DOI: 10.2428/ecea.2013.20(12)132 ECOL CHEM ENG A. 2013;20(12):1461-1470

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INVESTIGATIONS OF BIO-DRYING PROCESS OF MUNICIPAL SOLID WASTE

BADANIA BIOSUSZENIA ODPADÓW KOMUNALNYCH

Abstract: Operation analysis of the mechanical-biological stabilization reactor was presented. Minicipal waste undergoes mechanical pretreatment and then the fraction 0–80 mm rich in organic matter is treated by oxidic method in the reactor. Results of investigations of raw MSW (0–80 mm) and stabilat (0–20 mm, 20–80 mm) which are the resulting material after the 7th days bio-drying processes, were discussed. The loss of ignition (LOI), humidity, pH, the amount of sulfur, chlorides, heavy metals and the biologically stable state are the main investigated parameters. To evaluate the material stabilization, the determination of the O_2 uptake and CO_2 production was measured. The results allowed to evaluate the work effectiveness of the industrial reactor constructed for MSW treatment. The experiments were led using an OXYMAX respirometer ER-10 (Columbus Instruments), an ion chromatograph 883 Basic IC plus, spectrometer with plasma ICP.

Keywords: mechanical-biological stabilization, biodrying MSW, respirometry

Introduction

The *mechanical-biological treatment* (MBT) is an integrated process which includes: the mechanical processing (crushing, screening, separation and compaction) [1] and the biological (aerobic and anaerobic methods) [2]. MBT systems are led to treatment *municipal solid waste* (MSW) for reducing the amount of waste going to landfill. As a result, this method provides the energy recovery (energy, electricity) or the material recovery (organic recycling). Generally, two aerobic methods are available: the composting and the *mechanical biological stabilization* (MBS) also called a biodrying [3]. The MBS is a relatively new direction. Produce of *residual derived fuel* (RDF) is

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the main idea of biodried technologies. Alternative option for using MBS is stabilization/preparing of waste going to landfills. Preparing waste for disposal is a result of law requirements [4].

Evaluation work effectiveness of industry reactor for biostabilization organic fraction was the main aim of the analysis. The reactor is an element of technology for mechanical-biological treatment of waste (MBT).

Mechanical-biological stabilization plant

The analyzed MBS technology includes: screenings, the reactor, module of active aeration with stove and finally bio-filter which removes odors. The scheme of biodrying technology was presented in Fig. 1. The reactor has rectangular shape and was made of galvanized steel. The reactor treats the 0–80 mm fraction of MSW. The biodrying bed is approximately 2/3 of total height of the reactor. The retention time is 7–14 days. The downcast ventilator (air flow) and the exhaust ventilator (moisture removal) work continuously. Engine power of the downcast ventilator is 7.5 kW. The maximum amount of air flow to the reactor is 4500 m^3/h. Exhaust ventilator with motor power 4.0 kW, which is both moisture removal and air flow for biofilter, works with a yield of 3000 m^3/h.

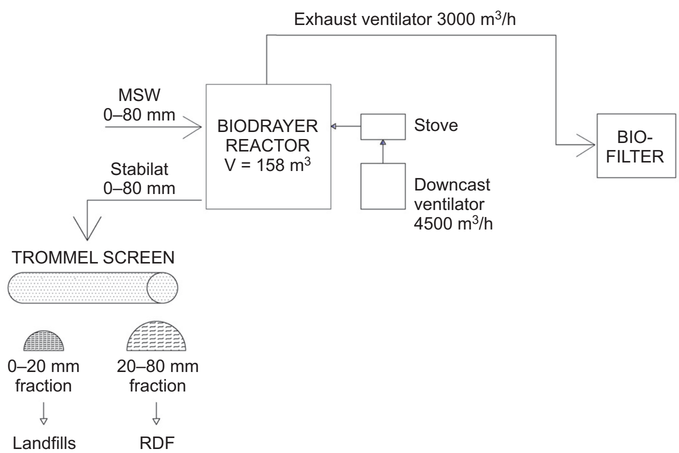

Fig. 1. The scheme of MBS plant with active aeration for stabilization MSW

The MBS idea involves the separation of waste after biological drying to fraction 20 mm and 20–80 mm. According to the technology concept, dried fraction 0–20 mm (code 19 12 12 – wastes from mechanical treatment) goes to the landfill. Fraction 20–80 mm (code 19 12 10 – combustible waste, refuse derived fuel) is treated by the thermal methods, which is in accordance with § 5.6. Regulation [5].

In connection with the technology concept, which assumes that fraction 0–20 mm are going to landfill, measurement of loss on ignition was made. The results were compared with requirements of the Minister of Economy [4]. Biodried 0–20 mm fraction can be classified with code 19 12 12*. According to the Regulation [4] waste code 19 12 12 may be taken to a landfill for non-hazardous and inert waste if they fulfill the requirements set out in the annex 4 [4]:

– loss of ignition (LOI) < 8 % d.m.,

– total carbon organic (TOC) < 5 % d.m.,

– heat of combustion max. 6 MJ/kg d.m.

Based on § 7 [4] these criteria will be obliged from 1.01.2016, however, selective control parameters of waste going to landfill will be realized, how difficult it is to fulfill these stringent parameters. These requirements will help to reduce the amount of landfilled waste significantly.

The criteria for stabilat

MBS technologies treated the municipal solid waste. Process of biological drying should take place in closed reactor with active aeration for minimum 7 days, which is in accordance with § 4.4. Regulation [5]. Finally, waste after MBP technologies should fill one of following criteria [5]:

– Loss of ignition (LOI) < 35 % dry mass, and the amount of total carbon organic (TOC) < 20 % d.m., or

– The loss of organic matter in processes before and after stabilization should be higher than 40 % d.m., or

– Respiration Activity RA_4 < 10 mgO_2/g d.m.

In order to assess the correctness of MBS process, there were analyzed LOI and respiration activity of 0–20 mm fraction and LOI of 20–80 mm fraction.

There are three types of measurement biological stability. The reactivity/stability of the MBT products can be determined by aerobic and anaerobic methods [6]. The aerobic indices are based on respiration techniques, while the anaerobic on biogas production. Respiration techniques are based on the measurement of the loss of O_2 in the reactor and are the most accepted because of the precise information about the real biological activity of the samples [6]. One of respirometric parameter is RA_4, that presents microbiological oxygen consumption for 4 days. RA_4 parameter determines the ability of waste for further biological decomposition [3]. The respiration activity is measured in an oxygen atmosphere, for a 30 g minimum sample weight and the humidity of 40–50 % [6]. The amount of oxygen consumed by microorganisms can be determined by methods: the static (without a continuous supply of air during the assay) and the dynamic (with a continuous supply of air). The most popular equipment for determining RA_4 are Sapromat and Oxitop (static method). In these equipments may occur the anaerobic atmosphere and disturbing of the final result. Moreover, products of the biological decomposition led to next mistake which equipment register as CO_2. Micro-Oxymax and Costech are respirometry equipment working basing on dynamic

* Other wastes (including mixtures of materials) from mechanical treatment of wastes other than those mentioned in 19 12 11.

methods [7–9]. Figure 2 presents the test stand for dynamic measurement O_2 uptake and CO_2 production.

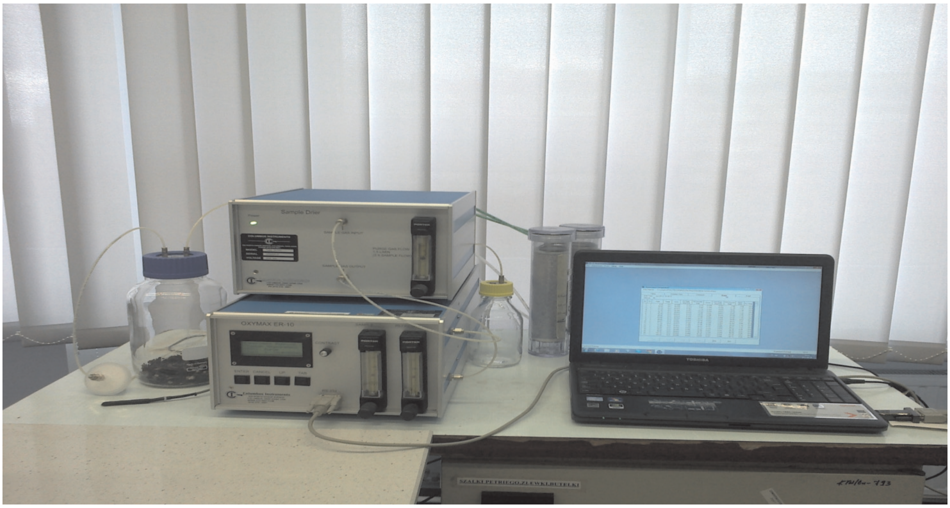

Fig. 2. The test stand for measuring biological activity – respirometer Oxymax ER-10

Materials and research methods

Investigations included two phases: the study of waste going to the stabilization and testing of the biodried waste MBS, which called stabilat. Table 1 and 2 present the characteristic parameters of investigated materials. The probes of 0–80 mm MSW fraction were taken according to the standard procedure – the method of quartering [10]. Investigations of humidity were determined by weight loss mass of dried waste at 105 ^{o}C [11]. The weights of the dried waste samples were approximately 1000 g. Measurement of loss on ignition was determined by 5 g samples according Polish Standards [12].

The basis for the analysis of chlorides, sulphates and heavy metals Cd, Cu, Cr, Ni, Pb, Zn was a procedure for preparing the water extract of solid wastes according to procedure presented in Fig. 3 [13]. Samples taken to water extraction tests were in natural size. The liquid used to prepare the extraction test was distilled water. Testing procedure was carried out at room temperature.

Three extracts should be treated separately. The amount of determined element in first water extract should be calculated from formula [13]:

$$q_1 = \frac{V_1 \cdot c_1}{m} \tag{1}$$

where: q_1 – the amount of determined element [g/kg d.m.],
V_1 – volume of water extract in first step [cm^3],

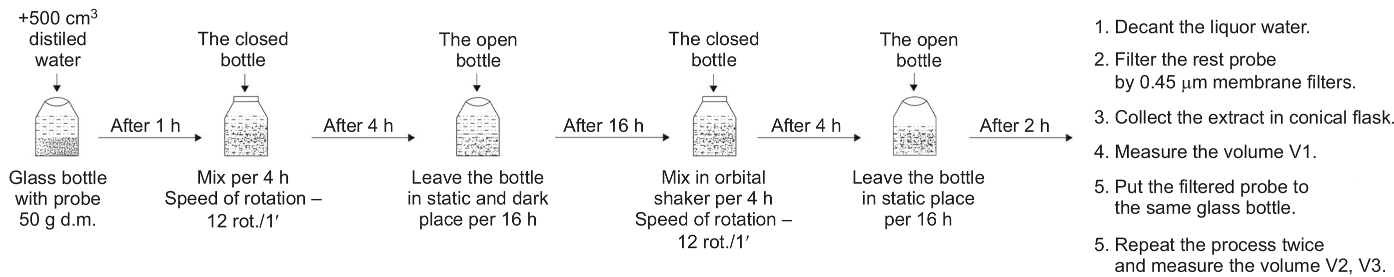

Fig. 3. The procedure used for water extraction test from waste (according to [13])

c_1 – concentration of determined element [mg/cm^3],
m – weight of dry mass [g].

The amount of determined element in water extract in second step should be calculated from formula [13]:

$$q_2 = \frac{V_0 \cdot c_2}{m} \tag{2}$$

where: q_2 – the amount of t determined element [g/kg d.m.],
V_0 – volume of water used to extract in second step [cm^3],
c_2 – concentration of determined element [mg/cm^3],
m – weight of dry mass [g].

The amount of determined element in water extract in third step should be calculated from formula [13]:

$$q_3 = \frac{V_0 \cdot c_3}{m} \tag{3}$$

where: q_3 – the amount of determined element [g/kg d.m.],
V_0 – volume of water used to extract in third step [cm^3],
c_3 – concentration of determined element [mg/cm^3],
m – weight of dry mass [g].

The total amount of determined element in g/kg d.m. should be calculated from formula [13]:

$$Q = q_1 + q_2 + q_3 \tag{4}$$

The elutes obtained in above mentioned procedure were the object further investigations.

The amounts of anions were measured by ion chromatograph 883 Basic IC plus, while the heavy metals by ICP plasma spectrometer.

The biological stability was determined by dynamic tests using a respirometer Oxymax ER-10. The respirometer took a series of gas measurements with 5 minutes interval, recording the net increase or decrease in the concentration of the monitored gases. Research sample weight for 0–80 mm fraction was 100 g, input moisture 41.39 %, shredding < 9 mm.

The idea of technology is based on biological stabilization municipal solid waste 0–80 mm fraction with continuous aeration for 7 days. After processes the stabilats were directed to a rotary screen. Two output streams 0–20 mm and 20–80 mm were the separated products. Stabilized fraction 0–20 was tested analogously to the 0–80 mm fraction. The oxygen uptake and production of carbon dioxide were measured only for 0–20 mm fraction with parameters: probe mass 300 g, input moisture 42 %, shredding < 9 mm.

Results

Average values of moisture, loss on ignition (LOI), chlorides and sulphates anions are presented in Table 1. Results presented in Table 1 were averages from three investigations.

Table 1

Humidity, LOI in probes and chlorides, sulphates ,pH in elutes from waste taken before and after 7-days stabilization

Sample	Fraction [mm]	Investigations directly in waste probes		Investigations in extraction test		
		Humidity [%]	Loss of ignition LOI [% d.m.]	Chlorides Cl^- [mg/kg d.m.]	Sulphates SO_4^{2-} [mg/kg d.m.]	pH
Before stabilization	0–80	45.00	62.10	1135.41	1347.83	7.39
After stabilization	0–20	30.48	24.80	2339.20	7614.69	7.5
After stabilization	20–80	35.61	49.20	458.08	1416.26	7.6

Table 2 summarizes the data respiration activity of the raw MSW 0–80 mm fraction and the 0–20 mm stabilized fraction. Respirometric activity was examined for stabilat 0–20 to verify work of the reactor that must achieve requirement level $AT_4 < 10$ mgO_2/g d.m. [5]. The oxygen consumption measured for 4 days for fraction 0–80 mm was 47.85 mgO_2/g d.m. Results of analysis were compared with law requirements for waste disposal [5].

Table 2

The measurment gases for 0–80 mm and 0–20 mm fractions after bio-drying process in industrial reactor

Fraction [mm]	Accumulative consumption O_2 [mg/96 h]	Accumulative production CO_2 [mg/96 h]	Averge ratio CO_2/O_2 [-]	Consumption O_2/96 h [mgO_2/g d.m.]
0–80	2870.89	3578.19	1.16	47.85
0–20	1633.23	1939.48	1.04	8.17

Figure 4 and 5 illustrate values of heavy metals tested by spectrometry methods in elutes. The following wavelengths in [nm] were taken to analyze the elements:

– Cd 228.802
– Cu 327.393
– Cr 267.716
– Ni 231.604
– Pb 220.353
– Zn 206.200

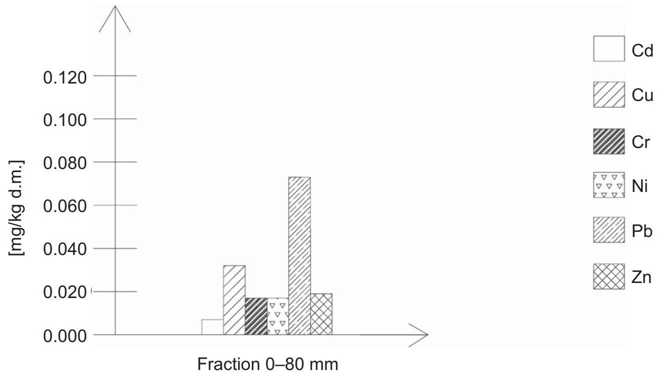

Fig. 4. Heavy metals analysis in elutes in the waste before stabilization in the bioreactor with active aeration

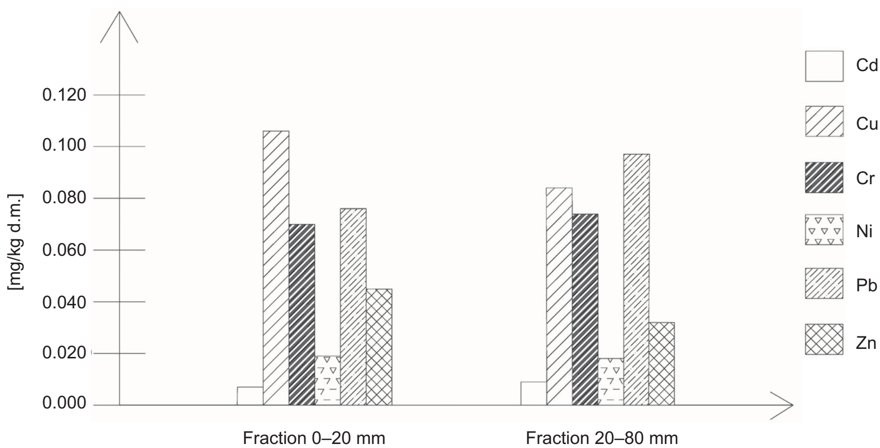

Fig. 5. Heavy metals analysis in elutes in the waste after 7-day stabilization in the bioreactor with active aeration

Conclusions

The 7-days biodrying processes were completed with decreased 10.61 % of moisture content in the 20–80 mm fraction, and 14.52 % decrease in the 0–20 mm fraction. The amounts of chlorides, identified in water extract, increased 1.5 times in stabilized waste. However, the amount of Cl^- is lower than limit values of 15 000 mg/kg of dry matter determined by Decree of the Minister of Economy [4]. There is a noticeable dominance 7 614.69 mg/kg d.m. of SO_4^{2-} anions in the water extract fraction 0–20 mm, but it is still below the acceptable level of 20 000 mg/kg d.m. defined in law regulation [4].

Decomposition of complex substances into simpler and partly mineralizated matter are results of stabilization processes [14]. Therefore, the amount of heavy metals in stabilat fractions was decreased. The largest increase, up more than 75 %, was observed in the case of chromium. As a result of the changes taking place in the stabilat, a significant increase in the content of copper was detected, that amounted to 69.55 % for the 0–20 mm fraction and 61.44 % for the 20–80 mm fraction. The smallest average increase of 10.82 % was observed for nickel. The metal content in the waste is conditioned by the presence of unwanted materials for example: ferrous and non-ferrous metals and hazardous waste such as batteries, fluorescent lamps. Segregation of waste „at the source" is needed solution to reduce the content of heavy metals in the waste directed to biological treatment [15].

The amount of heavy metals is in the limit of detection. Limited values in accordance with annex 3 [4] are in [mg/kg d.m.]: Cd = 1, Cu = 50, Cr = 10, Ni = 10, Pb, and Zn = 10 = 50.

Loss on ignition of raw waste was 62.10 % d.m. After stabilization LOI was much lower (24.80 % d.m for 0–20 stabilat fraction and 49.20 % d.m. for 20–80 mm fraction). According to requirements for MBS technology [5] LOI should be lower than 35 %. Therefore, only the fraction of 0–20 mm had been properly treated in MBS technology.

In accordance with the criteria in the Regulation [4], none of the stabilized fraction can't be landfilled. Losses on ignition are much higher than the limit value of 8 % d.m. In conclusion, to fulfill the criteria set out in polish legislation [4] and [12], the biodrying process of MSW in the industrial reactor, should be extended to the point where the fraction directed to the landfill (0–20 mm) will reach LOI values lower than 8 % d.m.

The maximum 10 mgO_2/g d.m. respiration activity is the another criteria for MBS technology what was compared with results presented in Table 2. The 0–80 mm fraction was the most biologically active. The total oxygen consumption for 4-days of 0–20 mm fraction was 8.17 mgO_2/g d.m. It allows to make the conclusion that the investigated 0–20 mm fraction had been properly treated in the MBS because the respirometer activity was < 10 mgO_2/g d.m. [5].

Acknowledgements

The authors would like to thank MSc. Jolanta Rajca, MSc.Eng Joanna Długosz and Dr Eng. Jarosław Gawdzik for laboratory help. Investigations were led using: OXYMAX respirometer ER-10 (Columbus Instruments), ion chromatograph 883 Basic IC plus, and spectrometer with plasma ICP. Equipments were founded by MOLAB Project "The development of laboratories of public universities in Swietokrzyskie Region". Number of Project in Kielce Univeristy of Technology: POIG 02.02.00-26-023/08-00.

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Abstrakt: Artykuł prezentuje analizę pracy reaktora służącego do mechaniczno-biologicznej stabilizacji odpadów. Odpady komunalne poddawane są wstępnej mechanicznej przeróbce, a następnie frakcja 0–80 mm najbogatsza w materię organiczną poddawana jest obróbce tlenowej w reaktorze. Przeprowadzono badania odpadów komunalnych kierowanych do reaktora (0–80 mm), a także stabilizatu (0–20 mm, 20–80 mm) powstałego po 7-dniowym suszeniu. Wyznaczono następujące parametry: straty prażenia (LOI), wilgotność, pH, siarczany, chlorki, metale ciężkie oraz aktywność oddechową. W celu określenia stabilizacji materiału mierzono ubytek O_2 i produkcję CO_2. Uzyskane wyniki pozwoliły ocenić efektywność pracy reaktora zgodnie z kryteriami prawnymi. Badania prowadzono z użyciem urządzeń zakupionych ze środków unijnych: respirometr OXYMAX ER-10, chromatograf jonowy 883 Basic IC plus, spektrometr z plazmą ICP.

Słowa kluczowe: mechaniczno-biologiczna stabilizacja odpadów, biosuszenie odpadów komunalnych, respirometria