CIVIL AND ENVIRONMENTAL ENGINEERING REPORTS

No. 6 2011

THE METHODS TO INTENSIFY WASTE DECOMPOSITION

Monika SUCHOWSKA-KISIELEWICZ*
Institute of Environmental Engineering
University of Zielona Góra
Szafrana st. 15, 65-516 Zielona Góra, Poland

Landfilling is still a popular waste disposal method. However, currently it is insufficient practice for effective waste management. Conventional waste disposal leads to pollutant emissions by a long periods of time and requires applying specific emission control and treatment method. Old landfill might require aftercare for decades or centuries. The consequences of this is long –term risks for environment and human health. Currently, the primary task posed for modern landfill management systems is the use of efficient and economic technology of waste treatment and disposal. The paper presents, according data from subject literature, the impact of leachate recirculation and aerobic degradation of waste and mechanical-biological treatment of wastes before their storage on the reduction of pollution emissions from landfills.

Keywords: Landfills; Leachate; Municipal solid waste; Mechanical biological treatment wastes, Recirculation, Aerobic degradation

1. INTRODUCTION

Increase of awareness on degradation processes running in landfills have been the cause of finding new ways of waste disposal. Traditional landfills are designed as dry storage where the amount of leachate is decreased by reducing infiltration of precipitation and groundwater. Waste decomposition on these landfills runs under anaerobic conditions with limits the moisture content. Waste decomposition in these landfills proceeds slowly and pollutant emissions removed with leachate and biogas pose long-term risks to the environment and human health. These risks are associated with [25]:

* Corresponding author. E-mail: M.Suchowska-Kisielewicz@iis.uz.zgora.pl

- Production of leachate with high concentrations of organic contaminants, metals and large number of pathogens that may pose serious risks to groundwater;
- Long-term methane emissions, odours and volatile organic compounds;
- Slow stabilization of waste that causes long-term pollutant emissions to the environment and costly monitoring.

Traditional landfills are equipped with biogas and leachate collection system and leak detection systems. However, probability of leakage and uncontrolled biogas emissions form those landfills, taking into account even the hundreds of years of pollutant emissions [13], is high. Hence, traditional landfills require long term and costly monitoring of emissions for many years after their closure. This increases the total cost of these systems operation. Currently, the primary task posed for modern landfill management systems is the use of efficient and economic technology of treatment and disposal of wastes.

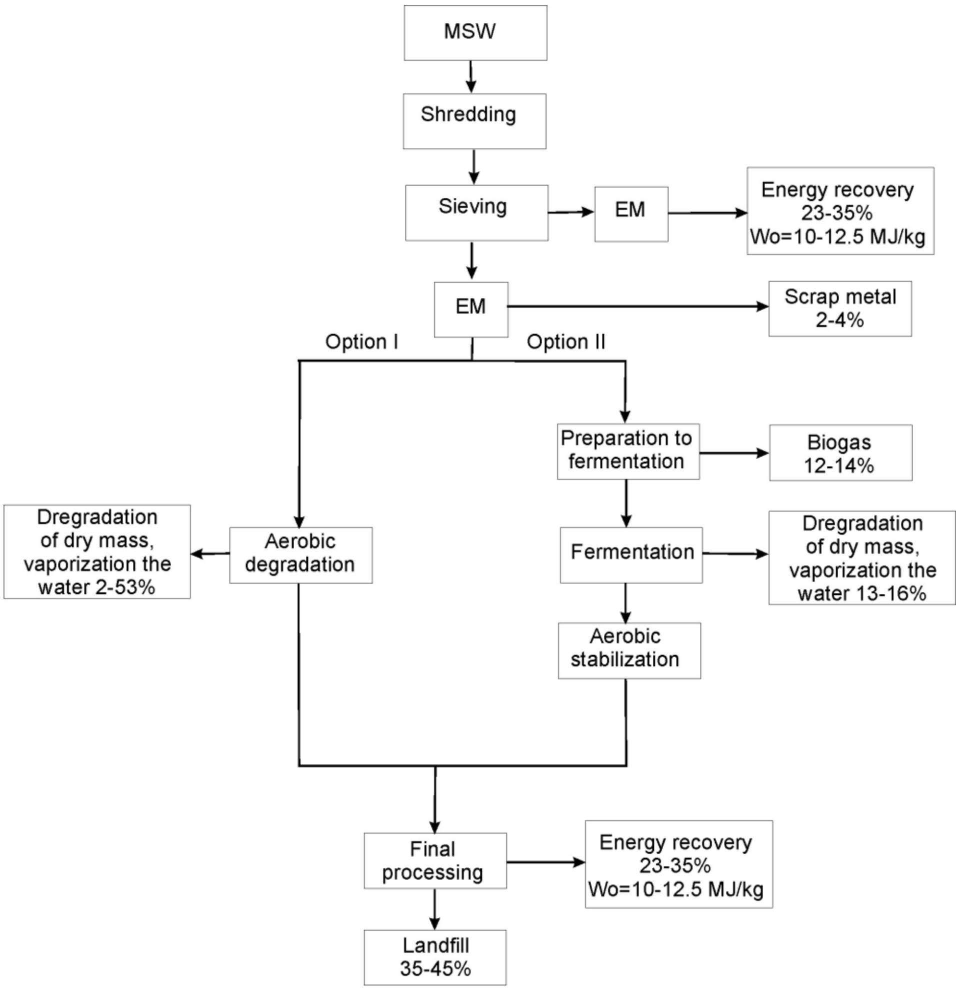
The paper presents, according data from subject literature, the impact of leachate recirculation and aerobic degradation of waste and mechanical-biological treatment of wastes before their storage on the reduction of pollution emissions from landfills.

2. MECHANICAL-BIOLOGICAL TREATMENT OF WASTE

Mechanical-biological treatment of wastes (MBT) includes the following processes: shredding, sieving, sorting, classification and separation and waste stabilization, carried out in various configurations. The objectives of mechanical processing is separation of waste stream into factions allowing reuse (as recycled material and / or energy) and the fraction of waste that can be stabilized in the aerobic or anaerobic conditions. The basic goal of MBT, except for material recovery and recycling, is the reduction of emissions of methane and pollutant load from landfills, improvement of methane conditions in landfills, and the reduction in the volume and weight waste [15, 17, 29, 35]. The result of MBT is the reduction of organic and nitrogen pollutants in leachate and biogas even up to 80-90% [1, 20, 31, 37].

The recommended method of biological stabilization of wastes in developing countries before they are landfilled is the aerobic degradation, which requires less investment and operating costs than anaerobic processes [6]. Technology of waste stabilization carried out in aerobic condition contributes to the rapid formation of stable methane conditions in the landfill [17], the reduction of production of leachate and loads of organic pollutants and thus the reduction of the potential for landfill emissions [28]. The processes of MBT are applied to treated mixed (not sorted) municipal waste, which were previously selected as wastes suitable for reuse (recycling) and residual wastes (municipal wastes remaining after the separation of biodegradable wastes from them). MBT technologies in their present form were developed in Germany in the late 1990s.

MBT technology after the introduction of The European Council Directive on the Landfill of Wastes 1999/31/EC is being developed and used to reduce the amount of biodegradable wastes deposited in landfills. The general scheme of the process of mechanical-biological treatment of municipal waste is shown in Figure 1 [20].



EM - electromagnet
Wo - heat incineration

Fig. 1. The general scheme of MBT process [20]

2.1. The effectiveness of MBT

Table 1 shows the chemical composition of leachate which was removed from wastes pre-treated in aerobic conditions, deposited in the landfill in Lunenburg and in anaerobic reactors in the laboratory, and the chemical composition of untreated municipal wastes, which were in the acid and methane phase [31].

Table 1**.** The chemical composition of leachate from the landfill MBT and landfill MSW [31].

Parameter	MPT Luneburg, initial phase of landfilling	Laboratory scale landfilling of MBT waste, initial phase	Untreated MSW acid phase	Untreated MSW methane phase
pH	7.5	7.0 - 7.5	4.5-7.5	7.5 - 9.0
COD, mg O_2/dm^3	700 – 2500	2000 - 2400	6000 - 60000	500 – 4500
TOC, mg/dm^3	300 – 950	-	2000 - 30000	200 – 2000
BOD_5, mg O_2/dm^3	1 – 55	100 - 1100	4000 - 40000	20 – 550
COD/ BOD_5	20 – 150	2 - 20	2	15 – 20
TKN, mg/dm^3	10 – 37	-	1350	1350
NH_4-N, mg/dm^3	0 – 27	90 - 130	750	750
NO_3-N, mg/dm^3	15 – 66	-	-	-
NO_2-N, mg/dm^3	0.1 - 1.7	-	-	-
$N_{inorganic.}$, mg/dm^3	16 – 75	-	750	750
$N_{Total,}$ mg/dm^3	35 – 140	200 - 250	1350	1350
COD/N_{Total}	4.6 - 8.7	10	8 – 12	2 - 3
AOX, mg/dm^3	0.1 - 0.9	-	0.3 - 3.4	0.3 - 3.4

The concentrations of contaminants removed in the leachate from MBT wastes were similar to concentrations in leachate from MSW occurring in the methane phase and significantly lower than the ones observed in leachate from MSW occurring in the acidic phase. The results presented by Robinson et al. [31] (Table 1) were consistent with research by Leikam and Stegmann [16], where the chemical composition of leachate from MSW and from pre-treated biofraction in aerobic condition were compared.

Moreover, Leikam and Stegmann [16] found, as well as Robinson et al. [31], that in wastes which have been aerobically processed before landfilling there is no acid phase, that is characterized by high concentrations of pollutants in the leachate.

The effectiveness of aerobic waste treatment depends on several factors such as: time and intensity of aeration (Table 2), susceptibility to degradation and the process conditions described by the content of moisture and the temperature in the bed of waste landfills [7].

Table 2. The duration of aerobic stabilization (weeks) in relation to the achieved degree of decomposition of organic waste [7]

Type of installation	The duration of aerobic stabilization (weeks) in relation to the achieved degree of decomposition of organic waste					
	10%	20%	30%	40%	50%	60%
Static pile	13	31	46	59	-	-
Static pile - chimney draught	8	18	31	47	-	-
4 weeks of aeration the compressed air + the maturation in static pile	4.5	8.5	17	32	-	-
8 weeks of aeration the compressed air + the maturation in static pile	2	3	4	6	9	21
16 weeks of aeration the compressed air + the maturation in static pile	2	3.5	5	9	16	31

Höring et al. [11] have designated the values of emission of organic carbon in landfill gas and leachate, and loads of total nitrogen and chloride in leachate removed from the untreated and treated wastes stabilized in laboratory reactors (Table 3).

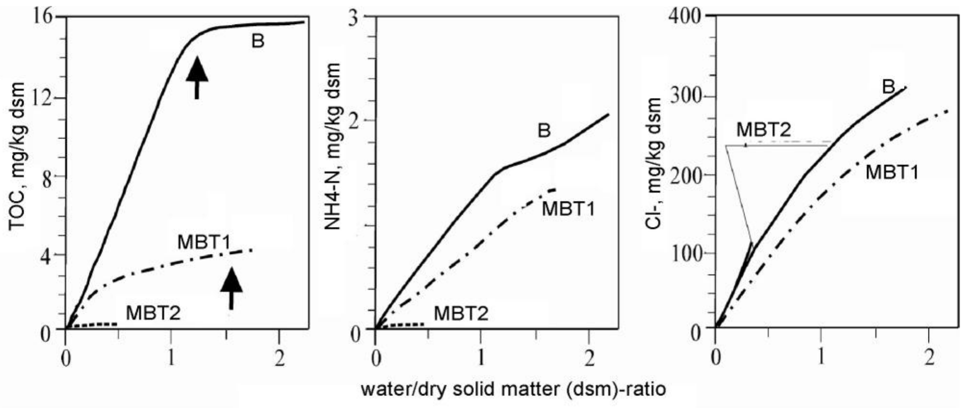
Tabela 3. Loads of pollutants removed in gas and leachate from MSW and MBT wastes [11]

Loads of pollutants removed in gas and leachate	Unit	MSW	MBT
Carbon removed in gas	dm^3/kg sm gC_{org}/kg sm	134 - 233 71.7 - 24.7	12 - 50 6.4 - 26.8
Loads of pollutants removed in leachate			
TOC	g/kg sm	8 - 16	0.3 - 3.3
TN	g/kg sm	4 - 6	0.6 - 2.4
Cl^-	g/kg sm	4 - 5	4 - 6

The authors found that emissions from MBT landfills were much lower than in untreated wastes, indicating that it was caused by lack of easily degradable organic matter in those wastes. The consequence of the reduction of easily degradable organic matter was a very low production of gas and slow release of organic matter and nitrogen into the leachate. Furthermore, Höring et al. [11] found that in the wastes after an effective process of MBT there is only organic matter which is hardly biodegradable (lignin, waxes, humic acids), whose degradation requires the development of a suitable population of microorganisms.

According to Stegmann [4] intensive waste composting (16-30 weeks), helps to reduce landfill gas emissions even by 80-90% compared to the emissions from untreated waste. This corresponds to a decrease in biogas production up to 15-20 m^3/Mg MBP, while the typical production of biogas from MSW is 165 m^3/Mg [32].

Brinkmann et al. [1] obtained a reduction of organic pollutants emissions represented by the TOC and ammonia nitrogen removed from wastes by 80-90% after 25 weeks of intensive aeration. After five weeks of intensive composting the reduction of these pollutants was significantly lower (Fig. 2). In this and most other research there was no reported effect of aeration on the reduction of the chloride content [1, 6, 20] (Fig.2).



B – biofraction- milled by a hammer mill with magnetic separation of scrap metals and separation of fraction > 60mm
MBP1 – Biofraction (<60 mm) submitted to a 35-day intensive composting process
MBP2 - Biofraction (<60 mm) composed for an overall period of 6 months

Fig. 2. Mass transfer of contaminants into leachate,for different degrees of waste pre-treatment [1]

3. RECIRCULATION OF LEACHATE

A new approach to the landfilling is operating them as bioreactors, in which degradation is enhanced by the use of appropriate operational processes. The most commonly used technique for intensification of processes taking place in landfills is leachate recirculation. It improves conditions for the decomposition of wastes and is an effective method of leachate treatment. Documented the benefits of its use are as follows [19, 21, 26, 38, 39]:

- reduction in the volume of leachate directed to wastewater,
- improvement of the quality of leachate,
- increase in the rate of biogas production,
- • acceleration of the settlement of the deposit of wastes, which leads to an increase in the dispositional capacity of the landfill.

The principal processes taking place in a landfill with the recirculation of leachate are similar to the processes occurring in traditional landfills. However, in the fields of wastes stabilized with recirculation, the subsequent phase of its stabilization is carried out intensively and is more controlled than in a landfill without recirculation [23]. Recirculation increases the amount of moisture in the wastes, reduces the concentration of potential inhibitors of methanogenesis [18] and provides nutrients and enzymes necessary for the development of micro-organisms [36]. Moreover, recirculation accelerates the decomposition of organic waste components, accelerates the increase of methane production [34] and the reduction of pollutants in leachate which are recirculated to the landfill.

Treatment of leachate which are recirculated into the landfill occurs most efficiently in a stable phase of methane fermentation, in which the organic substances present in leachate are used for biogas production, and heavy metals are immobilized [26]. According to Pohland and Kim [24], the required time needed for the appearance of the methanogenic phase in landfills with recirculation is 2-3 times shorter than in a landfill without recirculation, VFA concentrations have a low, constant range of values after 1 year, and the COD after about 2 years and a stable phase of methanogenic can already be observed after 1 year.

Recirculation of leachate which is too intensive, as a result of recirculation of large amounts of organic acids, can lead to inhibition of methanogenic phase [14]. Chugh et al [2] found that the best results of leachate recirculation defined as stable production of methane and low concentrations of COD in the leachate can be obtained using the recirculation of leachate at a level of 30% of the volume of the wastes deposited. Reinhart and Al-Yousefi [26] showed that the leachate recirculation reduces the time of waste stabilization from several decades to 2-3 years. Oonk and Woelders [22] in a pilot-scale studied effect of time of recirculation on the reduction of the pollutants concentration in leachate from untreated biofraction stabilized with recirculation (Table 4).

Results of their research showed that the level of concentration of organic pollutants in leachate depends on the duration of recirculation. The concentrations of organic pollutants (COD, BOD5 and TKN) in the leachate after 12 months of recirculation were lower than those found in the leachate from wastes stabilized without recirculation, respectively by 68, 77 and 10% and by 49, 36 and 77% lower than from wastes stabilized with 6-month recirculation. The low reduction of TKN in the waste with a 12 month recirculation found during the research was explained by the accumulation of ammonia nitrogen in the wastes caused by the recirculation of leachate rich in ammonia nitrogen. Oonk and Woelders [22] and San [33] also showed that low frequencies of recirculation can lead to more concentration of ammonium nitrogen in leachate, and an increase in the frequencies of recirculation to its decrease.

Tabela 4. Composition of leachate removed in leachate from untreated biofraction stabilized with recirculation [22]

Parameters	Composition of leachate		
	without recirculation	with recirculation– 6 months	with recirculation – 12 months
COD, mg O2/dm^3	60700	39200	19400
BOD5, mg O2/dm^3	42000	26000	9400
TKN, mg/dm^3	4700	5400	4200
Chloride, mg/dm^3	4700	5700	6500
pH	7.1	7.8	8.2
Chromium, mg/dm^3	450	670	1300
Nickel, mg/dm^3	770	350	450
Copper, mg/dm^3	64	18	330
Zinc, mg/dm^3	2500	180	560
Cadmium, mg/dm^3	<0.5	<0.5	<0.5
Lead, mg/dm^3	180	28	56
Arsenic, mg/dm^3	<50	210	190
Mercury, mg/dm^3	0.63	0.35	0.58

4. AEROBIC LANDFILL

Aerobic landfills are a method that allows the intensification of the wastes degradation which have a high potential for emissions of pollutants into the environment. Aerobic landfills are primarily focused on reducing the duration of the wastes stabilization, reducing the amount of leachate, improvement of their quality, reducing the quantity of methane, volatile organic components and odours (ammonia, hydrogen sulfide) [5].

Benefit from the operation of an aerobic landfill [9]:

- Improvement of the quality of leachate and the reduction of the time of their emission, which leads to lower costs associated with monitoring and treatment of leachate;

- Low production of methane that reduces the impact of landfill emissions on global warming;
- High degree of waste stabilization;
- Low investment and operating costs;
- Simple design and a clear operational unit;
- Ease of monitoring.

Additional advantages of the use of aerobic landfills are:

- Landfills are operated as aerobic bioreactors, in which the processes of decomposition are controlled and directed to their intensification;
- Injection of oxygen can be carried out using the existing system of collection and transport of leachate and / or biogas, which significantly reduces the costs of modernization of traditional landfills;
- Aerobic technology can be used together with leachate recirculation, which increases the rate of waste stabilization and reduces the amount of leachate and the size of their concentration;
- Aerobic landfills are characterized by a high degree waste stabilization.

Operation of landfills as aerobic bioreactors may be dictated by various objectives: reduction of the potential of landfill for emissions contaminant and its time monitoring [12], the reclamation old landfills [28], reduction of odours [27] and acceleration of wastes settlement [10].

The main objective of aerobic landfills is the intensification of waste stabilization, reduction of organic matter content in the mass of waste, reduction of pollutant concentrations in leachate, reduction of methane production, and acceleration of wastes settlement.

Efficiencies of aerobic degradation processes is dependent on maintenance of optimum conditions of storage. Main parameters influencing the efficiency of these processes are as follows: the content of oxygen in the mass of wastes, their temperature as well as the moisture.

Read et al. [27] investigated the efficiency of areobic degradation of wastes in optimum conditions of areation, recirculation as well as temperature in two aerobic landfills: Columbia Country Landfill and Live Oak Landfill (Table 6).

Their results confirmed a favourable influence of aerobic processes of degradation on decreasing the emission of contamination. They found, that aerobic landfills are characterized by:

- Significant increase in the rate of biodegradation of wastes in comparison to the degradation of wastes in anaerobic conditions;
- Reduction in the volume of leachate associated with high evaporation;
- Reduction of organic substances in leachate;

- Significant reduction of methane production, odours and volatile organic compounds.

Furthermore they determined that the rate of wastes degradation in aerobic landfills is comparable to the degradation rate of wastes composted, and that the aerobic landfills are characterized by high efficiency of decomposition of easily degradable organic substances, but also relatively rapidly decompose inert wastes, bulky wastes and wood and plastic [27, 30].

Tabela 6. Parameters and the efficiencies of wastes degradation on two aerobic landfills: Columbia Country Landfill and Live Oak Landfill [27]

Parameters	Columbia Country Landfill	Live Oak Landfill
Operating parameters		
Cell size (ha)	1.6	1
Awerage waste deph (m)	3	10
Total waste volume (m^3)	45	49
Age of waste At start of project (months)	18	36
Leachate injection rate (dm^3/d)	13.5	25.2
Air injection rate (m^3/min)	56	100
Annual rainfall (cm/year)	137	114
Waste mass temperatures (^oC)	40-60	40-60
Efficiencies of degradation		
Biodegradation rate[1]	increased by 50%	increased by 110%
Reduction of waste settlement (m/m)	9%	10%
Reduction of metan production	50-90 %	50-90%
Reduction of leachate BOD	70%	70%
Reduction of leachate VOC	75-99%	50%
Duration of study (months)	18	9
Reduction of odors (ammonia, sulphur hydrogen)	Noticeable	Noticeable
Reduction of leachate volume	86%	50%

[1] Based on CO_2 production, O_2 uptake and waste mass temperature

Fricke et al. [8] found that the values of parameters determining the degree of wastes stabilization (total organic carbon in elution test - TOC_{eluate}, tests on respiration activity - AT_4 respiration, the rate of biogas production GB_{21}), correlate with the reduction of biodegradable organic matter and are characterized by similar dynamics of change.

The authors also found that is possible to achive the degradation of organic matter (around 80% of total degradation) after 4-6 weeks of aerobic waste stabilization conducted under optimum conditions (controlled oxygen content, moisture and temperature). Another benefit of the operation of aerobic landfill is reduction the concentration of ammonia nitrogen and heavy metals in leachate.

Estes et al. [5] showed that the reduction of ammonia nitrogen during aerobic degradation is higher by about 90% than in the case of anaerobic stabilization. Rich et al. [28] in their research found that heavy metals in landfills are not aerobically immobilized in such volumes as in anaerobic landfills, hence the number of these compounds in leachate is lower [27].

5. CONCLUSION

On the basis of the above research it can be concluded that techniques directed at treatment of wastes before they are landfilled and the intensification of the processes occurring on existing landfills contribute to the effective reduction of emissions of pollutants removed into the environment in leachates and biogas. The main objective of these methods is the minimization of a negative impact of the wastes landfilling on the environment by reducing landfill methane production and the volume of pollutants discharged into leachate, and the reduction of the time of their emissions and monitoring landfills.

Both mechanical-biological treatment of municipal wastes before they are landfilled and the recirculation of leachate into the landfill efficiently reduce pollutants emitted in leachate and methane.
However, in comparison to those technologies the aerobic degradation is characterized by a better response to the requirements posed for a modern landfill.

This technology besides reducing the quantity and quality of leachate produced, eliminates the problem associated with the production of methane gas from landfills, which leads to the elimination of the impact of waste disposal on the increase in the greenhouse effect and improves the economic conditions of waste disposal and management. This is due primarily to a low capital and operational costs of aerobic landfills, and a short time of monitoring emissions from those landfills. Combining technology of MBP with aerobic landfills and the recirculation of leachate can be a better method of minimizing the negative impact of landfills on the environment and human health.

REFERENCES

1. Brinkmann U., Höring K., Heim M., Ehrig H.J.: *Effect of pre-composting on the long-term behaviour of MSW landfills,* [in]: Proceedings of Sardinia'95, Fifth International Landfill Symposium, S. Margherita di Pula, CISA, Cagliari, Italy, 2-6 October 1995: 971-985.

2. Chugh S., Clarke W. Pullammanappallil P., Rudolph V.: *Effect of recalculated leachate volume on MSW degradation*, Waste Menagement 1998, 564-73.
3. Cossu, R., Raga, R., Rossetti, D.: *The PAF model: an integrated approach for landfill sustainability*, Waste Management 2003, 37-44.
4. El-Fadel M., Fidikakis A.N. Leckie J.O.: *Environmental impacts of solid waste landfilling*, Journal of Environmental Management 1997, 1-25.
5. Erses, A. Onay T., Yenigun O.: *Comparison of aerobic and anaerobic degradation of municipal solid waste in bioreactor landfill*, Bioresource Technology 2008, 5418-5426.
6. Fricke K., Santen H., Bidlingmaier W.: *Biotechnological process for solving waste management problems in less economical developed countries*, [in:] The Eigth International Waste Management and Landfill Symposium, Sardinia 2001, 181-194.
7. Fricke K., Mümmich K., Ziehmann G., Turk T., Wallmann R.: *Auswirkungen der Artikelverordnung auf die MBA – und Deponietechnik*, Bio – und Restabfallbehandlung, 2001.
8. Fricke, K., Santen, H., Wallmann, R.: *Comparision of selected aerobic and anaerobic procedures for MSW treatment*, Waste Management 2005, 799-10.
9. Hanashima M.: *Pollution control and stabilisation process by semi-aerobic landfill type; the Fukuoka method*, T. Christensen, R. Cossu, R. Stegman (Eds.) Proceedings of Sardinia 99-7thInternational Waste management and landfill Symposium. Cagliari. Italy: Environmental Sanitary Engineering Centre, 1999.
10. Heyer, U.K., Hupe, K., Koop, A., Ritzkowski, M., Stegmann, R.: *The low pressure aeration of landfills: experience, operation and cost*, [in]: Peper p-resented at the Ninth Sardinia International Waste Management and Landfill Symposium, 2003.
11. Höring K., Kruempelbeck I., Ehrig H.J.: *Long term emission behavior of mechanical-biological pre-treated municipal solid waste*, [in]: Christensen T.H., Cossu R., Stegmann R., (Eds): Proc. Sardinia'99, 7, Int. Waste Management and Landfill Symposium, Cagliari 1999, 409–418.
12. Jacobs, J., Scharff, H., Van Arkel, F., de Gier, C.W.: *Odour reduction by aeration of landfills: experience, operation and cost*, [in]: Proceeding Sardinia 2003, the Ninth International Waste Management 2003.
13. Kruempelbeck, I., Ehring, H.J. Long term behavior of municipal solid waste in Germany. Proceedings Sardinia 99, the senenth International Waste management and landfill Symposium, Cagliari, Italy, 1999.
14. Ledakowicz S., Kaczorek K.: *Laboratory simulation of anaerobic digestion of municipal solid waste*, [in:] Appropriate Environmental and Solid Waste

Management and Technologies for Developing Countries, Istanbul 2002, 1139-46.
15. Leikam, K., Stegmann, R.: *The emission behavior of mechanically-biologically pretreated residual waste*, Waste Reports Emissionsverhalten von Restmull, ABF-BOKU, Vienna, Austria, 1995.
16. Leikam K., Stegmann R.: *Influence of mechanical-biological treatment of municipal waste on landfill behavior*, Waste Management 1999, 424-429.
17. Lornage, R., Redon, E., Lagier, T., Hebe, I., Carre, J.: P*erformance of low cost MBT prior to landfilling: Study of biological treatment of size reduced MSW without mechanical sorting*, Waste Management 2007, 1755-1764.
18. Morris J.W.F., Vasuki N.C., Baker J.A., Pendleton C.H.: *Findings from long-term monitoring studies at MSW facilities with leachate recirculation*, Waste Management 2003, 653-666.
19. Mostafa A.W., Walied Z., Neeraj G.: *Effect of leachate recirculation on municipal solid waste biodegradation*, Journal of Canada Water Quality Research 1999, 267-280.
20. Münnich K., Mahler C.F., Fricke K.: *Pilot project of mechanical-biological treatment of waste in Brazil*, Waste management 2005, 150-157.
21. Novella P.H., Ekama G.A., Blight G.E.: *Effects of liquid replacement strategies on waste stabilization at pilot-scale*, The Sixth Landfill Symposium, Sardinia 1997, 387-396.
22. Oonk H., Woelders H.: *Full-scale demonstration of treatment of mechanically separated organic residue in a bioreactor at VAM in Wijster*, Waste Management 1999, 535-542.
23. Öztürk I., Arikan O., Demir I., Demir A., Inane B., Kanat G., Yilmaz S.: *Solid Waste Characterization in Instanbul*, Instanbul Technical Univesity Report Department of Environmental Engineering 1997, 4-29.
24. Pohland F.G., Kim J.C.: *In situ anaerobic treatment of leachate in landfill bioreactors*, Water Sciene and Technology 1999, 203-210.
25. Read, A., D., Hudgins, M., Philips, P.: *Perpetual landfiling through aeration of waste lessons test cells in Georgia (USA),* Waste Management 2001, 617-629.
26. Reinhart D.R.: *Full-scale experience with leachate recirculating landfills: case studies*, Waste Management 1996, 347-365.
27. Read, A., D., Hudgins, M., Philips, P.: *Areobic landfill test cells and their implications for sustainable waste disposal*, Geographical Journal, 2001, 235-247.
28. Rich, Ch, Gronow, J., Voulvoulis, N.: *The potential for aeration of MSW landfills to accelerate completion*, Waste Management 2008, 1039-1048.

29. Rieger, A., Bidlingmaier, W.: *The reactivity of mechanically-biologically pretreated residual waste*, Waste Reports Emissionsverhalten von Restmull, ABF-BOKU, Vienna, Austria, 1995.
30. Ritzkowski, M., Stegmann, R.: *Mechanisms affecting the leachate quality in the course of landfill in situ aeration*, [in]: Papert presented at the Tenth Sardine International Waste Management and landfill Symposium, 2005.
31. Robinson H.D., Knox K., Bone B.D.: *Improved definition of leachate source term from landfills Phase 1: review of data from European landfills*, Science Report Environment Agency September 2004 (http//www.environment-agency.gov.uk).
32. Robinson H.D., Knox K., Bone B.D., Picken A.: *Leachate quality from landfilled MBT waste,* Waste Management 2005, 383-391.
33. Šan I., Turgut T., Onay P.: *Impact of various leachate recirculation regimes on municipal solid waste degradation*, Journal of Hazardous Materials 2001, 259-271
34. Sanphoti N., Towprayoon S., Chaiprasert P., Nopharatana A.: *The effects of leachate recirculation with supplemental water addition on methane production and waste decomposition in a simulated landfill*, Journal of Environmental Management 2006, 27-35.
35. Soyez, K., Plickert, S.: *Mechanical-Biological Pretreatment of Waste-State of the Art and Potentials of Biotechnology*, Acta Biotechnologa 2002, 271-284.
36. Sponza D.T., Ağdağ O.N., 2004.: *Impact of leachate recirculation and recirculation volume on stabilization of municipal solid wastes in simulated anaerobic bioreactors*, Process Biochemistry 2004, 2157-2165.
37. Stegman R. Vorteile der Restmüll.: *Aufbereitung zur Senkung der Gasemissionen von Deponien*, [in:] Aufbereitung fester Siedlungsabfälle vor der Deponierung, Zentrum für Abfallforschung, Technical University of Braunschweig 1991, 341-359.
38. Warith A., Zekry W., Gawri N.: *Effect of leachate recirculation on municipal solid waste biodegradation*, Journal of Canada Water Quality Research 1999, 267-280.
39. Warith M.: *Bioreactor landfills: experimental and field results,* Waste Management 2002, 7-17.

METODY INTENSYFIKACJI DEGRADACJI ODPADÓW

S t r e s z c z e n i e

Wzrost świadomości procesów przebiegających na składowiskach oraz wzrastająca ilość wytwarzanych odpadów przyczyniły się do szukania nowych dróg rozwiązań dla metod zagospodarowywania odpadów. Tradycyjne składowisk projektowane są jako składowiska „suche” ukierunkowane na minimalizację ilości powstających odcieków. Rozkład odpadów na takich składowiskach przebiega w warunkach beztlenowych z ograniczonym dostępem wilgoci. Procesy w nich zachodzące przebiegają wolno, a emisje zanieczyszczeń usuwanych wraz z odciekami i biogazem powodują długotrwałe zagrożenie dla środowiska i zdrowia człowieka. Składowiska te jeszcze wiele lat po ich zamknięciu wymagają długotrwałego i kosztownego monitoringu kontroli wielkości emisji zanieczyszczeń. Technologie takie jak przetwarzanie odpadów przed ich składowaniem oraz techniki intensyfikacji procesów rozkładu odpadów zdeponowanych na składowiskach, są rozwiązaniami ukierunkowanymi na osiągnięcie stawianych współczesnej gospodarce odpadowej celów.

W artykule przedstawiono wpływ recyrkulacji odcieków, tlenowej degradacji odpadów na składowisku oraz mechaniczno-biologicznego przetwarzania odpadów przed ich składowaniem na zmniejszenie wielkości emisji zanieczyszczeń ze składowisk w oparciu o dane literaturowe.