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THERMOGRAPHIC EVALUATION OF CaO ADDITIVE ON THE PROCESS OF WASTE HYGIENIZATION

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Abstract

Municipal Solid Waste (MSW) is the mixture of many waste types, including organic waste (garden and park waste, food and kitchen waste, paper and cardboard etc.). Such waste creates a living environment for various microorganism species, many of which are known as pathogenic. The presence of microorganisms in favorable conditions (pH, organic matter content, carbon content, moisture, appropriate granulation) leads to decomposing of organic matter, which is accompanied by an increase in temperature. Microorganisms in waste pose a serious risk for staff operating at waste treatment plants. Moreover, heat released by their activity may cause a fire in waste storage facilities. Therefore, it is necessary to search for methods of waste stabilization and hygienization. The most commonly applied technology for waste stabilization is its processing in Mechanical Biological Treatment (MBT) plants. Such treatment is capital – and time-consuming, however. Waste liming can become an alternative method for stabilization and hygienization of waste. Lime addition is one of the oldest method known by humans for hygienization of certain waste materials, such as animal waste. Currently, liming is applied in sewage sludge treatment as one of the initial operations and is necessary for further sludge management processes.

The aim of the research was to valuate temperature changes during mixed MSW hygienization process with CaO addition in the amount of several percent by using a thermographic camera.

The reaction of CaO with waste is short and lasts no longer than 20 minutes. The maximal temperatures were reached after 65-124 seconds from the time of CaO addition. The most dynamic increase in temperature were observed up to approx. 120th second of the process, with the rate dependent on the initial moisture of the material. The observed pH values indicate that the maximal dose of CaO additive should not exceed 3%. Such a dose is sufficient for waste to reach pH 12, which, according to literature, guarantees the deactivation of microorganisms.

Key words: CaO, Municipal Solid Waste, hygienization, thermography

INTRODUCTION

Mixed Municipal Solid Waste discarded by residents is collected and transported (in Poland) directly to Regional Installation for Municipal Waste Treatment (RIMWT). The status of RIMWT can be acquired by such facilities as: MBT plants, incineration plants, landfills and composting plants for green waste(Act 2015). In an optimal system the waste immediately after delivery should be directed to processing (recovery). Due to chance events, failures, maintenance outages or holiday breaks, the waste can be temporarily stored. During the storage self-heating processes can occur in waste as the result of the decomposition of the biodegradable waste fraction. There are even known cases of self-combustion of alternative fuel (waste generated from mixed MSW) during storage (Yasuhara 2006, Yasuhara *et al.* 2010, Gao and Hirano 2006). Hogland and Marques (2003) described self-combustion incidents for fuel stored in piles even after 6 months from the date of fuel production. The increase in the temperature is a result of the decomposition of organic matter by microorganisms present in the fuel, due to the optimal growth conditions, i.e. large volume of free spaces, significant degree of material refinement and the content of organic matter from MSW (Malinowski and Wolny-Koładka, in print). Therefore, it is necessary to search for methods of waste stabilization and hygienization which could be applied prior to further waste processing.

Hygienization of waste through the addition of CaO (waste liming) is an exothermic reaction described by the following equation (1):

$$CaO + H_2O \rightarrow Ca(OH)_2 + 1140\ kJ \cdot kg^{-1} CaO \tag{1}$$

During waste liming a process of waste dehydration occurs, which results in decrease in waste mass up to 32%. The simultaneous heat release causes a temporary increase in temperature of the mixture, which eliminates the majority of microflora species as well as spores and eggs of pathogens. The positive aspect of waste liming is also the change in pH values from acidic to basic (ESW 2016, Aarab *et al*. 2006, Husillos Rodríguez *et al*. 2012, Healy *et al*. 2016, Malczewska 2011, Pesonen *et al*. 2016). The most common application of liming takes place in sewage sludge treatment processes. The sewage sludge with lime additive undergoes hygienization (meant as destruction of pathogens and parasites), which is the result of temporary increase in pH. The hygienized sludge is safe for further applications and unburdensome for the surroundings. For full stabilization a dose of 0.3 kg lime per 1 kg sludge dry mass in recommended. The sludge after liming and fulfilling appropriate standards can be directed to agricultural of other environmental applications.

The application of CaO in waste hygienization processes consists in using the heat released as a result of CaO hydration. This method is commonly applied to neutralize pathogenic bacteria, mainly *E. coli* and *Salmonella Sp*. The usage of CaO in waste hygienization processes is indicated by legal regulations concerning environmental and particularly agricultural applications of treated waste. The technical descriptions of the process discussed concern mainly dehydrated sewage sludge, for which high efficiency of hygienization through liming has been proven (ASTM 1990, EPA 2007, Malczewska 2011, Nagaoka *et al.* 1996).

The aim of the research was to valuate temperature changes during mixed MSW hygienization process with CaO addition in the amount of several percent by using a thermographic camera. The indirect aim of the analysis was to determine the maximal temperatures reached during the process of MSW liming and the reaction times.

MATERIALS AND METHODS

All the analyzes were carried out between January and May 2016 using the equipment owned by the Faculty of Production and Power Engineering (University of Agriculture in Kraków, Poland). For each of 3 test cycles a new portion of mixed MSW was obtained from a Mechanical Biological Treatment plant (MIKI Recycling Ltd.), located in Kraków (southern Poland). The waste was collected in rural areas of Kraków agglomeration. The samples for the research were prepared according to the method recommended by the European Committee for Standardization: Characterization of Waste – Sampling of Waste Materials – Framework for the Preparation and Application of a Sampling Plan (PN-EN 2006, 14899).

A general samples were delivered to the laboratory and divided into representative samples weighing 300 g each (with two relative water content values: 35 and 40%). Subsequently, to the representative samples a portion of CaO was added, amounting for 1, 2, 3, 5 and 10 wt% CaO in a sample, respectively. Analyzes for each waste/CaO composition repeated 3 times.

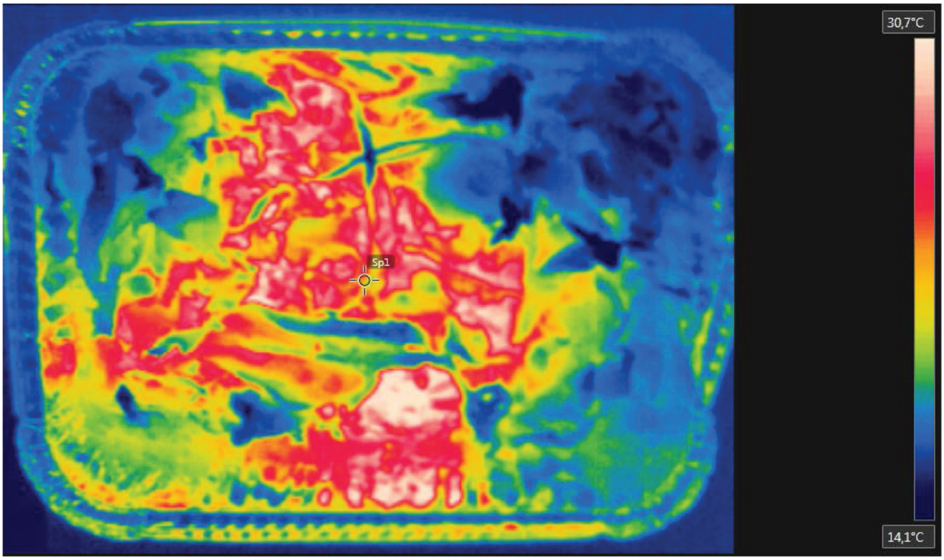
The research was oriented towards establishing an optimal dose of lime additive to waste. The control parameters which were analyzed included temperature and pH values. In order to achieve the research goal, highly reactive quicklime (producer: Lhoist Ltd.) was used. The waste samples were placed on aluminum plates sized 15 x 25 x 6 cm. Lime was added to the waste samples. For first ten seconds waste and lime were mixed intensively. Next, pictures (thermograms – thermal images) were taken using thermographic camera with a time interval of 15 seconds. Mixing took place in plates, whereas the camera was mounted to a stand arm directly above the plate with waste at the distance of 60 cm.

In order to analyze temperature changes in time, a thermographic camera ThermaCAM e300 (producer: Flir Systems) was used. For each thermal images created minimal, maximal and averaged temperatures were determined in Quick Report 1.2 software. Parameters of the camera set for the research were as follows: thermal resolution – 0.1^{o}C, color depth – 16-bit, image size – 320x240 dpi (which allows for simultaneous data registration for 76 800 points).

Thermographic measurements of temperature consist in measuring intensity of the thermal radiation (in a wave length range from 0.9 to 14 μm) emitted by all objects whose temperature exceed absolute zero (0 K, – 273.15^{o}C). Thermography is used in such technical and industrial applications as: civil engineering, heat engineering, diagnosis of electrical and mechanical systems, medicine (Wróbel 2010). The results of thermographic measurements (achieved using a thermographic camera equipped with an infrared radiation detector) are presented on a digital image (a thermogram). Colors on such an image represent different temperature values (which are recorded in a separate file). In order to acquire reliable results, differences in emissivity coefficients of analyzed objects (materials) and the potential impact of the surroundings (which may distort the obtained thermogram) should be taken into consideration. During carrying out the research air temperature and surroundings temperature were also measured. The emissivity coefficient for the analyzed material was set at 0.95, which resulted from former investigations (Malinowski and Wolny-Koładka 2015)

RESULTS

As an outcome of the research a set of thermograms were obtained (one of them is presented on Figure 1). The irregular pattern of colors results partially from differences in emissivity coefficients, but mainly is caused by diversified intensity of the reaction between waste (or water which waste contains) and lime.



Source: Own elaboration

Figure 1. A thermogram of waste submitted to hygienization

Table 1 shows changes in maximal temperatures during liming of two sets of homogenous waste samples containing water in the amount of 35 and 40 wt%, respectively. For first ten seconds waste and lime were mixed intensively. After this time a dynamic increase in temperature was observed, which gradually became less intense. The maximal temperatures were achieved in both analyzed samples after no less than 60 seconds from the beginning of the process. The rate at which heating in each sample took place was determined by sample's water content – a 5 wt% change (from 35 to 40 wt%) resulted in a 50 % decrease in the reaction time. The amounts of lime added to the waste occurred to be of significance as well. Comparing results from tests with two most different doses of lime (1 and 10 wt%), it was observed that in the case of a 10 wt% dose the maximal temperature was higher about 25°C above the analog temperature measured for the sample with 1 wt% lime additive. The similar tendency in heating time was noticed – the samples with a 1 wt% lime dose needed from 24 to 54 more seconds to reach the maximal temperature than in the case of the samples with the highest lime content. Comparing the results for tests, in which CaO additives amounted for 1, 2, 3 and 5 wt%, only little fluctuations (about 10-12%) were observed.

Based on a statistical analysis carried out for data concerning maximal, minimal and averaged temperatures (presented in Table 1) and on an analysis of measurement uncertainty, a measurement error was estimated at the level of

0.8°C for measuring temperature and 3 s for measuring time. A significance level for calculations was set at p = 0.05.

Table 1. Waste liming process characteristics

No.	Initial water content [wt%]	CaO additive [wt%]	Maximal temperature of the samples		Averaged temperature of the samples		Minimal temperature of the samples		Final pH [-]
			Value [°C]	Time to reach [s]	Value [°C]	Time to reach [s]	Value [°C]	Time to reach [s]	
1.	35	1	24.1	173	19.4	305	15.7	323	10.6
2.		2	26.8	153	20.2	305	16.4	359	11.3
3.		3	29.2	141	20.5	267	16.6	307	12.0
4.		5	38.2	120	22.4	224	16.9	293	12.9
5.		10	52.9	124	27.4	269	17.3	338	14.3
6.	40	1	26.4	89	19.7	189	15.7	205	10.5
7.		2	27.9	83	20.0	202	16.0	222	11.0
8.		3	31.2	79	20.6	179	16.6	218	12.5
9.		5	36.2	62	22.6	165	16.4	207	12.9
10.		10	52.3	65	23.7	148	17.2	193	13.0

Source: Own study

According to authors' knowledge, already by adding 1 or 3 wt% CaO to the waste, the pH values after liming process should guarantee the complete hygienization of the material, despite the fact that the temperature did not exceed 30°C in cases of such little lime doses. After the end of the process no secondary increase in temperature was observed, which allows for the statement that the waste became stabilized. Moreover, it was noticed that constant mixing of waste material with lime do not contribute significantly to the increase in temperature – the difference was at the level of 0.1-0.2°C, which is less the standard deviation for temperatures measured during the process.

CONCLUSIONS

The reaction between CaO and waste is short and do not exceed 20 minutes. The maximal temperatures were reached after 1-2 minutes from the time of CaO addition. The most dynamic increase in temperature was observed in first 2 minutes of the process. The initial moisture of the sample influenced the temperatures achieved during the process. The maximal value of the averaged temperature (averaged value including all temperatures on waste's surface measured with a thermographic camera) was observed after a few minutes from the beginning of the process. The increase in minimal temperatures was the slowest. It indicates the fact that the process of liming do not occur uniformly in all the waste volume (which result, among others, from the inhomogeneous waste composition). The higher waste content and bigger lime dose added to the waste, the faster was the process and the higher maximal temperature was observed. After the liming process there was no secondary increase in temperature of the waste observable. Thus, it can be stated that as the result of the process the waste became stabilized.

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