OVERVIEW ON MECHANICAL-BIOLOGICAL PRETREATMENT OF RESIDUAL MSW

J. HEERENKLAGE AND R. STEGMANN

TU Hamburg, Harburger Schloßstraße 37, D-21079 Hamburg

SUMMARY: Mechanical-biological techniques may be applied as the sole process to pretreat municipal solid waste (MSW) or, as preferred in rural areas, in combination with central thermal treatment. By pretreating the MSW the landfill volume and emissions are significantly reduced and the landfill characteristics are improved. The landfill criteria of the "TA Siedlungsabfall" (Technical Directive MSW) are met exept for ignition loss and eventually TOC for which alternative parameters have to still be developed.

1 INTRODUCTION

In addition to the high standards required of landfill technique and landfill sites, the "TA Siedlungsabfall" prescribes that in Germany in the future waste has to be pretreated in order to improve the landfill conditions and to reduce the emission potential.

To characterize the waste fractions to be landfilled, the thresholds are stated in Appendix B of the TA Siedlungsabfall as classification criteria. The classification values of Table lmainly assess the strenght, the proportion of organics and the eluate behaviour according to "DEV S4" (German standard methods) of the MSW to be landfilled. The levels set can only be met by appropriate waste pretreatment; suitable methods being thermal and mechanical-biological.

By applying thermal processes, the levels according to TA Siedlungsabfall are observed but the reuse of the ashes is limited. Mechanical-biological processes present an "alternative" to therrnal pretreatment. Compared to incineration, fewer gas emissions are caused, however, the remaining potential pollutant emission of the residues to be landfilled is in total higher than that of slags.

Each method of pretreating MSW has advantages and disadvantages and cannot be regarded as a general technique. Specific conditions have to be respected within a waste management concept when a choice is made as to the appropriate process and the advantages and disadvantages of each process variant have to be evaluated. The processes of thermal waste pretreatment have often been discussed in literature and will not be dealt with here. In the following, experimental results obtained in mechanical-biological pretreatment are presented.

Proceedings Sardinia 95, Fifth International Landfill Symposium
S. Margherita di Pula, Cagliari, Italy; 2-6 October 1995

Table 1. Technical Directive on MSW, Appendix B, Landfill assignment cirteria (TA Siedlungsabfall, 1992)

No.	Parameter	Classification Values Landfill Class I		Landfill Class II	
1	strength				
1.01	shearing strenght	≥ 25	kN/m²	≥ 25	kN/m²
1.02	axial strain	≤ 20	%	≤ 20	%
1.03	uniaxial compressive strenght	≥ 50	kN/m²	≥ 50	kN/m²
2	Organic proportion of dry residues of the original substance[2)]				
2.01	determined as ignition loss	≤ 3	Mass-%	≤ 5	Mass-%[3)]
2.02	determined as TOC	≤ 1	Mass-%	≤ 3	Mass-%
3	Extractable lipophile components of the original substance	≤ 0,4	Mass-%	≤ 0,8	Mass-%
4	Eluate criteria				
4.01	pH value	5,5 - 13,0		5,5 - 13,0	
4.02	conductivity	≤ 10000	µS/cm	≤ 50000	µS/cm
4.03	TOC	≤ 20	mg/l	≤ 100	mg/l
4.04	Phenols	≤ 0,2	mg/l	≤ 50	mg/l
4.05	arsenic	≤ 0,2	mg/l	≤ 0,5	mg/l
4.06	lead	≤ 0,2	mg/l	≤ 1	mg/l
4.07	cadmium	≤ 0,05	mg/l	≤ 0,1	mg/l
4.08	chromium-VI	≤ 0,05	mg/l	≤ 0,1	mg/l
4.09	copper	≤ 1	mg/l	≤ 5	mg/l
4.10	nickel	≤ 0,2	mg/l	≤ 1	mg/l
4.11	mercury	≤ 0,005	mg/l	≤ 0,02	mg/l
4.12	zinc	≤ 2	mg/l	≤ 5	mg/l
4.13	fluoride	≤ 5	mg/l	≤ 25	mg/l
4.14	ammonium-N	≤ 4	mg/l	≤ 200	mg/l
4.15	cyanides, readily volatile	≤ 0,1	mg/l	≤ 0,5	mg/l
4.16	AOX	≤ 0,3	mg/l	≤ 1,5	mg/l
4.17	water-soluble proportion evaporation residue	≤ 3	Mass-%	≤ 6	Mass-%

[1)] 1.02 can be applied together with 1.03 equivalent to 1.01. The strength has to be determined in each individual case according to the static requirements for the landfill stability. The values of 1.02 in combination with 1.03 must be kept particularly for cohesive fine-grained waste.

[2)] 2.01 may be applied equivalent to 2.02; requirement does not apply for contaminated soil excavation to be deposited at monolandfills.

[3)] Does not apply to ashes and dusts from coal firing units, which do not need approval according to the BImSchG (German Immission Protection Act).

2 PRESENT SITUATION AND OBJECTIVES

Different kinds of waste are deposited at MSW landfills without pretreatment and cause emissions during landfill operation of approximately 150 m^3 biogas/Mg and 5 $m^3/h*a$ polluted leachate. Due to biological degradation processes heavy settlings take place between 20-25%, which may damage sealings, gas extraction and leachate collection pipes. Flow of paper and plastic, large number of birds, animals, noise, dust, and odours also contribute to a negative image of landfills. The leachate obtained has to be collected and treated with great technical expenditure, the biogas produced is extracted and flared or used as an energy source (Stegmann, 1994).

The processes taking place in a landfill cannot be controlled and even after closing of the landfill, gas and leachate continue to be produced for an unpredictable period of time (decades) and have to be treated (Stegmann, 1994).

By the mechanical-biological waste pretreatment, processed in the landfill over long periods of time (decades) will be shortened to a few months. Figure 1 illustrates the objective of pretreatment. The emission potential contained in the waste is extracted to a large extent during pretreatment so that , compared to unpretreated wastes, only minor emissions occur, which can be controlled and treated with little expenditure. The emissions occurring during pretreatment have to be collected and treated.

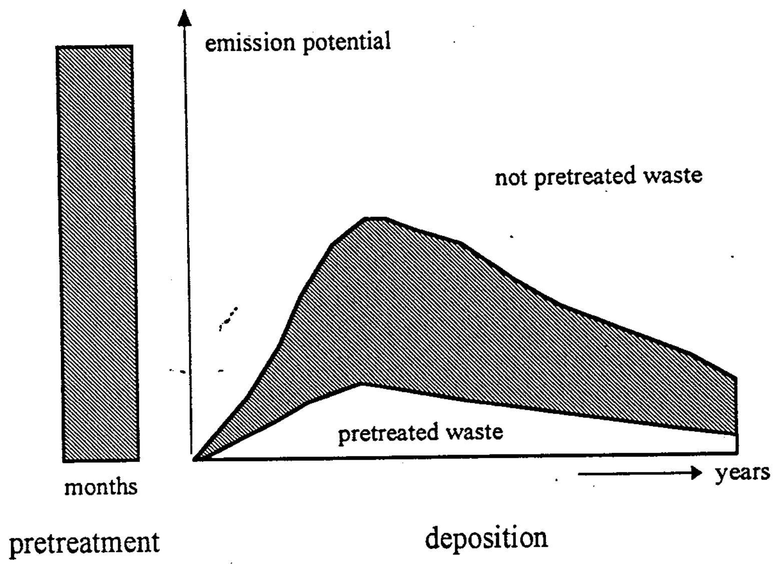


Figure 1. Shift of the emissions from landfilling to pretreatment

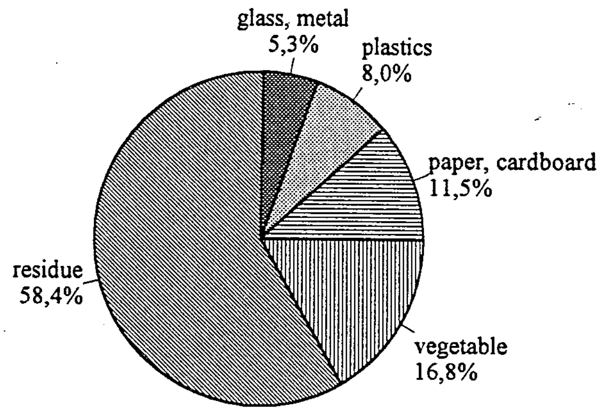
The following goals shall be pursued by waste pretreatment:

- reduction of the landfill volume by separation and recycling of the reusable components and degradation of the organic matter
- reduction of the emission potential of leachate and landfill gas by biological inertization
- significant reduction of deposit formation (incrustations) in the leachate collection system
- removal of contaminants from the residual waste by separation of disturbing components
- improvement of landfill operation by reducing dust emissions, paper flow and odour emission
- less expenditure for compaction due to better compactability
- minor settlings (favourable for the early installation of a surface cap)
- possibility of baling of waste and the operation of a „dry landfill".

3 CONCEPTS OF MECHANICAL-BIOLOGICAL PRETREATMENT

In municipal waste management priority has to be given to waste prevention, waste that cannot be avoided has to be recycled and the remaining residual wates have to be treated prior to landfilling. In spite of extensive measures to prevent and recycle waste there is still a considerable quantity of residual waste left, which cannot be reused. According to first prognoses, the waste quantity will, after intensive separation of the reusable material, be reduced by 35-45% by weight until the year 2000. The waste composition will not essentially change despite country-wide introduction of biowaste composting and recycling of packaging materials (glass, paper, light packagings).

Figure 2 illustrates a prognosis for the year 2000. It can be seen that in spite of high recycling rates of 60-80% considerable quantities of reusable materials still remain in the MSW. According to previous investigations a potential of 25-40 % by weight of biologically degradable materials is contained in the residual MSW (Stegmann, 1995).



with the following recycling rates:

60 % plastics
75 % paper/cardboard, vegetable, glass, compounds
80 % metal

Figure 2. Pronosis for the country-wide composition of residual waste in the year 2000 (Bilitewski, Nistroj, 1994)

With regard to their properties the residual wastes can be classified in reusable and disturbing materials, a light fraction of high calorific value, a heavy mineral fraction, and a fraction rich in organics. Within a waste management concept, there are several variants for the conception of mechanical-biological pretreatment:

- mechanical-biological pretreatment as an alternative to thermal waste pretreatment,
- mechanical-biological pretreatment as an equivalent process in combination with thermal pretreatment after separation of the waste streams into one of high calorific value (Refuse Derived Fuel - RDF) and one predominantly biologically degradable,
- or mechanical-biological pretreatment as a pretreatment step before thermal waste treatment to reduce the quantity of waste to be incinerated.

Techniques for composting and material recovery have been applied for several years. These processes, however, are aimed at material recovery, not at environmentally compatible pretreatment of waste prior to landfilling. In principle, the processes can be transferred to waste pretreatment, but they have to be adapted to the target of pretreatment of residual waste and to the composition of residual waste. The conception of mechanical-biological pretreatment is represented in Figure 3.

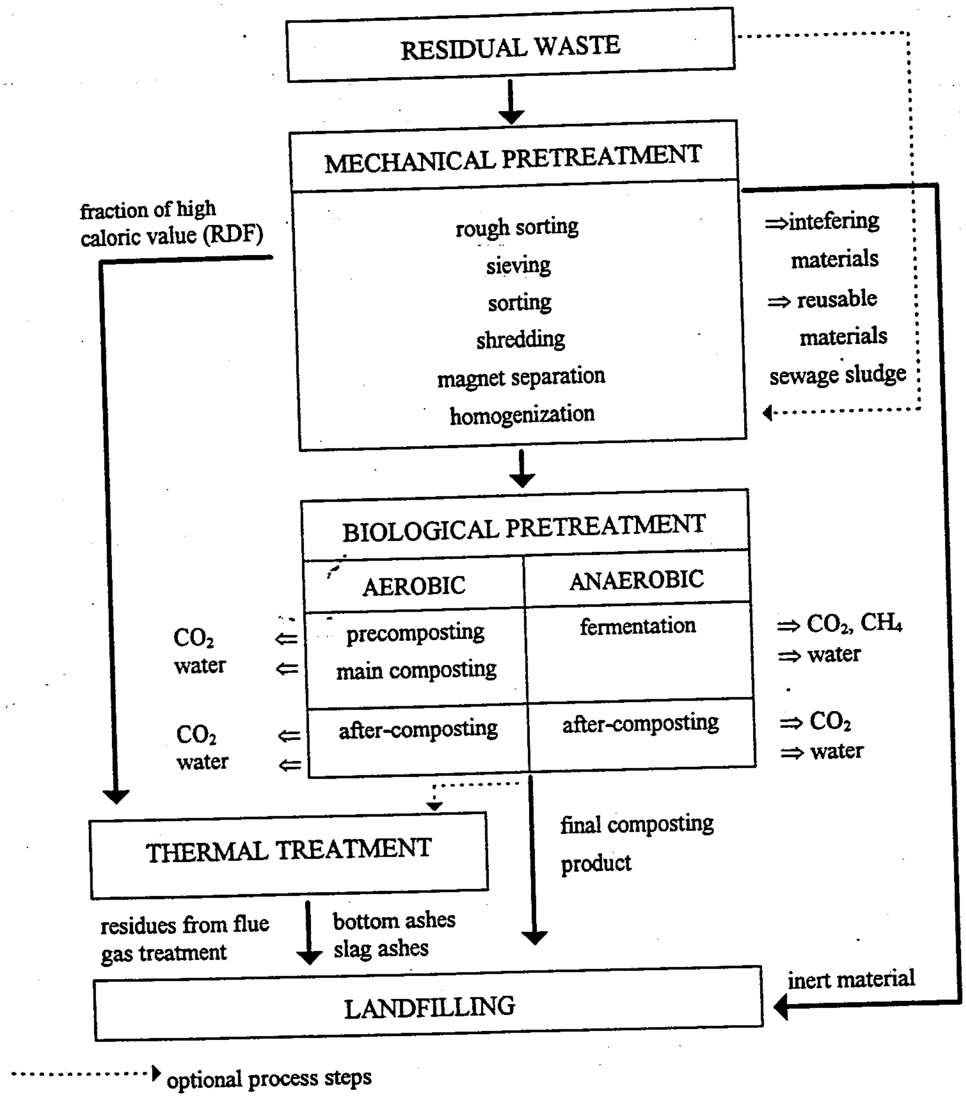


Figure 3. Rough conception of residual waste pretreatment (modified after Rospunt, 1991)

The plants for residual waste pretreatment should be completely enclosed in buildings and the exhaust air treated by appropriate filter systems. Mechanical and biological conditioning should be operated largely automatically in order to minimize the health risk for the operators. To minimize gas and dust exposure a vacuum should be applied to the pretreatment halls; the exhaust air has to be deodorized by means of suitable exhaust air treatment plants.

3.1 Mechnical conditioning

In the mechanical pretreatment step, the waste should be conditioned for the subsequent biological and thermal pretreatment. The waste agglomerate is separated according to composition into different waste streams and conditioned. In principle the mechanical treatment step has to meet the following requirements:

- removal of contaminated and disturbing waste components prior to treatment in aggregates
- separation of contaminants and reusable material
- separation of the waste mixture (into light fraction containing plastics, heavy minerals and biologically degradable waste)
- creating optimal conditions for biological pretreatment
- shredding of the waste to improve is landfill properties.

By separating the inert heavy materials, the Class II landfill volume may possibly be saved, since it may be separately deposited at an inert wate landfill (landfill Class I). By sorting out the light fraction containing waste of high calorific value the biological pretreatment step may be kept smaller; the RDF may be baled and intermediately stored until thermal treatment. The mechanical pretreatment can be divided into various process steps as shown in Table 2.

Table 2. Process steps and aggregates for mechanical pretreatment (Rospunt, 1991)

PROCESS STEP	AGGREGATE	OBJECTIVE
waste receipt and presorting	flat bin, conveyer belt	control of delivered waste, rough homogenization, intermediate storing
sorting	sorting belt	removal of problematic and reusablewaste components
separation	air classification, ballistic separation	separation into material streams of high calorific value and high mineral content
screening	sieve-drum, snail grinder	separation into several of different properties
Fe-separation	magnet separator	removal of Fe-metals
shredding	hammermill, shredder	size reduction
homogenization	homogenization drum	adjustment of water content, if necessary optimization of nutrient content, addition of sewage sludge, decomposition of composite materials, mixing

In the first step the waste is received, temporarily stored and roughly presorted to avoid undesirable waste components later damaging treatment aggregates.

Handsorting of the inhomogenous residual waste mixture is problematic for hygienic reasons and should be avoided or minimized. Mechanical sorting of the residual waste is generally effected by ballistic or inclined sorting. The material reuse from MSW fractions is in general considered problematic, since clean source separation is not possible (Helten Management Consultants, 1993;

Thome-Kozmiensky, 1992). In many cases sieve drums are used for screening. Magnetic separators should be installed at several places to reach homogeneity of the material sorted out and to remove the Fe-fraction to a large extent. As Fe-separators roller, drum, and above-conveyer magnets are applied. Shredding and separation of the waste mixture is effected according to its composition by means of various aggregates. As shredding aggregates mostly fast-running hammer or impact mills are applied as well as slow-running knife crushers, screw, worm and cascade mills. High calorific value waste (RDF) is generally separated before the homogenization step. For that purpose, air sifters may be useful. Homogenization is a prerequisit for leading various material streams together prior to biological pretreatment. By the rotating movement of the sieve drum, the waste is crushed and conditioned to provide bioavailability. When sewage sludge is added it can be added directly from the collection vessel into the homogenization drum.

3.2 Biological pretreatment

The goal of biological pretreatment is the degradation of the organic components and possibly also drying. During decomposition, the organics (hydrocarbons) are degraded to CO_2, water, and biomass under heat production. During the first phase (pre- and main composting) the readily degradable substances are decomposed under high oxygen consumption. In the subsequent phase, characterized by low oxygen consumption, the mean-degradable substances are treated. In a following step the composting material can be dried to reduce the mass (volume) and stabilize the landfill properties or, in case of subsequent incineration, to improve the combustion quality. The composting systems presently available in the German market may be classified into five categories (Kern, 1993):

- DRUM COMPOSTING
- BIN/CONTAINER COMPOSTING
- WINDROW COMPOSTING (TRIANGULAR OF PLANE WINDROWS)
- ROW/TUNNEL COMPOSTING
- BRIKOLLARE COMPOSTING

Pre- and main composting can be effected in bins, tunnels or embedded windrows. During the phase of pre- and main composting, the material has to be turned at certain time intervals (e.g. weekly). If necessary, the composting material has to be size-reduced before, while or after turning to enhance the biological degradation processes. The post-composting generally takes place as windrow or areal composting. By appropriate mechanical preparation steps (e.g. air sifter) the light and heavy waste can be separated before and after post-composting. Aeration of the composting material shall be conducted in a way that the exhaust air to be treated is minimized and evaporization of water is limited. By adjusting the temperature at <60°C odour emission can be minimized.

3.2.1 Combination of anaerobic/aerobic waste treatment

In the anaerobic pretreatment the organic waste residues are converted to biogas and digestion residue. The anaerobic pretreatment has several advantages compared to aerobic treatment, e.g. minor space requirements, modular construction, a net gain in energy from biogas production as well as minor odour problems due to closed construction.
Fermentation has always to be run in combination with composting, since not all organic substances (e.g. lignin containing components) can be degraded in an anaerobic milieu within acceptable treatment times.

Depending on the individual process conception, the biochemical degradation processes take place in one or two-stage proceses. While in the one-stage fermenter (fermentation reactor) all degradation takes place in parallel, hydrolysis/acidification and methanization of the substrate in two-stage processes take place in separate reactors.

Solids content and temperature are further distinguishing features of various process conceptions. Wet fermentation is operated at a solids content of up to 10% by weight referred to as dry weight. Dry fermentation works with solids contents of more than 25%. Some dry processes totally dispense with turning the material; in one case discontinuous mixing is attained by pressing in biogas. Dry processes in part do not apply a dewatering step. The technical expenditure of one-stage processes is smaller than that of multiple-step processes, while the treatment time is shorter with two-step processes. Mesophilically operated plants work at fermentation temperatures between 30 and 40°C, thermophil fermentation takes place at temperatures around 55°C. The latter operation method probably cuases a faster substrate turnover, which may lead to a shorter residence time in the reactor and a higher degree of hygienization. With the thermophil operation method the degree of hydrolyzation of the residual waste is higher.

Units operated discontinuously are fed with substrate and discharged after the fermentation process is terminated. With the continuous operation mode, during short intervals of time fresh substrate is added and fermented material is discharged (Heerenklage et al., 1994).

4 ASSESSMENT OF LANDFILL PROPERTIES OF PRETREATED WASTES

Previous experiences with mechanical-biological pretreatment are mainly based on investigations in laboratory or pilot scale. The only industrial-scale plant in operation is in Schaffhausen (Switzerland). Figure 4 represents a flow sheet of the Schaffhausen plant.

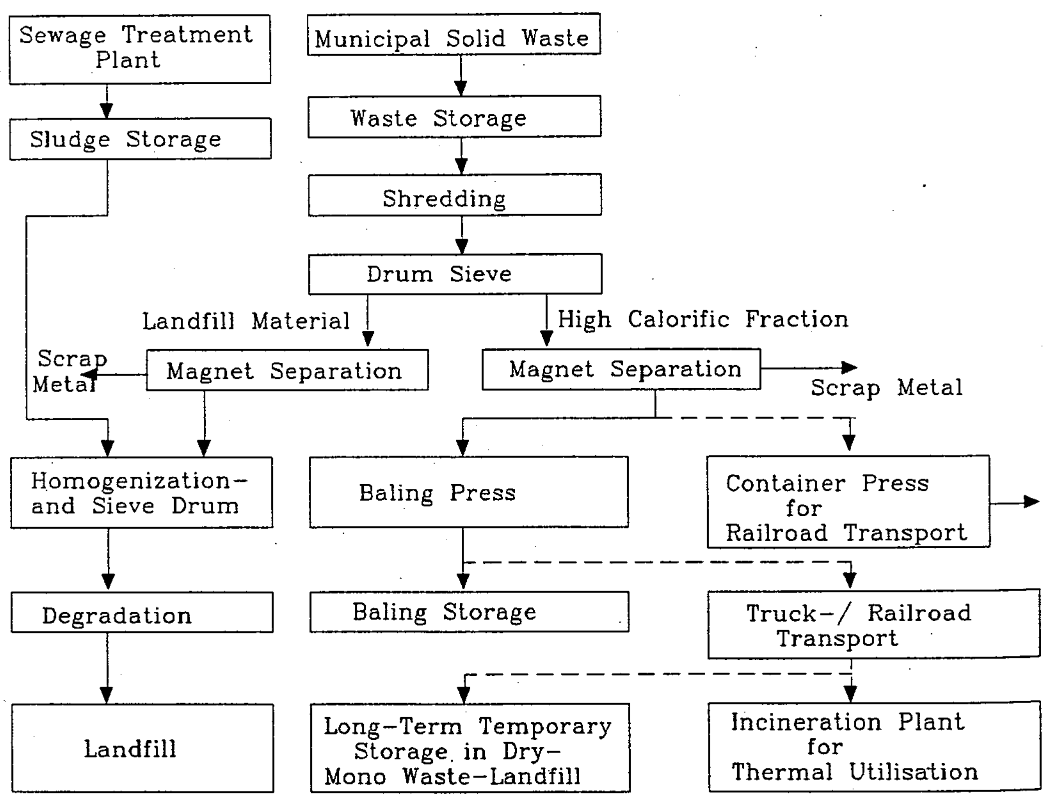


Figure 4. Flow sheet of the mechanical-biological pretreatment in Schaffhausen (Bühler, 1993)

After the mechanical pretreatment, the RDF is separated. The waste material left after screening is blended with sewage sludge in the homogenization drum and then biologically pretreated. The residual waste from this process step is landfilled, the RDF is temporarily stored and eventually thermally treated.

The mass balance of the residual waste treatment in the Schaffhausen plant is shown in Figure 5. From a residual waste input of 86% by weight and 14% by weight of sewage sludge addition, about 50% by weight is RDF and 28% by weight is composting material. 2% is separated as iron scrap. The composting material is moistened by adding 10% by weight of water (input). Due to biological degradation processes and aeration, the system looses about 24% by weight (output) caused by biodegradation. The organic dry matter is reduced by approximat4ely 6% by weight (referred to the total balance).

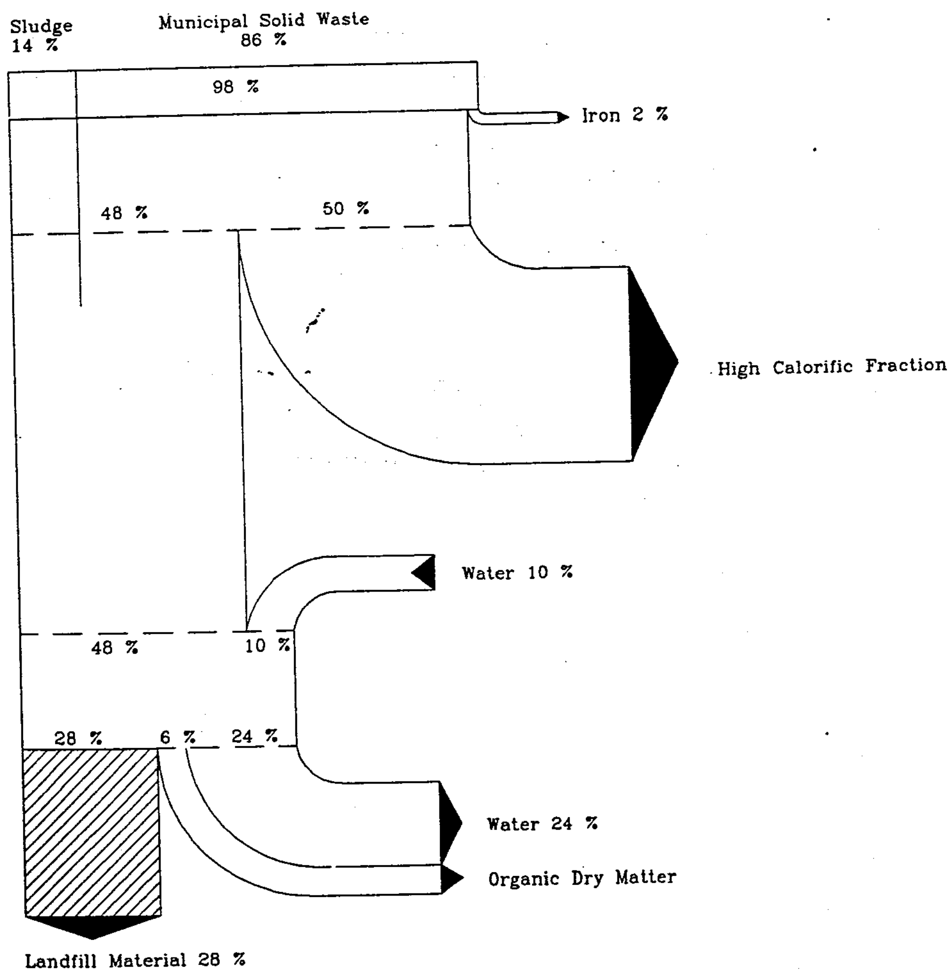


Figure 5. Mass balance of the mechanical-biological pretreatment in Schaffhausen (Bühler, 1993)

4.1 Stabilization Criteria

After mechanical-biological pretreatment the waste to be landfilled meets - apart from ignition loss and possibly TOC - all parameters required in Appendix B of the „TA Siedlungsabfall“. After mechanical-biological pretreatment the ignition loss of the waste to be landfilled amounts to 20-40% by weight for organics of mean degradability. By separation of RDF the organic content is further reduced; the required organic thresholds of 5% as ignition loss and 3% as TOC will not be kept even if the processes could be further optimized.

That these two parameters particularly determine the organic content of the waste is much contested, since they do not describe the biological degradation potential which causes emissions, such as landfill gas and leachate. To assess the biological activity, the respiration activity, BOD of solids, gas production potential, and self-heating tests are much more expressive.

A means to additionally minimize the biochemical degradation processes taking place in the landfill body is the dry-stable deposition. To provide dry-stable conditions in the residual waste, residual moisture contents between 25 % and 10 % in extreme cases are stated (Wiemer, 1993). Experiences with waste composting show that bilogical degradation processes are prohibited at residual moisture contents of below 20-25 % by weight.

4.2 Landfill Volume

The mass reduction after mechnical-biological pretreatment by separation of the reusable fraction, loss of water and mineralization amount to 20-40 % by weight, depending on the treatment concept and residual waste composition (Müller and Fricke, 1993; Scheffold and Vogel, 1992).

The density of the built-in material is expected to be increased after mechanical-biological pretreatment from about 0.8-0.9 Mg/m^3 to 1.2-1.4 Mg/m^3. As a consequence, the settling behaviour of the waste in the landfill body will be significantly improved.

The reduction in landfill volume is represented in Figure 6. The volume to be landfilled will be reduced after mechanical pretreatment by up to 30 % and after additional biological pretreatment the volume will be reduced to 60 % by volume of non-pretreated waste (Ketelsen, 1993).

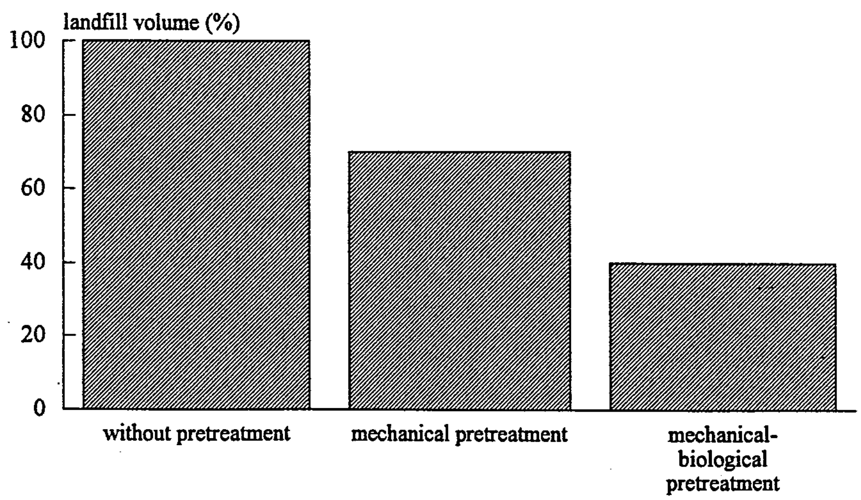


Figure 6. Saving of landfill volumne after mechanical-biological pretreatment (Heerenklage et al, 1994)

4.3 Landfill Emissions

After mechanical-biological pretreatment the gas and leachate potential of the landfill will be reduced. Figure 7 gives a prognosis of landfill gas production after prevention and reuse of waste as well as after mechanical-biological pretreatment. The remaining gas production is reduced after prevention/reuse and mechanical-biological pretreatment by about 50-90 % to 20-80 Nm^3/Mg of pretreated residual waste (Ketelsen, 1993).

During the gas phase, significantly higher contaminants concentrations are to be found in the exhaust air of non-pretreated MSW than of pretreated residual waste (Deipser and Stegmann, 1993; Poller, 1990; Damiecki, 1992).

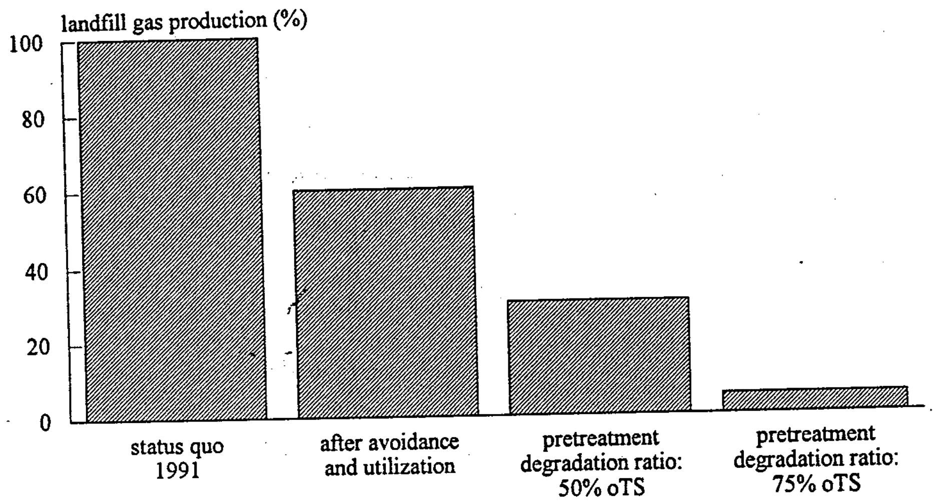


Figure 7. Prognosis for landfill gas prduction after realization of waste management concepts and mechanical-biological pretreatment (Ketelsen, 1993)

The organic load in the leachate is minimized by up to 80% (Collins, 1992). The emission behaviour of calcium (Ca) and iron (Fe) is positively influenced by the biological pretreatment of the residual waste (Kaiser and Chang, 1993). By leaving out the acidic phase minor sulfate concentrtions in the leachate are to be expected compared to non-pretreated RMSW (Stegmann et al., 1994). The costs of leachate treatment are reduced.

5 CONCLUSIONS

The mechanical-biological pretreatment of MSW can be applied within a waste management concept as a sole process or in combination with thermal pretreatment. During mechanical pretreatment, the waste is separated according to its material-specific properties and prepared for the subsequent treatment steps. The low organic waste content is aerobically treated in the biological process step or in combination of anaerobic/aerobic processes where it is largely biologically degraded and eventually dried. Plastic materials, which are not biodegradable within a predictable period of time but are of high calorific value, can be thermally treated.

The emissions of mechanical-biological pretreatment have to be collected and deodorized. The landfill emissions are significantly reduced when the waste is mechanical-biologically pretreated prior to deposition. In addition, the landfill properties of pretreated waste are improved and by the increased density of the waste, minor settlings will take place in the landfill body. the volume to be landfilled will be reduced by mechanical-biological pretreatment by up to 60 %.

Apart from ignition loss and possible TOC the pretreated wastes meet the landfill requirements of the „TA Siedlungsabfall“ But these two parameters to determine the organic content are much contested, since they do not necessarily describe the degradation potential of the waste. Suitable parameters alternative to ignition loss and TOC have to be standardized to be able to describe the biological degradation potential. The determination of the fermentability and respiration activity evaluate the biological degradation potential of residual waste and may be considered as alternative parameters. These parameters could be included in Appendix B of the „TA Siedlungsabfall“ as supplement or alternative to ignition loss. If necessary, an analysis has to be made for the specific material groups to describe the individual residual waste concerning their suitability for biological or thermal treatment.

Additional investigations will be necessary to optimize theindividual process steps of the mechanical-biological pretreatment. The efficiency of mechanical pretreatment has to be examined for the individual waste types to further optimize the composting process and to essentially improve the landfill characteristics. The treatment time during pre- and main composting has to be optimized to minimize the costs. Concerning the discussions about potential health risks caused by germs and volatile gas components extensive controls have to be made. Anaerobic processes should be integrated in the biological treatment concepts.

For certain residual waste streams the thermal treatment in combination with mechanical-biological pretreatment is quite sensible. By separating RDF during mechanical pretreatment the biological step may have smaller dimensions. For rural regions the waste management concept should provide a few centrally located incinerators besides the mechanical-biological pretreatment plants installed in situ.

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