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THE CHANGES IN EXHAUST GAS AND SELECTED WASTE PROPERTIES DURING BIOSTABILIZATION PROCESS

ZMIANY SKŁADU GAZÓW PROCESOWYCH ORAZ WYBRANYCH WŁAŚCIWOŚCI FIZYKOCHEMICZNYCH ODPADÓW PODCZAS STABILIZACJI TLENOWEJ

Abstract: In recent years mechanical-biological waste treatment facilities increasingly apply the biostabilization process to treat the undersize fraction (most frequently less than 80 mm in diameter) obtained from municipal solid waste. The process lasts at least 14 days in closed but aerated chambers. The process gas exiting the chamber is transferred to biofilters filled with biomass, which ensure odours elimination. The aim of the study was to analyze the aerobic biostabilization process of selected waste groups using a laboratory BKB 100 reactor, especially in the aspect of exhaust gas composition changes. The bioreactor was equipped with a 116-liter, thermally insulated chamber, controlled air flow and a system of gases and temperature analyzers. The analyzed parameters were: CO_2 and O_2 concentration in the emitted gases, the temperature changes during the process, waste density, C:N ratio, organic matter content as well as moisture content. As a result of the research it was stated that the temperature changes in the processed waste vary in different seasons and might depend on the share of fine and biodegradable fractions in waste. In the case of waste collected in summer or autumn the thermophilic phase began during the 2nd or 3rd day of the process and lasted about 5-6 days, causing a considerable CO_2 emission (with the maximum between the 1st and 4th day). The changes in O_2 and CO_2 concentration were directly connected with the process intensity. Waste collected during winter or spring and subjected to the process didn't reach the temperature which would ensure waste stabilization and hygienization.

Keywords: municipal solid waste, undersize fraction, aerobic biostabilization

Introduction

Mechanical-biological treatment (MBT) facilities integrate mechanical processes, (such as comminution, separation, sieving, classification) and biological processes, which occur in aerobic and/or anaerobic conditions [1-3]. As a result of the mechanical processes, which in most cases include waste separation in drum screens (with 80 mm square-shaped meshes), two fractions are obtained: undersize and oversize. The undersize fraction contains the considerable share of organic substances and is subjected to biological treatment [2]. Among most commonly used biological processes applied at this stage are aerobic biostabilization and biodrying process [2]. These processes consist in autothermic self-heating of treated material, which results from the heat released during organic matter decomposition [2]. Thus, they seem to be an interesting alternative of waste treatment from the economical point of view. Biological treatment methods for biodegradable municipal

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waste bring about decrease in microbial activity as well as reduction of gaseous emission (CO_2, SO_2, NO_x and CH_4) in case of subsequent landfilling of processed waste [1-7]. Regulation of the Polish Minister of the Environment concerning MBT determines that biological treatment of waste can be executed at the initial stage in a closed bioreactor with an aeration system and post-process gas ventilation to biofilters, for the period of 2 weeks at minimum in the processes of aerobic biostabilization [8].

The main aim of the research was to analyze the aerobic biostabilization process of the undersize fraction (particle size less than 80 mm) separated from municipal solid waste, especially in the aspect of exhaust gas composition changes. The process was carried out in the laboratory bioreactor (type: BKB 100). Analyses were repeated four times. The analyzed undersize fraction was collected at the Regional Installation for Municipal Solid Waste Treatment.

Materials and methods

This study was conducted at the Faculty of Production and Power Engineering (University of Agriculture in Krakow, Poland). The bioreactor (type: BKB 100) with the chamber volume of 116 dm^3 was used for the experiments (Fig. 1). Tests were carried out using aerobic biostabilization process of organic matter. The waste for research (the undersize fraction separated from municipal solid waste (Ø < 80 mm)) was obtained from a mechanical and biological waste treatment plant (MIKI Recycling Ltd.), located in Krakow (southern Poland). To determine temperature changes during the process, which lasted for approx. 14 days, a PT1000 temperature sensor was used. Analyses were carried out for the period of 14 days (or more, in some cases), which is required by the Regulation on the MBT for biological processes of waste treatment [8]. In spring and summer the experiments were conducted for 14 days. In case of waste collected in autumn and winter the process time was longer - 16 and 22 days, respectively. It was possible to regulate the air flow into the investigated waste, to display the recorded temperature changes occurring in stabilized material, as well as to analyze emitted gases (oxygen content, carbon dioxide content, methane content and hydrogen sulphide content in exhaust gas). The air supply was maintained at 0.5-1.5 $m^3 \cdot (kg\ d.m. \cdot d)^{-1}$. The aeration intensity was regulated according to the Schultz rule, which states that the oxygen demand depends on process temperature as follows [9]:

$$W = 0.1 \cdot 1.067^t$$

where: W - oxygen demand [mg $O_2 \cdot (g\ d.m. \cdot h)^{-1}$], t - temperature in a range 20-70ºC.

The average temperatures of air supplied to the bioreactor differed in each season and were as follows: 15ºC in winter, 17ºC in spring, 26ºC in summer and 19ºC in autumn.

The analyzed waste originated from rural outskirts of Krakow agglomeration. The samples were collected once a quarter (in January, April, July and October), the mass of each sample was 60 kg at minimum. The laboratory samples were prepared according to the standard [10]. For each sample following characteristics were determined: morphological composition [2], moisture content [11], dry organic mass content [12], C:N ratio, waste density (at the beginning and at the end of the process) as well as Kjeldahl nitrogen content. The latter analysis was conducted in presence of selenium mixture using Kjeltec 1026

System II analyzer (producer: Tecator) and was preceded by the sample mineralisation in concentrated H_2SO_4. Total organic carbon content was determined by oxidative titration.

Fig. 1. The BKB 100 bioreactor used in the research

Results

Table 1 shows the morphological composition of the undersize fraction from waste processed at MIKI Recycling Ltd in Krakow between January and October 2015. As the results reveal, the fraction of fine material (particle size less than 10 mm) constitutes a predominant share in analyzed waste, independent on the season. In waste collected in July (summer) there are considerable shares of organic waste and glass, as well. In Table 1 a sum of biodegradable waste, calculated according to NWMP and [2, 13], is also given. The least shares of such waste were noticed in case of samples collected in January (winter) and April (spring), the highest - for samples taken in October (autumn).

Table 1

Morphological composition of undersize fraction in different seasons

No.	Waste group	Winter ±*SD**	Spring ±*SD**	Summer ±*SD**	Autumn ±*SD**
		[%]	[%]	[%]	[%]
1.	Fine fraction	43.1 ±5.1	34.7 ±1.0	22.4 ±2.7	30.4 ±2.1
2.	Organic waste	14.8 ±4.4	5.9 ±4.4	20.8 ±0.8	15.8 ±3.6
3.	Wood	0.2 ±0.1	0.9 ±0.3	1.2 ±0.7	2.2 ±0.4
4.	Paper	8.1 ±4.4	14.2 ±4.1	9.9 ±2.7	16.1 ±3.3
5.	Textiles	3.8 ±2.0	2.9 ±1.6	2.8 ±2.0	3.3 ±1.1
6.	Plastics	8.8 ±2.4	14.7 ±4.7	7.4 ±2.3	8.6 ±4.5
7.	Glass	12.5 ±0.5	17.8 ±2.9	18.0 ±3.4	13.1 ±6.0
8.	Metal	1.1 ±0.6	3.6 ±2.0	1.1 ±0.5	0.4 ±0.1
9.	Composite waste	0.2 ±0.1	1.4 ±1.2	3.8 ±0.9	2.7 ±0.3
10.	Hazardous waste	0.4 ±0.1	0.6 ±0.2	1.1 ±0.6	0.2 ±0.1
11.	Personal hygiene product	0.3 ±0.1	0.4 ±0.1	1.8 ±0.8	0.8 ±0.3
12.	Inert waste	6.7 ±5.0	2.9 ±0.3	9.7 ±1.3	6.4 ±2.2
	Total share of biodegradable waste	**38.0 ±4.2**	**33.6 ±5.1**	**41.9 ±2.9**	**46.2 ±3.3**

**SD* - standard deviation

The changes in temperature values during biological waste treatment processes indicate the occurrence of three subsequent phases [14]. The most important is the second one - the thermophilic phase [15], in which a sudden temperature increase is observed. It ensures stabilization and hygienization of waste [16, 17]. Figure 1 presents the changes in temperature measured inside the bioreactor (in its central area) during the analyzed processes. The thermophilic phase for waste collected in summer or autumn was observed already in the 2nd or 3rd day of the process and lasted approx. 5-6 days. The increase in temperature to the level of 60 or more degrees Celsius is supposed to ensure proper stabilization and hygienization of the processed material. For waste collected in winter or spring the thermophilic phase occurred much later (after 13 and 6 days of the process, respectively), which might have been caused by high fine fraction content and low share of biodegradable waste in the processed material. The rate of temperature changes during the process and temperature values measured in summer and autumn tests resembled the results presented in [2].

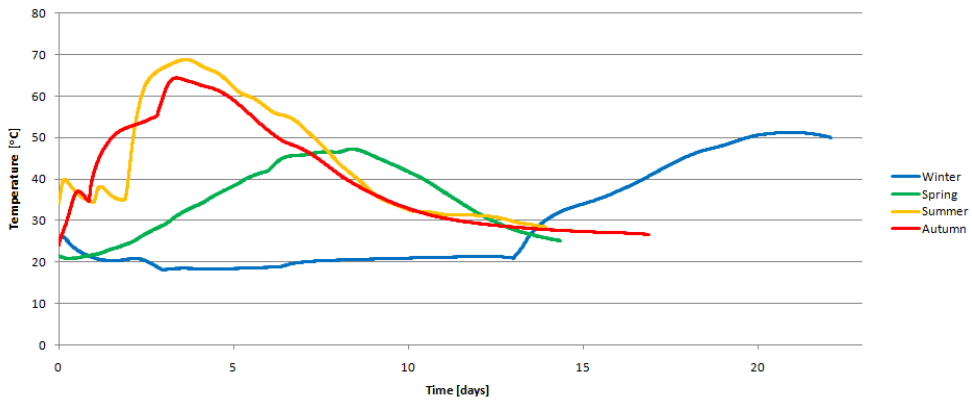

Fig. 2. Temperature changes during biostabilization of undersize fraction

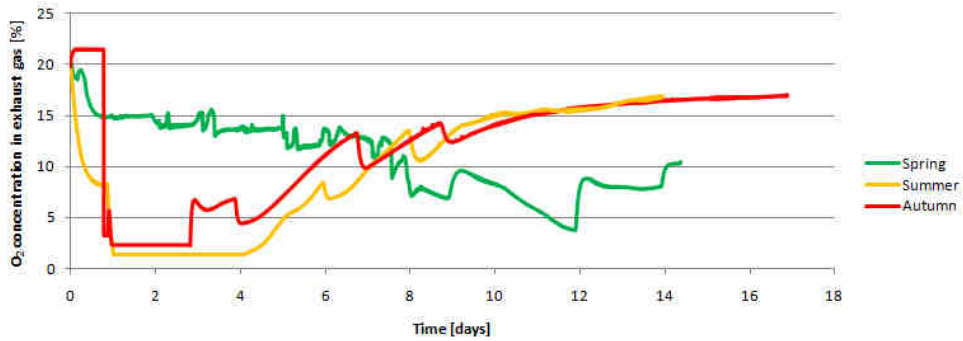

Fig. 3. Changes in O_2 concentration in exhaust gas during biostabilization of undersize fraction

To ensure that the process is carried out properly the analyzed waste has to be supplied with a sufficient amount of air. It is necessary for organic matter decomposition, which results from intense growth of aerobic microorganisms [18]. CO_2 content in exhaust gas is the best indicator for assessing the intensity of biological processes in waste. Figures 3 and 4 present the changes in O_2 and CO_2 concentration in emitted gases. For samples collected in summer and autumn the changes in gaseous emission were observed in first days of the process, which resembles the temperature curves in Figure 2. In spring the changes were less intense and O_2 concentration did not lower to less than 4%. Due to technical issues it was not possible to measure exhaust gas composition in winter. The presented curves (Figures 3 and 4) do not include CH_4 and H_2S measurements - concentrations of these gases were below 0.2%, which is less than inaccuracy rate of the analyzing instrument (BIOTEX-XL).

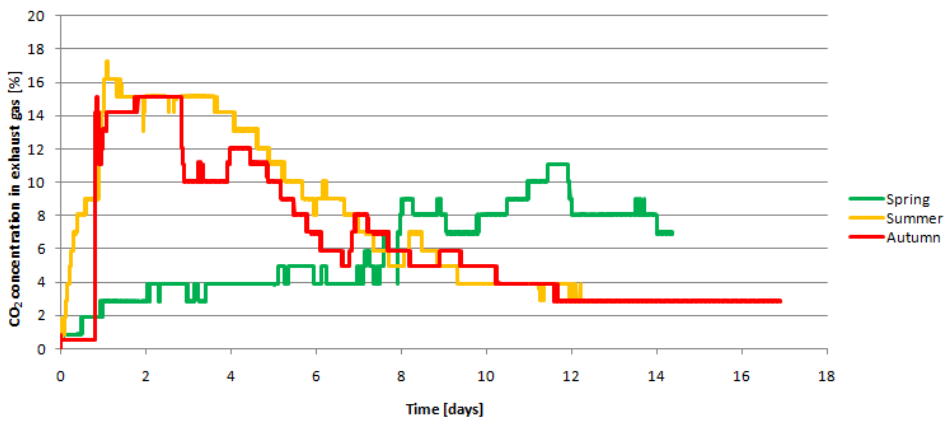

Fig. 4. Changes in CO_2 concentration in exhaust gas during biostabilization of undersize fraction

Table 2

Changes in selected properties of stabilized waste

No.	Property	Unit	Season	Before the process	After the process
1.	Waste density	[kg·m^{-3}]	Winter	539.7	611.9
			Spring	520.9	551.3
			Summer	490.0	530.7
			Autumn	466.9	475.9
2.	Moisture content	[% w.w]	Winter	38.3 ±1.4	26.9 ±6.8
			Spring	29.0 ±6.2	26.5 ±4.1
			Summer	35.6 ±2.3	30.9 ±2.1
			Autumn	27.6 ±4.8	24.2 ±3.8
3.	Organic matter content	[% d.m.]	Winter	47.6 ±0.9	44.5 ±0.6
			Spring	52.8 ±1.9	42.3 ±2.1
			Summer	53.6 ±1.4	44.5 ±0.9
			Autumn	55.0 ±0.9	42.3 ±7.0

As a result of the biostabilization process, some considerable changes in waste properties were observed (Table 2). In each cycle of tests waste density increased - the

values varied from 466.9 $kg \cdot m^{-3}$ (the minimal density of processed material) to 611.9 $kg \cdot m^{-3}$ (the maximal density), while waste volume and mass decreased about 11 ±3% and 2.3 ±0.4%, respectively. Apart from winter tests, in all experiments the occurrence of leachate from the bioreactor was observed. Average carbon content in waste dry mass varied from 19.8 to 25.1% before the process and from 17.9 to 22.3% after the process. Average nitrogen content in waste dry mass also changed - from the range 0.6-0.94% before the process to 0.8-0.82% after the process. C:N ratio in analyzed waste decreased during biostabilization from approx. 30 to 25. Moisture and organic matter content in the processed waste decreased slightly, while ash content increased. In each test minor changes in pH occurred - the average values rose from 7.3 (close to neutral) before the process to 7.9 (more basic conditions) after the process.

Conclusions

The main conclusions drawn on the results presented above are:

1. The morphological composition of waste, especially fine fraction (particle size less than 10 mm) and biodegradable waste content, can influence the intensity of aerobic biostabilization.
2. Temperature changes in processed waste during biostabilization are not the same in each season. The thermophilic phase, which corresponds to the highest CO_2 emission, for waste collected in summer and autumn occurred already in the 2nd or 3rd day of the process and lasted approx. 5-6 days.
3. The changes in O_2 and CO_2 concentration in exhaust gas were directly connected to the intensity of the process. In case of tests carried out in summer and autumn the highest CO_2 emission was measured between the 1st and 4th day of the process.
4. In case of waste collected in winter and spring it was not possible to reach the process temperature which would ensure proper stabilization and hygienization of the material.

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ZMIANY SKŁADU GAZÓW PROCESOWYCH ORAZ WYBRANYCH WŁAŚCIWOŚCI FIZYKOCHEMICZNYCH ODPADÓW PODCZAS STABILIZACJI TLENOWEJ

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Abstrakt: W zakładach mechaniczno-biologicznego przetwarzania odpadów komunalnych do przetwarzania biologicznego frakcji podsitowej (najczęściej o uziarnieniu poniżej 80 mm), wydzielonej ze strumienia zmieszanych odpadów komunalnych, coraz częściej wykorzystuje się proces stabilizacji tlenowej. Proces ten przebiega przez okres co najmniej 2 tygodni w zamkniętych i napowietrzanych kontenerach. Powietrze procesowe odprowadzane jest do biofiltra wypełnionego biomasą, która ma zapewnić redukcję uciążliwych zapachów. Celem badań była analiza przebiegu procesu stabilizacji tlenowej w laboratoryjnym bioreaktorze BKB 100 ze szczególnym uwzględnieniem zmian w składzie emitowanego powietrza procesowego. Bioreaktor był wyposażony w termicznie izolowaną komorę o pojemności 116 dm^3, system pozwalający na kontrolowane wprowadzanie powietrza do procesu, system czujników temperatury oraz analizator gazów poprocesowych. Analizom podlegał udział CO_2 i O_2 w objętości emitowanych gazów procesowych, zmiana temperatury w czasie trwania procesu, a także gęstość odpadów, stosunek C:N, zawartość substancji organicznej i wilgotność. W wyniku przeprowadzonych analiz stwierdzono, że przebieg zmian temperatury w stabilizowanej masie

wsadowej nie jest jednakowy w poszczególnych porach roku i może ona zależeć od udziału frakcji drobnej oraz zawartości odpadów ulegających biodegradacji. Faza termofilna dla odpadów pobranych w okresie lata i jesieni nastąpiła już w 2-3 dniu procesu, trwała około 5-6 dni i spowodowała dużą emisję CO_2. Zmiana zawartości O_2 oraz CO_2 była bezpośrednio powiązana z intensywnością procesu. Odpady pobrane w okresie zimy i wiosny nie osiągnęły temperatury, która mogłaby wskazywać na stabilizację i higienizację materiału. Odpady pobrane latem i jesienią charakteryzowały się największą emisją CO_2 pomiędzy 1 a 4 dniem procesu.

Słowa kluczowe: odpady komunalne, frakcja podsitowa, stabilizacja tlenowa