the materials produced and the decision, in which component the pollutants are accumulated. Actually, there is lack in information about the ecological consequences, due to a lack in the methodological and data base, but also due to the dominance of economy. But for a sustainable development, both aspects must be considered equally for proper decisions.

3.1 Directing pollutants streams

Generally, the question arises to which waste stream the pollutants should be assigned to - e.g. a decision is necessary, whether toxic heavy metals should be enriched in the high calorific fraction, or in the recycling fraction, or the fraction for deposition. In Germany, the landfill audience calls for a minimisation of the pollutants in the material for deposition, but there no hint is given, in which fraction is should be enriched.

Considered under market aspects, the RDF fraction should have only a low pollutant concentration, for a low polluted product is better comparable with normal fuels, as coal. Seen under the aspect of a recycling economy, a low pollutant concentration of the recycling components is demanded, as in glass, minerals, and metals, for an accumulation in the material cycle is to be prevented, because there are no sinks for the pollutants, in opposition to the incineration, where the pollutant are destroyed and/or accumulated in the slag and the ash, which normally are not recycled, but leave the material cycles. An exception is given, if the incineration residues form a part of a product, as in the use of RDF in cement kilns, where the product "cement" is formed by use of the residues of the RDF.

For a decision, an economic as well as ecological analysis of the very special situation is necessary, which but can be made only on a sufficient data base. Some new investigations (Rotter, 2001), where balances of the material streams, the calorific values, as well as the pollutants (Pb, Cd, Cl) were studied, give some useful information: An optimum configuration includes a separation of the coarse grain fraction, a magnetic separator, as well as a ballistic separator with fine grain separation. In this combination, a RDF-fraction is produced which contains a mass and a calorific portion of 39% and 47%, resp. At the same time, in this fraction a decrease of the pollutants is achieved. An enrichment of the pollutants takes place in the high calorific coarse grained fraction as well as in the medium calorific fraction from ballistic separation.

The investigation clarifies, that a more expensive material separation comes down with more fractions (scarce grained fraction, fine fraction, and heavy fraction), for every of which suitable ways of further treatment have to be found.

3.2 Ecological effects of gas stream management

In the management of the gas streams considerable improvement were reached in the last years, which in Germany was due to the regulations in the 30. BImSchV. An important aim is the reduction of the specific TOC load in the waste gas to an amount of less than 55 g per ton of waste. To reach this goal, several measures are applied, as

- recycling of process gases in the single process steps, e.g. after cooling and de-moisturing
- encapsultion of machinery and apparatus
- re-use of waste gases in consecutive process steps, especially for the biological process
- separation of highly polluted gas streams and separate treatment of waste gas streams due to the kind and magnitude of the pollution
- application of different cleaning techniques, as biofilters, scrubbers, and thermal oxidation, according to the specific contamination
- energetic use of bio-gas
- collecting the residual waste gas and drawing off through furnaces
- prevention of diffuse emissions.

These measures are applied after the specific needs of the facilities. But in the most cases, the application of the RTO is unavoidable to reach the said limit value in the TOC. As a special aspect in this case we have to consider, that a proper ecological balance is necessary to come down with a environmentally beneficial solution - due to the fact, that the thermal process reduces the TOC load, but on the expense of energy for the incineration. Especially the greenhouse gas balance is to calculate. In some practical cases, the benefits of the RTO process are very small , in the case of the Rennerod facility e.g. 0,82 kg CO_2 equivalents per ton of t waste (see Table 3), so that even low alterations in the items considered may result in a negative environmental impact. To prevent this effect, a lower energy input into the RTO is necessary. This can be realised by a higher TOC value in the waste gas before cleaning, thus acting as a fuel for the RTO, as well as by a higher waste gas temperature. This may cause a change in the process layout, which in the past was directed to low TOC loads and medium temperature due to the needs of the biofilter operation.

Table 3 - Greenhouse gas balance of the RTO (after BZL, 2000).

	Item	Rennerod facility	Aßlar facility
		[kg CO_2-equiv./Mg waste]	
Loads	Natural gas production	0,21	0,015
	CO_2 from natural gas burning	6,17	0,44
	CO_2 fromTOC-oxidation	0,62	0,62
	Electrical energy	3,4	3,4
	Laughing gas	< 1,9	< 1,9
Benefits	Mineralisation of hydrocarbons	- 8,67	- 8,67
	Methane oxidation	- 4,45	- 4,45
	Landfill gas use	0	- 69,2
Sum		< -0,82	< -75,95

3.3 Effects of recycling of waste components

The separation of substances for recycling purposes is an essential element of the material flux management of MBP, for it contributes to an improved material economy. It is generally estimated useful. But a successful recycling not only needs a market for the products, but also have to consider, that the overall ecological balance of the recycling and the application of the recycled material is positive.

In the case of the separation of non-ferrous metals and plastics, there are effects mainly on the greenhouse gas potential. For plastics more than 80 % improvement in the global warming effect is possible, if the degree of separation rises from 20 to 80 %. Which improvement is practically achieved, depends on the specific composition of the plastics as well as the standards and the efforts of the treatment. A separation of the aluminium fraction is of lower benefit.

4. CONCLUSIONS

The material streams of MBP consist of the waste for deposition, the RDF-fraction, the recycling components, as well as the gas streams. Technologically, the mechanical separation is of most importance. The separation performance has to be optimised after the special process target, especially the output of energy in the RDF fraction. A general decision is necessary, in which material stream the pollutants shall be accumulated. Market economy effects have to be considered, but also an estimation of the environmental effects. An improved overall ecology of MBP is possible by recycling for re-use especially of plastics.

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