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SHORT-TERM AEROBIC IN SITU STABILIZATION OF MUNICIPAL LANDFILLS: LABORATORY TESTS

The simulation of the in situ aerobic stabilization of waste was carried out in laboratory scale lysimeters for a short period of time. In leachates, BOD_5, COD, VFA, N-NH_4^+, TKN and pH were assayed and in outlet gas the concentrations of methane, oxygen and carbon dioxide were determined. Whilst aerating waste, one could observe a decrease of organic load in leachates and lack of methane emission. After finished short-term aeration an increase in leachates indices occurred and methane in outlet gas from lysimeter appeared. In subsequent days after finished aeration one could observe a decrease in the indices of leachates and further production of methane.

1. INTRODUCTION

Gas from landfills may be used for energetic purposes for 10–15 years. After this period of time one may still observe proceeding anaerobic processes causing the emission from a landfill (HEYER and STEGMANN 1997; KRÜMPELBECK and EHRIG 2000). The vast majority of old landfills does not contain or possesses a damaged isolating layer and the layer covering a landfill (PRANTL et al. 2006). This threat is caused by the dispersed emission from landfills which may last even decades. The dispersed emission from the old landfill may occur into the air, water and soil.

The application of the forced aeration of landfill let accelerate the process of aerobic stabilization of waste. The air may be pumped into the landfill through perforated pipes. Additionally, the landfill is equipped with a system of perforated pipes through which the gas from waste is sucked off. The air supplied to waste contributes to the acceleration of biological degradation of biodegradable organic components (*in situ* stabilization) (HANTSCH et al. 2003). During aerobic degradation of waste the biodegradable mass is in majority converted into carbon dioxide

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and water (MERTOGLU et al. 2006). The aeration of waste causes reduction in odors, a decrease in methane concentration in gas and, furthermore, it accelerates landfill settlement and carbon emission from waste through carbon dioxide increases (RITZKOWSKI et al. 2003). During the short period of time of aeration some organic fraction are better available for anaerobic microorganisms in the following anaerobic processes (SPENDLIN 1991).

Many investigations concerning the aerobic stabilization of waste were carried out both in landfills and in laboratories. The research taking place in landfills was attempted among others by RITZKOWSKI et al. (2003, 2006), COSSU et al. (2003, 2007) and HEYER et al. (2005, 2007). During stabilization of old landfills by *in situ* method there could be noticed a reduction in methane emission, a decrease in pollution load in leachates, the acceleration of sedimentation of waste lump as well as an increase in temperature inside the landfill. An increase in temperature inside the landfill was caused by the intensive aerobic processes. In Europe the stabilization of old landfills was carried out in Kuhstedt, Amberg, Milmersdorf, Modena, Legnago. Numerous examinations on the subject were performed in laboratories: STEGMANN (2003), RITZKOWSKI et al. (2006), HANTSCH et al. (2003), KRZYSTEK et al. (2003), PRANTL et al. (2006) and ZIELENIEWSKA-JASTRZĘBSKA et al. (2007). In the investigations carried out in laboratory scale an influence of aeration intensity and the amount of re-circulated leachates were examined thoroughly. During the experiments with wastes subjected to aerobic stabilization it was observed that the aeration of waste contributes to a decrease of emission through gas and leachates.

PRANTL et al. (2006) simulated both the aerobic stabilization of waste and the period after finished aeration in lysimeters containing from 10 to 15 kg dry waste. Waste for these lysimeters was taken from an old landfill and then appropriately processed. During simulation of aerobic stabilization of waste an influence of the rate of the supplied air and of re-circulated leachates were examined. With a view to compare the stabilization of waste by *in situ* method in certain lysimeters the anaerobic conditions were maintained. In the test checking an impact of aeration, lysimeters were aerated for 513 days. For comparison, in one of the lysimeters the aeration of waste was simulated only for 270 days, and, next, for 243 days the changes occurring after quicker completion of aeration were observed. The anaerobic phase after a long running period of aeration causes a slight increase in respiration activity again, indicating the existence of biological available organic substances.

The aim of the present paper was to investigate an influence of short-term *in situ* aeration on the course of stabilization of landfill processes, carried out in laboratory scale in lysimeter, occurring both during the process of aeration and after its completion.

The performance of the process was monitored by reduction in time of basic indices of organic load (BOD_5, COD), the level of content VFA, nitrogen compounds (TKN, $N\text{-}NH_4^+$) and changes in biogas composition.

2. MATERIALS AND METHODS

2.1. APPARATUS AND PROCESS PARAMETERS

The experimental simulation of landfill was carried out in lysimeters of working volume 15 dm^3. The set-up of the experimental installation is shown in figure 1. The lysimeters consisted of a plastic cylinder of inner diameter 150 mm and height 1150 mm, closed on top and bottom with stainless steel covers, equipped with pipes for leachate recirculation, taking samples for analysis, supply and removal of gases. The humidity of waste was maintained by a system of leachate recirculation consisting of a bottle storing leachates from the lysimeter, a peristaltic pump (type 101 U/R, WATSON MARLOW PUMPS) and a sprinkler. The rate of the air pumped into the lysimeter was controlled by a mass flow-meter (a model 5850TR, Emerson). At the outlet of gas from the lysimeter gas analyzer (LMS Gas Data) as well as gas flow-meter (type TG01/05, Ritter with a recorder EDU 32) were located.

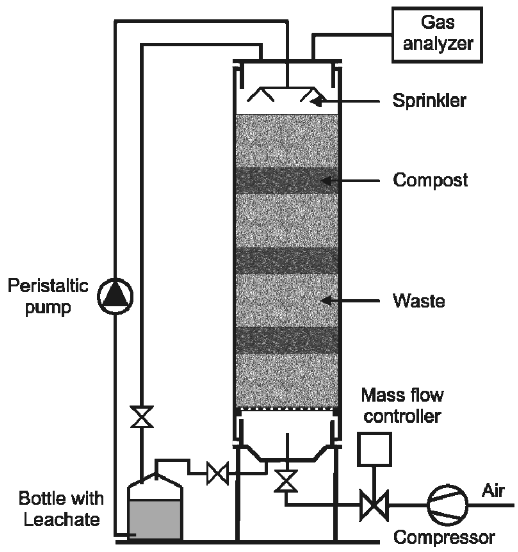

Fig. 1. Experimental set up

In the lysimeter the anaerobic conditions were maintained for about 6 months. During anaerobic conditions in the lysimeter one could observe the acidic and methane phase. When in the lysimeter the final methane phase occurred (ZIELENIEWSKA-JASTRZĘBSKA et al. 2007), and the production rate of biogas was decreased 10 fold with regard to the maximal production in the methane phase, the process of aerobic stabilization of waste commenced. The process of in situ aerobic stabilization of waste was carried out in a short period of time which lasted 28 days. On completion of aeration, leachates and the composition of biogas were monitored for the following 80 days.

In methane phase the maximal production of biogas was equal to 4 dm^3/d (65% v/v CH_4, 35% v/v CO_2). The aeration was started with the volumetric flow-rate of biogas production equal to 0,4 dm^3/d and the composition of biogas: 45% v/v methane and 55% v/v carbon dioxide. During the aerobic stabilization of waste 2 dm^3/h of the air were supplied into the lysimeter. In the course of the whole experiment leachates were recirculated once a day for 15 minutes with their volumetric flow rate equal to 1 ml/s. The investigations in the lysimeter were repeated three times.

2.2. SUBSTRATE

The lysimeter was loaded with model composition of municipal solid waste which was defined on the basis of the analysis of the morphological composition of waste for the city of Łódź (Ledakowicz and Kaczorek, 2004). The percentage composition of model waste is presented in table 1. The acceleration of simulation processes of landfills in the lysimeter was obtained by adding compost from the Compost Facility of Green Waste in Łódź. The layer of waste shredded to the size 2–4 cm was alternately laid with the layer of compost mixture. The lysimeter was loaded with 5 kg of model mass, and, next, 5 dm^3 of tap water were added.

Table 1

Waste composition

Waste composition	Composition %
Organic waste	28
Paper	19
Plastics	12
Textiles	4
Compost	27
Other inorganic	10

3. METHODOLOGY OF ANALYSIS

In leachates taken from the lysimeter the following indices were analyzed: biochemical oxygen demand (BOD_5) by dilution method (APHA Standard Methods, 1992), chemical oxygen demand (COD) by dichromate method (APHA Standard Methods, 1992), volatile fatty acids – VFA (in accordance with the Polish Standard PN-75/C-04576, using Büchi-Distillation Unit B-324 device), ammonium nitrogen

($N\text{-}NH_4^+$) by the method of distillation in the Büchi device, total nitrogen (TKN) according to the Polish Standard PN-75-C04576-17 in the Büchi device and pH (using pH-meter WTW pH 540 GLP).

In the gas leaving the lysimeter, the concentration of oxygen (O_2), methane (CH_4) and carbon dioxide (CO_2) was measured by the gas content analyzer LMS GAS DATA as well as biogas flow rate using the flow-meter Ritter (type TG01/05, with a recorder EDU 32).

4. RESULTS AND DISCUSSION

4.1. LEACHATES

In this study the effect of aeration on the changes of basic parameters of organic load in leachates and the amount and composition of gases generated both during aerobic simulation and after its completion were investigated. The aeration of waste commenced after the anaerobic processes lasting 6 months. The aeration of waste mass in the lysimeter was performed for 28 days. After finished aeration the leachates were analyzed by the following 80 days. The changes of organic substances content in leachates were characterized in an indirect way, analyzing the following organic load indices: biochemical oxygen demand BOD_5 and chemical oxygen demand COD. The changes of BOD_5 and COD during the aeration process and after its completion are presented in figure 2.

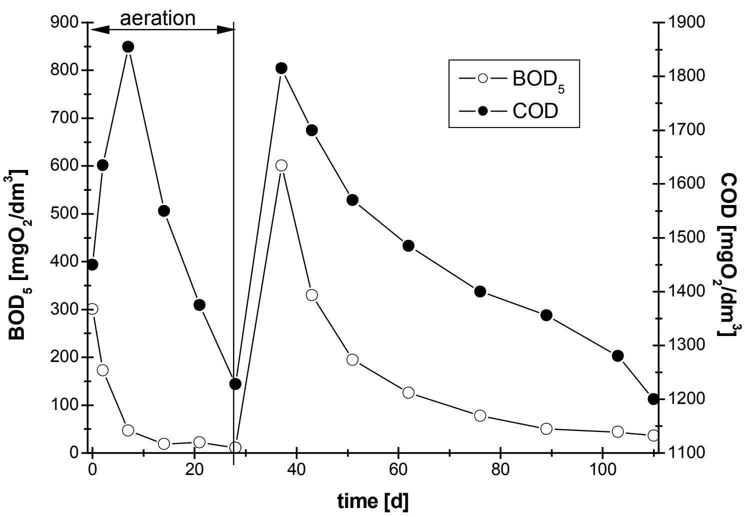

Fig. 2. The changes of BOD_5 and COD during the processes of degradation

The biochemical oxygen demand BOD_5 during the process of waste aeration decreased from 300 to 11 mgO_2/dm^3. Subsequently, after completion of aeration the value of BOD_5 within 9 days increased to 600 mgO_2/dm^3. In the following days the value of BOD_5 started to decrease exponentially, attaining on 80th day after completion of aeration the value of 36 mgO_2/dm^3. The value of BOD_5 after 80 days from the completion of aeration was greater than the value of BOD_5 obtained immediately after aeration. This increased value of BOD_5 indicates that in waste there is still present organic matter available for microorganisms. Presumably, the aerobic processes initiate the degradation of not easily degradable biodegradable matter, because the period was too short for a complete stabilization. In the investigations by RITZKOWSKI et al. (2006) a satisfactory effect of stabilization of wastes using in situ method in a laboratory scale was attained after 572 days of aeration.

The subsequent basic index of organic load in leachates was chemical oxygen demand (COD). The value of this index before the start of aerobic stabilization of waste was 1450 mgO_2/dm^3. Within the first 7 days of aeration the value of COD first increased to 1855 mgO_2/dm^3, and within the following days there could be observed a decrease of this index. The character of changes of organic load indices (BOD_5 and COD) after completion of aeration was similar. Initially, the value of COD was equal to 1230 mgO_2/dm^3 and after closing of air inflow to the lysimeter this value increased further to the value of 1820 mgO_2/dm^3, within 9 days, and then it started to decrease and, finally, after 80 days from finished aeration it reached the value of 1200 mgO_2/dm^3. The level of COD after 80 days from finished aeration was similar to the value of COD immediately after finished aeration. While in the investigations by Prantl et al. (2006) after aeration lasting 273 days one could not state a considerable increase in COD. Within subsequent 243 days after completion of aeration the value of COD was approximately constant and was equal to around 200 mgO_2/dm^3.

Another discussed indices of leachates was the concentration of ammonium nitrogen and total nitrogen. The character of changes of ammonium nitrogen content and total nitrogen during and after aeration is shown in figure 3. It may be noticed that the changes of these indices are very similar.

The concentration of ammonium nitrogen after 6 months of anaerobic processes and before aeration was equal to 9 mgN/dm^3 and total nitrogen 53 mgN/dm^3. The low content of ammonium nitrogen was probably caused by initial model composition of organic substances in the lysimeter, moisture with water and adding compost. In the research carried out by RITZKOWSKI et al. (2006) the concentration of ammonium nitrogen at the onset of aerobic simulation of wastes stabilization in a laboratory attained the value of 450 mgN/dm^3. However, their process conditions were quite different (wastes were taken from the old municipal landfill; amount of added air was 12 times higher; amount of recirculated leachates was twice larger). In the first 7 days of aeration both the concentration of ammonium nitrogen and total nitrogen increased. The concentration of ammonium nitrogen and total nitrogen on 7th day of aeration were equal to 13 mgN/dm^3 and 77 mgN/dm^3 respectively. Within the following days of aeration the concentration of ammonium nitrogen and total nitrogen started to decrease. A decrease in ammonium and total nitrogen concentration were observed when biogas production rate reached low values figure 3. At the end of aeration the concentration of ammonium nitrogen was equal to 7 mgN/dm^3 and total nitrogen 45 mgN/dm^3. Whereas, after finished aeration one could observe an increase of both indices. On 48th day after finished aeration the concentration of ammonium and total nitrogen reached a maximal value, which was equal to 18 mgN/dm^3 for ammonium nitrogen and 112 mgN/dm^3 for total nitrogen. Within the following days the concentration of ammonium nitrogen and total nitrogen decreased gradually. After 80 days from finished aeration the concentration of ammonium nitrogen was equal to 12 mgN/dm^3 and total nitrogen 60 mgN/dm^3 respectively. An increase of ammonium nitrogen after aeration could be caused by the lack of nitrification and the occurring processes of ammonification. The concentration of ammonium nitrogen and total nitrogen after 80 days from finished aeration was higher in comparison with the concentration at the beginning of the aeration (for N-am by 33% and for N-og by 71%), and at the end of aeration (for N-am by 13% and for N-og by 33%). Similarly, PRANTL et al. (2006) whilst investigating the aerobic stabilization of waste observed the fact that after aeration there took place an increase of concentration of ammonium nitrogen from the value below 1 mg N/dm^3 to the value of about 40 mgN/dm^3. It must be mentioned that this increased value of concentration of ammonium nitrogen was observed until the end of the process.

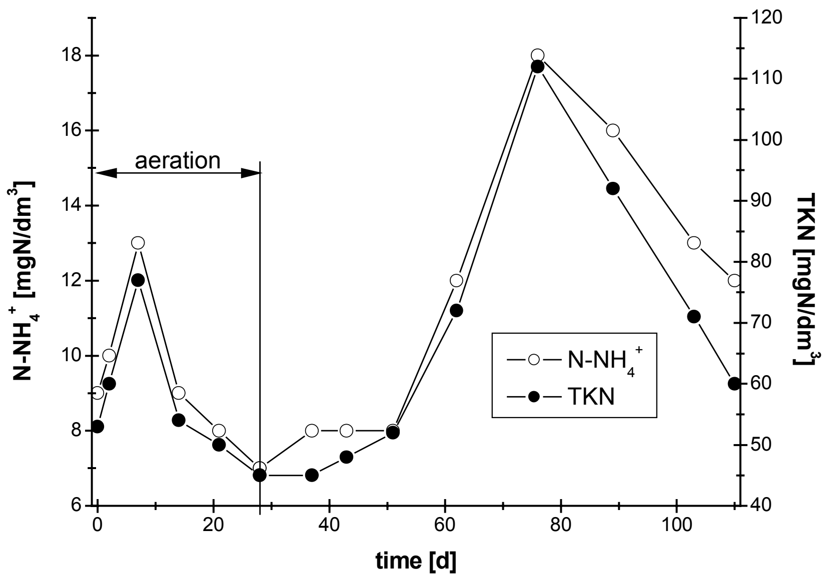

Fig. 3. Changes of content of N-NH$_4^+$ and TKN in the course of degradation process

In leachates the level of volatile fatty acids content (VFA) and pH were also analyzed. Figure 4 presents the changes of volatile fatty acids concentration and pH. During aeration it was stated that pH increased from 7.76 to 8,83. On the other hand, after aeration, the value of pH decreased to the value of 7.3 and was lower than before aeration.

During aeration of waste the concentration of VFA in leachates decreased from the value of 400 mg_{CH_3COOH}/dm^3 to 110 mg_{CH_3COOH}/dm^3. After finished aeration the concentration of VFA started to increase and on 9th day after finished aeration it attained its maximal value of 810 mg_{CH_3COOH}/dm^3. Within the next few days the level of concentration of volatile fatty acids started to decrease. After 80 days from aeration the concentration of VFA was equal to 260 mg_{CH_3COOH}/dm^3. The concentration of VFA after 80 days from finished aeration was lower than the VFA concentration before aeration by about 35% and greater than the value of VFA immediately after aeration.

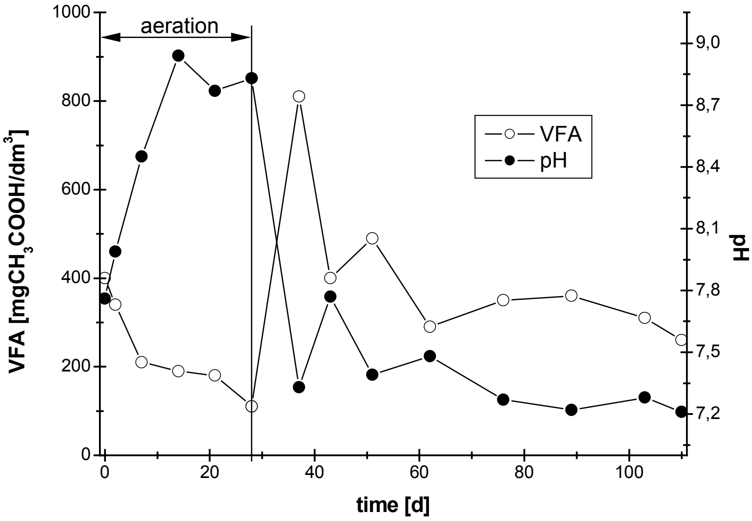

Fig. 4. Change in pH and VFA in the course of degradation processes

In table 2 the comparison of organic load indices of leachates are presented. Comparing the values of indices before aeration and after 80 days from finished aeration one could notice that only the concentration of ammonium and total nitrogen was greater after 80 days from finished aeration. Juxtaposing the values of organic load indices after 80 days from aeration with the indices immediately after aeration it was observed that in the first case only the value of COD was smaller. A decreased value of COD after 80 days from finished aeration could be evoked by a slower process of hydrolysis in waste or an accelerated degradation of organic mass in leachates.

Table 2

Comparison of indices of organic load in leachates

	BOD_5	COD	$N\text{-}NH_4^+$	TKN	VFA
A[a]–B[b]	+[d]	+	+	+	+
A–C[c]	+	+	–	–	+
B–C	–[e]	+	–	–	–

[a] A, value of an index before aeration.
[b] B, value of an index after aeration.
[c] C, value of an index after 80 days from finished aeration.
[d] +, means that after comparing an index, the value was positive.
[e] –, means that after comparing an index, the value was negative.

4.2. GAS

The composition of gas and its amount are important parameters defining a negative influence on the environment and processes occurring in lysimeters. The completion of aeration contributed to the relevant changes in the composition of gas. Figure 5 shows the changes occurring in the composition of gas. During aerobic stabilization

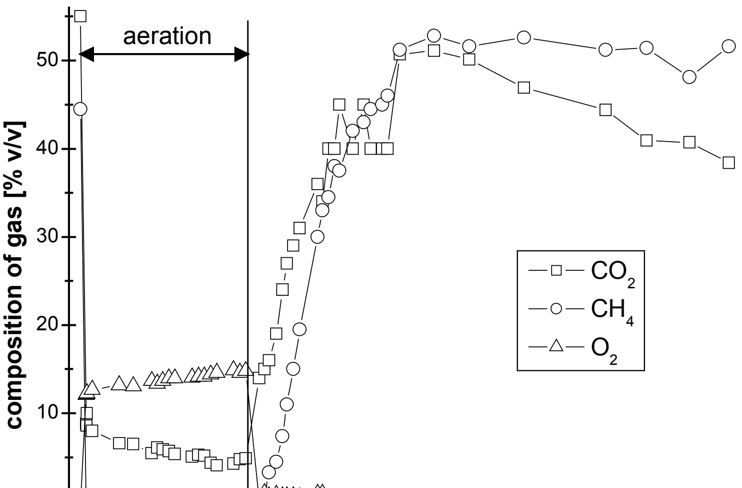

Fig. 5. Changes of outlet gas composition in time

of waste the concentration of oxygen in outlet gas from lysimeter was equal to 13% v/v, the concentration of carbon dioxide was equal to 5% v/v and the concentration of methane was equal to zero. After finished aeration the concentration of oxygen decreased to zero very quickly and the concentrations of methane and carbon dioxide started to increase. After 31 days from aeration the concentration of methane and carbon dioxide attained its maximal value (the concentration of methane and carbon dioxide were 51% v/v, and 49% v/v respectively). Within the following days after aeration it was noticed that the concentration of methane was maintained on the constant level (about 50% v/v), and the concentration of carbon dioxide decreased. After 80 days from finished aeration the concentration of carbon dioxide decreased to the value of 38% v/v. The gas production rate after aerobic conditions was approximately equal to 0.7 dm^3/d. The moment the aeration has finished one may observe a more rapid production of biogas when compared to the period before aeration (0.4 dm^3/d).

5. CONCLUSIONS

In this study the investigations of changes occuring in waste during and after short-term *in situ* aerobic stabilization were carried out. While performing the processes of simulation the composition of leachates and gas was analyzed. Analyzing the organic load indices of leachates it was noticed that for all indices after finished aeration in the first days there was observed an increase and, then, a decrease of their values. The highest increase of an index was observed for BOD_5 which incerased to 600 mgO_2/dm^3 on 9^{th} day after aeration. Whilst carrying out aerobic stabilisation all discussed indices decreased. However, on 80^{th} day after finished aeration it was noticed that only COD value decreased when compared to the moment after completion of aeration and the remaining indices were greater. The highest increase after 80 days from finished aeration, compared with the moment of completion of aeration, was observed for BOD_5. The value of this index rose from 11 mgO_2/dm^3 to the value of 36 mgO_2/dm^3. Comparing the values of indices before aeration and after 80 days from finished aeration it was stated that the concentration of ammonium nitrogen and total nitrogen were greater after 80 days from finished aeration. After this time the concentration of ammonium and total nitrogen was higher by 33% for $N\text{-}NH_4^+$ and by 71% for TKN when compared with the beginning of aeration as short-term aeration initiated the degradation of not easily degradable biodegradable matter.

Analyzing the composition of gas it was noticed that after finished aeration the concentration of oxygen decreased to zero very quickly while the concentration of methane and carbon dioxide started to increase. The concentration of methane and carbon dioxide attained maximal values after 31 days after finished aeration. On 80^{th} day from finished aeration the concentration of methane and carbon dioxide were equal to 50% v/v and 38% v/v respectively. The gas production rate after aerobic conditions was approximately equal to 0.7 dm^3/d.

An aeration of only 28 days does not lead to a sustainable reduction in emissions but rather to a intensification of the following anaerobic degradation period. The moment the aeration is finished, one may observe more rapid production of biogas than before aeration as well as an increase in the values of leachates indicators. It must be underscored that the solution to this problem is the aeration of wastes for a longer period of time so as to achieve better degradation of organic matter contained in wastes.

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