# Ex situ bioremediation of old landfills by MBT

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**Abstract**

In this paper, the *ex situ* neutralization of biologically active municipal landfills by carrying out processes of enhanced co-degradation with fresh household derived biowaste in bioreactors is presented. The system involves a combined method of low-solids (up to 10% w/v of total solids) aerobic degradation and anaerobic digestion for the recovery of energy (biogas) and the production of fine humus-like material which can be used as a soil amender or a substrate for further thermal treatment (pyrolysis, gasification).

**Keywords**

Biowaste, Landfills, Municipal solid waste degradation, Aerobic biodegradation, Anaerobic digestion, Bioreactors

# 1 Introduction

The environmental situation concerning the disposal of municipal solid wastes and the security of existing landfills makes it necessary to look for a technology which will reduce costs, environmental risks and progressive consumption of landscape as well as conserve water resources. In Poland, the number of municipal landfills reaches around 10 000, from which 1016 are working as organised landfills, while the others are mostly unauthorised dumping grounds causing a long-term environmental impact (STATISTICAL YEARBOOK OF POLAND, 2003). One of the methods aiming at minimization of the hazardous impact of old landfills on the environment caused by leakage of leachates and landfill gas emission is *ex situ* biodegradation of material deposited in bioreactors.

In this paper experimental investigations of a possibility of neutralization of biologically active municipal landfills by carrying out processes of enhanced co-degradation with household derived biowaste in bioreactors are presented. The system involves the following steps: mechanical processing (waste disintegration and equalization); biological processes (aerobic degradation and anaerobic digestion); thermal processes (pyrolysis, gasification, vitrification) (EUROPEAN PATENT OFFICE, EP 0-472-173-B1).

Kitchen garbage and other organic waste, collected separately, were ground and fed into a suspenser vessel where, diluted with waste water/sewage sludge, they generated a pumpable slurry for bioreactors. Water extracts of old organic material were prepared by repeated leaching of the waste taken from the landfill with hot water.

Biological section of the proposed method represents the natural processes that take place in a municipal landfill: an aerobic process which lasts until exhaustion of atmospheric oxygen contained in the landfill, and anaerobic processes: acidic fermentation and methane fermentation. The use of bioreactors and significant disintegration of wastes as well as carrying out the processes in the liquid phase contribute to a remarkable reduction of the process duration. Due to this, the subsequent phases of organic matter decomposition can be quick and efficient (Ledakowicz et al., 1999).

The dewatered biomass is further dried and granulated. Depending on needs, the granulated product can be used as a soil amender or may be subjected to pyrolysis and gasification (Krzystek et al., 2001). The final product of the technology may be a vitrified substance which constitutes a negligibly small part of the initial mass of wastes and is neutral for the environment.

Special attention is focused in this study on the biological treatment of fresh OF MSW and landfill drillings material in aerobic and anaerobic bioreactors in laboratory-scale experiments. It is well known that landfill material is characterized by high COD and low BOD5 values. In order to enhance the biodegradability of dump material (to make it finally biologically inert) it is reasonably to mix it with fresh OF MSW, having high BOD5 value. The mixing of fresh OF MSW and drillings from landfill will increase BOD5/COD ratio and the landfill material could be further biodegraded in a reasonable time period. A possibility of using sewage sludge from a sewage treatment plant for preparing a slurry of wastes which could be put into the bioreactors was also checked. The performance of batch processes, both aerobic and anaerobic, was monitored by TS, VS, COD, TOC, DOC, C/N reduction in time. The impact of process parameters on process efficiency was investigated.

# 2 Materials and methods

## 2.1 Biowaste source and characteristics

The organic fraction of municipal solid waste (OF MSW) from the city of Lodz, Poland, was collected fresh and ground in a laboratory tumbling mill to a size range of ca. 3 mm. Its composition was defined so as to correspond with a typical Polish organic waste (Steglinski, 1999). Average values of carbon and nitrogen parameters of the disintegrated biowaste are given in Table 1.

An organic fraction of solid municipal waste collected in the city of Lodz (Poland) and samples of deposits from the municipal landfills “Lublinek” (depth 5 to 6 m) and “Nowosolna” (depth 8 and 12 m) were used in the experiments. Fresh waste was ground with the addition of water in a ceramic ball mill. As a result, pulp with particle fraction below

3-5 mm was obtained. Water extracts of old organic materials were prepared by repeated leaching of the waste taken from the landfill with hot water (60-80°C). Experimental data covered measuring series of periodical biodegradation processes carried out in the bioreactors in aerobic conditions. Fresh waste suspensions prepared and supplied to the bioreactors contained about 4-7% dry matter. The initial pH of the fresh waste suspensions was about 5.4, of the waste suspension from the landfill about 7.2, while of their mixture – about 5.8 to 7.5.

**Table 1** Carbon and nitrogen parameters of ground biowaste

| **Parameter** | | **Average** |
|---|---|---|
| TS | g TS/kg | 235.3 |
| VS | g VS/kg | 197.1 |
| $COD_{TOT}$ | g COD/kg | 278.4 |
| $COD_{TOT}/VS$ | | 1.4 |
| TOC | g TOC/kg | 76.7 |
| TOC/TKN | | 30 |
| MPN | $ml^{-1}$ | $5 \cdot 10^6$ |

## 2.2 Analytical procedures

During biodegradation processes the following organic load factors were analyzed: total solids (TS) by the gravimetric method after drying at 105°C; volatile solids (VS) as a loss of weight between 105 and 450°C; chemical oxygen demand (COD) by the dichromate method (method 8000 Hach); total organic carbon (TOC) and dissolved organic carbon (DOC) contents in Coulomat 702 Li/C (Ströhlein Instruments); nitrogen (TKN) by Kjeldahl method (according to the Polish Standard PN-75-C-04576-17 in the Büchi device); volume of biogas produced by means of liquid level displacement; methane fraction of biogas by gaseous chromatography (LMS GasData); elemental composition of organic matter (content of C,H,N,S,O) by elemental analyzer NA-2500-M (CE Instruments).

Quality of the chemical analysis was checked by the use of standard solutions. Analytical errors were below 5%, for elemental analysis below 0.2%. The data from every triplicate experiment were calculated to obtain arithmetic mean values and standard deviations using computer programs (Microsoft Excel 2000, Microsoft Corporation; Microcal Origin 6, Microcal Software). The arithmetic mean values (n = 3) were used to plot graphs.

### 2.3 Reactor configuration and operation

The experimental data cover series of batch aerobic biodegradation processes and series of batch anaerobic digestion processes in laboratory scale reactors. The bioreactors (6 $dm^3$ of working volume) were equipped with standard control instrumentation – temp., pH, dissolved oxygen level (DOT), foam level and stirrer speed. Aerobic processes were carried out with temperature control (30°C ± 0.5°C), aeration intensity from 0.3 to 2 vvm (according to the requirements of microorganisms) and agitation of 500 rpm.

Anaerobic processes were conducted batchwise at the temperature of 36°C ± 0.5°C and pH > 6.0 (regulated by the addition of suspension of $Ca(OH)_2$ in NaOH in 1:1 weight ratio) in the bioreactor of 10 $dm^3$ of total volume ($V_L$ = 9 $dm^3$, agitation = 30 rpm). Initially, the reactor was filled with an anaerobic sludge from the municipal sewage treatment plant of Lodz (Poland). After an adaptation time (2 weeks at 36°C), 0.7 $dm^3$ aliquots were replaced by a mixture of fresh sewage sludge and biowaste slurry (1:1). When the gas production ceased, 0.7 $dm^3$ was again replaced by the biowaste slurry only. When the gas production ceased again a batch feeding once per day was started. After the process had stabilized, the loading was increased as indicated later. A cycle of aerobic and anaerobic processes was also carried out in various sequences (aerobic-anaerobic and anaerobic-aerobic).

## 3 Results and discussion

### 3.1 Aerobic biodegradation

The process of biodegradation in aerobic conditions covered wastes from a municipal landfill, an organic fraction of fresh household waste and their mixtures. It was found that the degree of biodegradation of the oldest waste taken from 12 m below the landfill surface was the slowest (Fig. 1). The degree of reduction of VS, COD and DOC was then about 30%.

Results obtained during the degradation of the mixture of waste from the landfill and fresh household waste were similar to those obtained in the processes involving only fresh waste (Fig. 2). For instance, when the initial dry matter content in the waste was ca. 6%, the degree of reduction of VS, $COD_{TOT}$, $COD_{LIQ}$ and DOC was 28.7%, 43%, 73.4% and 65.7%, respectively, in the process of fresh waste degradation and 50.7%, 46%, 75.1% and 69.4% in the degradation of the mixture with waste from the landfills. The degree of reduction of VS, COD and DOC in these processes in which only the landfill waste was subjected to degradation, was slightly lower. At dry matter content of about 3% the degree of degradation of VS and $COD_{TOT}$ was about 40% in the processes of degradation of both the landfill waste itself and the mixture with freshly collected waste.

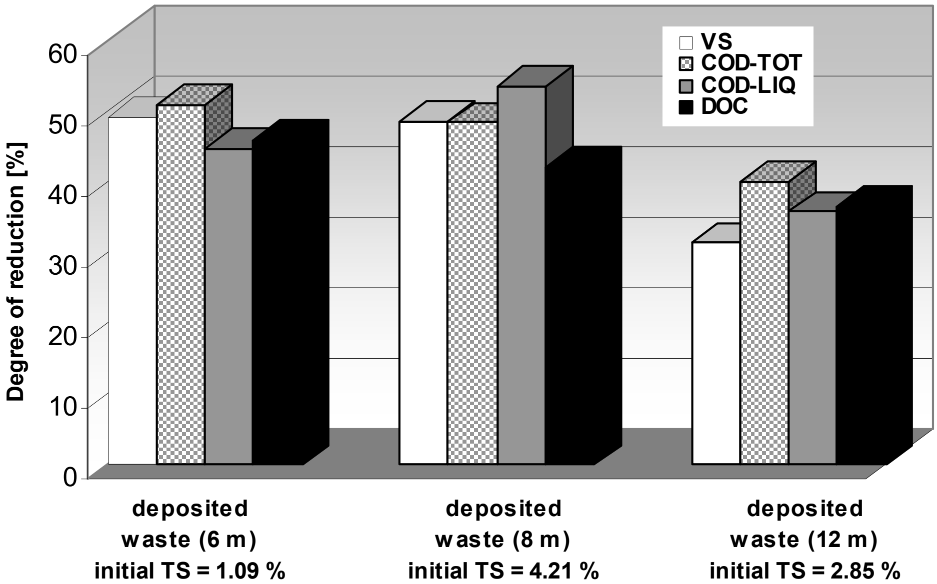


**Figure 1** Results of degradation processes of organic fraction of household wastes and deposited wastes after 120 h of processing

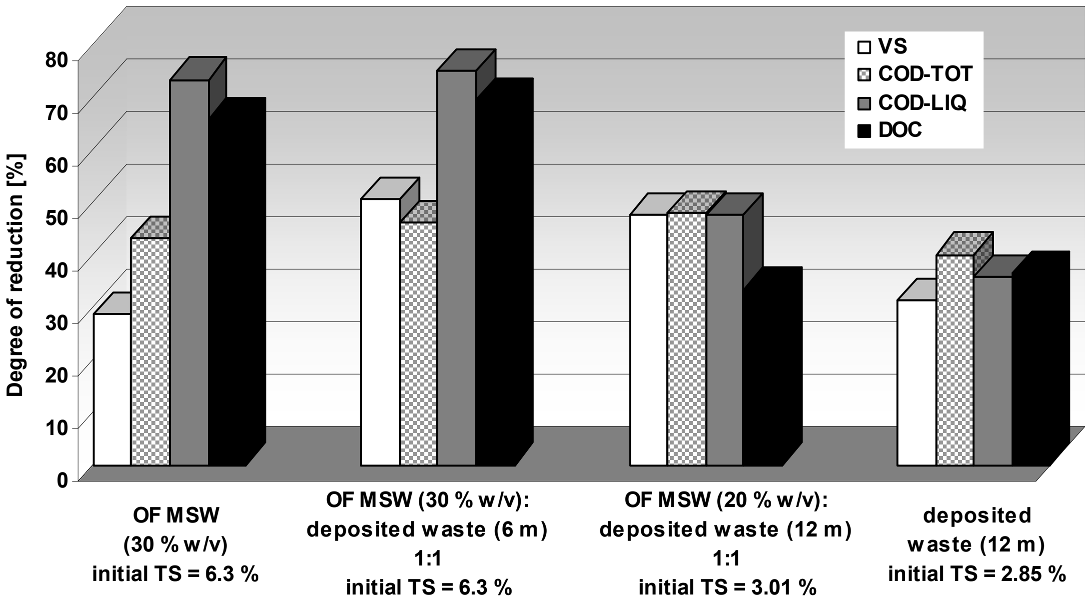


**Figure 2** Results of degradation processes of organic fraction of household wastes and deposited wastes after 120 h of processing

This shows that it is possible to carry out the processes of enhanced biodegradation of suspensions of landfill drillings material in bioreactors.

Investigations of changes in the elementary composition of dry matter in the organic fraction of household waste during biodegradation show a decrease of C/N ratio by about 15% with a parallel decrease of dry matter by ca. 35% after about 140 hours of the process (Fig. 3). Carbon content remained on a constant level (ca. 43.5 $g/100g_{TS}$), like the content of hydrogen and sulfur. Only the content of nitrogen increased slightly (by about 15%) and oxygen decreased (by ca. 5%). Similar changes were observed in the processes in which landfill waste was used. The experimentally determined oxygen demand was about 1.2 g $O_2/g_{TS}$ and was similar to a theoretical one calculated from a simple stoichiometric relation.

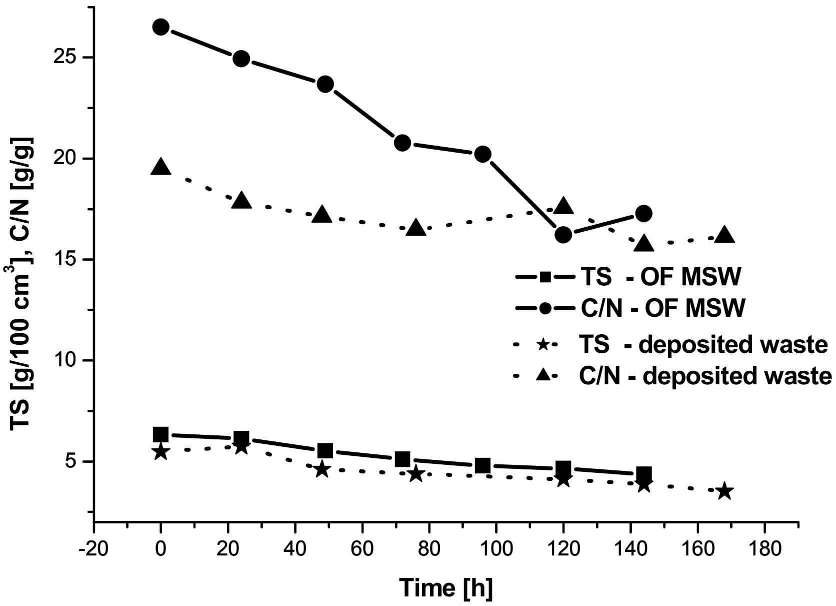


**Figure 3** Changes of C/N ratio and dry matter (TS) during aerobic biodegradation of organic fraction of solid waste and deposited waste

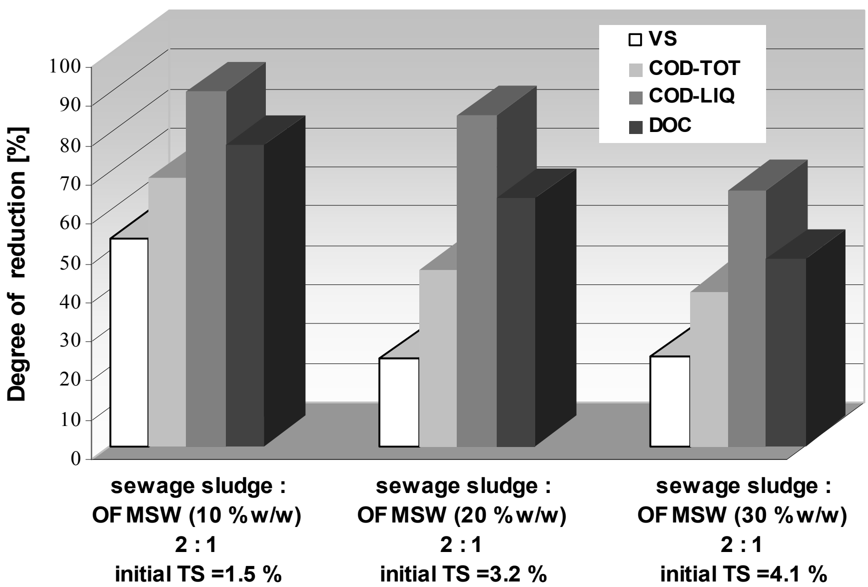


**Figure 4** Results of degradation processes of organic fraction of household wastes and sewage sludge after 120 h of processing

In the experiments described above OF MSW was diluted with tap water. A possibility of using for this purpose the sewage sludge from the sewage treatment plant was also checked. The experiments carried out with the slurry of solid household wastes diluted with sewage sludge (up to about 4% by weight of TS) at 30°C resulted in the organic load reduction similar to the processes in which the OF MSW was diluted with tap water. The results are shown in Fig. 4.

In these experiments the amount of solid wastes was changed in order to increase the initial concentration of solids. At the initial TS content of 4.1%, the degree of COD degradation, both total and in the liquid phase, was about 40% and 66%, respectively. For 1.5% of TS the COD reduction increased to about 70% and 91%, respectively.

## 3.2 Anaerobic digestion and the sequence of biological processes

Methane fermentation of household solid waste suspensions was optimized from the point of view of a maximum reduction of organic matter. A 50% reduction of VS, the yield of biogas of 500 $dm^3(kg\ VS)^{-1}$ was obtained in the batch processes lasting for 12 days (initial value of VS being 60 g $(kg_{wastes})^{-1}$).

The combined biological processes was investigated under two sequences: aerobic-anaerobic and anaerobic-aerobic. The amount of biogas obtained in the anaerobic process not preceded by the aerobic process was almost 4 times higher than in the reverse sequence (Fig. 5). However, the total degree of reduction of the main indices of organic load (VS, COD, DOC) of the two sequences was similar (about 75%, 99%, 85%, respectively), (KAHLE ET AL., 2001).

# 4 Conclusions

The results of investigations on intensive biodegradation of organic fraction of solid municipal waste show that the process is fast and the degree of organic substance degradation is high. It was achieved due to the application of the method of degradation in stirred bioreactors. Humus, obtained by biological treatment, can be used as a soil amender and/or can be pyrolyzed/gasified, fired directly in a boiler when mixed with other fuels or pelletized for use as a fuel source.

It has been found that it is possible to inertize biologically active municipal landfills by conducting the processes of enhanced degradation in bioreactors. Municipal waste subjected to degradation and its mixture with household solid waste were degraded on a level comparable with that of household solid waste only. However, the degree of reduction of VS, COD and DOC in these processes in which only the landfill waste was subjected to degradation, was slightly lower. After ca. 140 hours of the aerobic degradation processes, a decrease of both C/N ratio (by ca. 15%) and dry matter content (by ca.

35%) was observed. Theoretical oxygen demand was on a constant level, about 1.20 g $O_2/g_{TS}$ and did not depart from experimental values.

The experiments carried out with the slurry of solid household wastes diluted with sewage sludge resulted in the organic load reduction similar to the processes in which the OF MSW was diluted with tap water.

The combination of aerobic and anaerobic waste degradation processes enables high degrees of organic substance degradation at a simultaneous energy recovery in the form of biogas. From the point of view of the organic load reduction the sequence of biological processes does not play a substantial role.

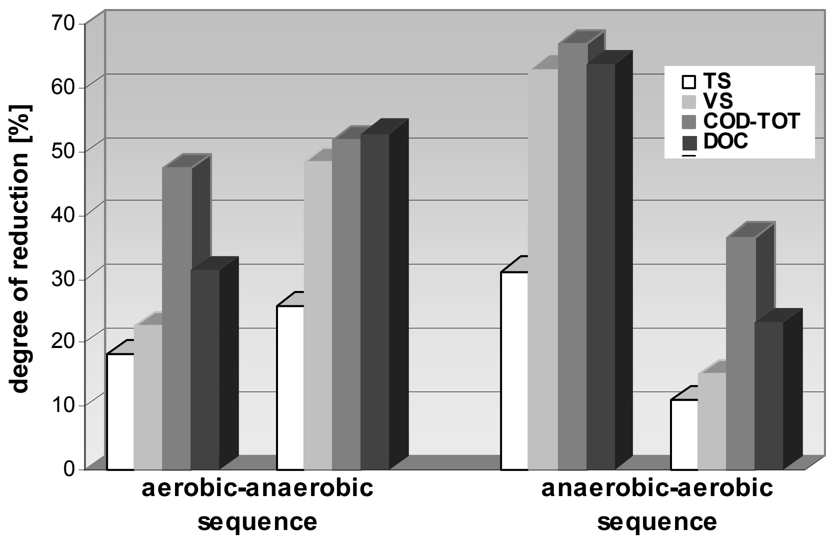


**Figure 5** Results of organic load reduction obtained in alternative sequences of batch aerobic and anaerobic processes

# 5 Summary

The aim of experiments was to investigate a possibility of neutralization of biologically active municipal landfills by carrying out processes of enhanced degradation in bioreactors. Water suspensions of solid deposits from a municipal landfill and their mixture with organic fraction of fresh household waste were subjected to aerobic biodegradation in bioreactors. The idea of bioremediation of old landfills was patented (European Patent Office, EP 0 472 173 B1).

Organic fraction of solid municipal waste collected in the city of Lodz (Poland) and samples of deposits from the municipal landfills “Lublinek” (depth 5 to 6 m) and “Nowosolna” (depth 8 and 12 m) were used in the experiments. Fresh waste was ground with the addition of water in a ceramic ball mill. As a result, pulp with particle fraction below 3-5 mm was obtained. Water extracts were prepared by repeated leaching of the waste from the landfill with hot water (60-80°C). Experimental data covered measuring series of periodical biodegradation processes carried out in the bioreactors in aerobic and anaerobic conditions.

Results obtained during the aerobic degradation of the mixture of waste from the landfill and fresh waste were similar to those obtained in the processes involving only fresh waste. However, the degree of reduction of VS, COD and DOC in these processes in which only the landfill waste was subjected to degradation, was slightly lower. At dry matter content of about 3% the degree of degradation of VS and $COD_{TOT}$ was about 40% in the processes of degradation of both the landfill waste itself and the mixture with freshly collected waste. It was found that the biodegradation of the oldest waste taken from 12 m below the landfill surface was the slowest. The degree of reduction of VS, COD and DOC was then about 30%.

The use of sewage sludge in waste slurry preparation resulted in the organic load reduction similar to the processes in which OF MSW was diluted with tap water. The combination of aerobic and anaerobic waste degradation processes enables high degrees of organic substance degradation at a simultaneous energy recovery in the form of biogas. From the point of view of the organic load reduction, the sequence of biological processes does not play a substantial role.

This shows that it is possible to carry out the processes of enhanced degradation of suspensions of landfill drillings material in bioreactors.

# 6 Literature


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