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ASSESSMENT OF THE IMPACT OF SEWAGE SLUDGE COMBUSTION TECHNOLOGY ON THE PROPERTIES OF ASHES

OCENA WPŁYWU TECHNOLOGII SPALANIA KOMUNALNYCH OSADÓW ŚCIEKOWYCH NA WŁAŚCIWOŚCI POPIOŁÓW

Abstract: The amount of sewage sludge produced at Polish and foreign sewage treatment plants constantly increases. Polish and European Union regulations on sewage sludge treatment lead to higher popularity of thermal treatment methods. Thermal methods cover among others incineration of sewage sludge in the fluidised bed or grate furnaces. The paper presents the test results of ashes produced from sewage sludge from Polish sewage sludge incineration plants equipped with fluidised bed - sewage treatment plant in Sitkowka-Nowiny near Kielce and with a stoker - sewage treatment plant in Olsztyn. The mobility of heavy metals from ashes from sewage sludge was investigated. The tests were performed using a methodology proposed by Community Bureau of Reference (BCR). It has been stated that the dominant fraction of heavy metals in ashes from sewage sludge taken at both plants was immobile.

Keywords: sewage sludge ash, mobility, heavy metals

Introduction

In Poland main methods of municipal sewage sludge utilization are applied in agriculture (22.4% of dry mass of sewage sludge generated in the year 2011), applied in land reclamation including reclamation of land for agricultural purposes (10%) and landfilled (10.4%) [1]. The environmental use of sewage sludge is seasonal and is regulated by waste act [2], regulations [3, 4], and the directive [5]. Furthermore, there are no suitable areas for this purpose. According to the National Waste Management Plan, only 7.5% of total number of sewage treatment plants provide sludge which can be used in agriculture [6]. Furthermore, from 1st January 2016 landfilling of unprocessed sewage sludge will be prohibited [7].

The consequence of these situations is an increase of the amount of thermal sewage sludge utilization, especially in big agglomerations [8, 9]. The thermal disposal of sewage sludge includes main methods: combustion (grate furnace, fluidized bed, smelting and rotary furnace), co-combustion (with: coal, other fuels, municipal solid waste), alternative processes (for instance, pyrolysis) [10]. In Poland the dominant combustion technology of sewage sludge is fluidized bed furnace (8 - installations). Combustion of sewage sludge in grate furnace is in 4 municipal waste water treatment plants [11].

The incineration does not provide a zero-waste disposal method since approximately 30% of the solids remain as ash [12]. The ash forming as a result of sewage sludge combustion process is included into the landfilled waste depending on the criteria it fulfils: non hazardous waste, hazardous waste or inert waste. One of the criteria is the limit of heavy metals [7, 13]. The concentration of heavy metals is not a sufficient indicator of

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waste environmental harmfulness. The mobility and bioavailability of heavy metals in the environment depends on the forms of their occurrence.

The use of sewage sludge ash in agriculture has been reported [14], processing sewage sludge ash to form materials like: brick [15, 16], glass-ceramics [17], lightweight aggregate [18, 19], asphalted paving mixes [20], cement mortars [21, 22].

The chemical and mineral composition of sewage sludge ash depends on. the thermal sewage sludge disposal technology [23].

The aim of this research was the evaluation of impact of combustion technology on sewage sludge ash properties, like heavy metals mobility. The analysed technologies of sewage sludge combustion were combustion in fluidized bed furnace and combustion in grate furnace.

Materials

Sewage sludge ash from combustion in fluidized bed

One of the waste water treatment plants with combustion sewage sludge in fluidized bed is installation in Sitkowka-Nowiny. This waste water treatment plant receives waste water from the sewer system in Kielce - capital of this region, Sitkowka-Nowiny municipalities and part of the Masłów municipality. The nominal flow capacity of this sewage treatment plant equals 270 000 PE. The total amount of waste water influent is municipal waste water 85% and 15% of industrial waste - mainly from the food and metal industries. This waste water treatment plant releases around 12 000 Mg/a [24]. The maximum amount of combustion sludge equals 88.8 Mg/d. This sludge thermal utilization installation is composed of main elements:

- receipt and storage of sewage sludge,
- sludge drying in discs dryer - drying at 215ºC, after drying sewage sludge has 36% d.m. Dried sludge after leaving the drier is directed to the mixing tank. In this tank dried sludge is mixed with screenings, sand and fat,
- combustion in fluidized bed - combustion at 850ºC.

Sewage sludge ash from combustion in grate furnace

One of the Polish sewage treatment plants in which the sewage sludge is incinerated in grate furnace is the sewage treatment plant in Olsztyn. The sewage is transported to the sewage treatment plant by means of a separate sewage system. The capacity of the sewage treatment plant equals 350 000 RLM. The amount of sewage sludge intended for combustion equals 760 Mg d.m. of sewage sludge. The maximum capacity of sewage incineration plant equals 15 Mg/d. The installation of sewage sludge combustion consists of belt drier and the combustion chamber with a grate.

Methods

The chemical composition of examined sewage sludge ashes was determined by means of emission spectroscopy method in XRF infrared. The phase composition of sewage sludge ash was determined with the use of XRD X-ray diffraction methodology. Grain size distribution of sewage sludge ash was made by laser diffractometer.

Mobility of heavy metals from sewage sludge ash

The BCR test was applied to determine the heavy metal fraction in sewage sludge ashes. The sequential extraction method used allows one to determine the mobility degree of metals which are present in the matrix. The methodology suggested by European Community Bureau of Reference was used. The tests were conducted in accordance with the four-step BCR sequential extraction procedure [24], introducing a change in the method of residual fraction mineralisation, *ie* aqua regia was used in the process of mineralisation [12]. The heavy metals in the obtained extracts were determined using an optical spectrometer with inductively coupled plasma ICP Perkin-Elmer Optima 8000.

Results and discussion

The chemical composition of sewage sludge ash is presented in Table 1. The compositions of both examined types of sewage sludge ash showed the dominance of silicon dioxide, calcium oxide and phosphorus oxide. The presence of both silicon dioxide and aluminium oxide is the result of rain water carrying mineral contamination into the sewage system, street cleaning as well as water-supply and sewer pipes corrosion [25].

Table 1

Chemical composition of sewage sludge ash

Component	**Sewage sludge ash from Sitkowka-Nowiny (SSA1)**	**Sewage sludge ash from Olsztyn (SSA2)**
	[%]	**[%]**
SiO_2	35.72	25.77
Al_2O_3	6.70	9.54
Fe_2O_3	9.56	5.12
CaO	17.46	20.70
MgO	4.51	4.48
SO_3	1.21	0.30
K_2O	1.61	1.87
Na_2O	0.52	0.55
P_2O_5	19.0	21.58
TiO_2	1.00	0.77
Mn_2O_3	0.14	0.13
SrO	0.05	0.10
ZnO	0.37	0.41
BaO	0.11	0.09
CuO	0.06	0.13
TOC	0.09	5.39

In both types of sewage sludge ash, in comparison to literature data [26], a large portion of biophile element - phosphorus was discovered. A high concentration of phosphorus in the ash is the effect of i.a using detergents by the inhabitants, sewage treatment method, especially with the use of coagulants for phosphorus precipitation.

The sewage sludge ash (SSA1) from fluidized bed incineration presented a high degree of mineralization (TOC - 0.09% d.m.), in contrast to grate furnace sewage sludge ash (SSA2) (TOC - 5.3% d.m).

Sewage sludge ash SSA1 presented the following phase composition: quartz, $Ca_9Al(PO_4)_7$, hematite, orthoclase, albite. The phase composition of sewage sludge ash SSA2 included quartz, $Ca_9Al(PO_4)_7$, feldspars. Both quartz and hematite are the typical sewage sludge ash as well as carbon fly ash phases.

Grain size distribution of both types of sewage sludge ash was shown in Figures 1 and 2. In sewage sludge ash SSA1 x_{50} equals 58.78 µm, x_{99} - 319.39 µm. Whereas in the sewage sludge ash SSA2 x_{50} equals 1480.77 µm, x_{99} - 2267.73 µm.

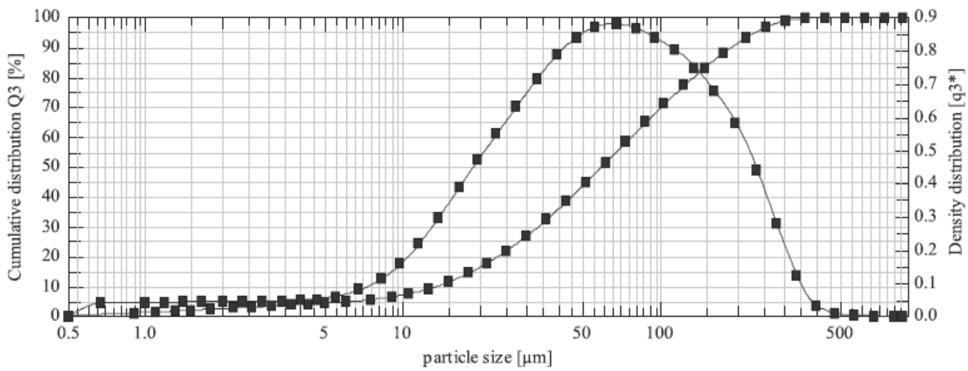

Fig. 1. Cumulative distribution and density distribution of sewage sludge ash from waste water treatment plant in Sitkowka-Nowiny

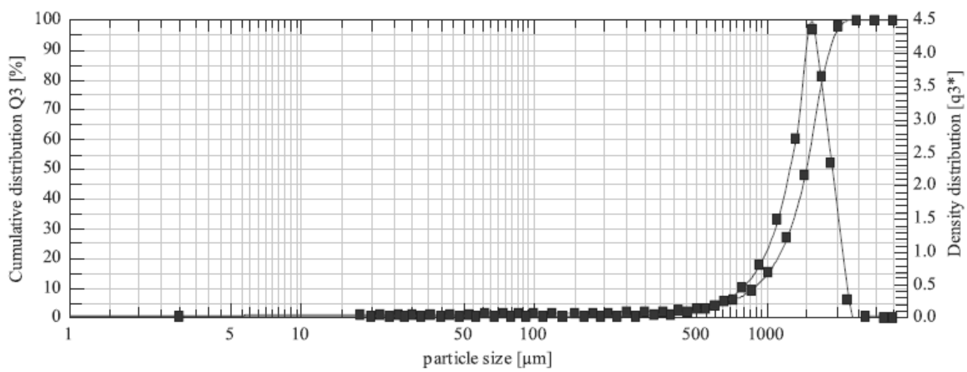

Fig. 2. Cumulative distribution and density distribution of sewage sludge ash from waste water treatment plant in Olsztyn

The heavy metals mobility of examined sewage sludge ash is presented in Tables 2 and 3 and Figures 3 and 4. The sewage sludge ash SSA2 presented a lower content of cadmium, lead and zinc in comparison to sewage sludge ash SSA1. As far as sewage sludge ash SSA1 is concerned, copper, chromium, nickel, zinc were present mainly in the immobile form - FIV. Whereas lead and cadmium dominated in a potentially immobile form (FIII). In sewage sludge ash SSA2 the dominant fraction of copper, chromium, nickel, lead and zinc was the immobile fraction (FIV). While the dominant fraction of cadmium in ash SSA2 was the mobile fraction (FI).

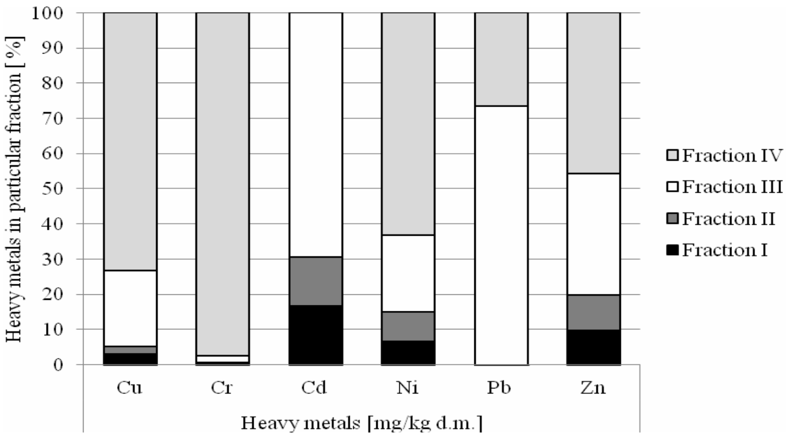

Fig. 3. The contribution percentage of heavy metals in particular fraction in sewage sludge ash from waste water treatment plant in Sitkowka-Nowiny

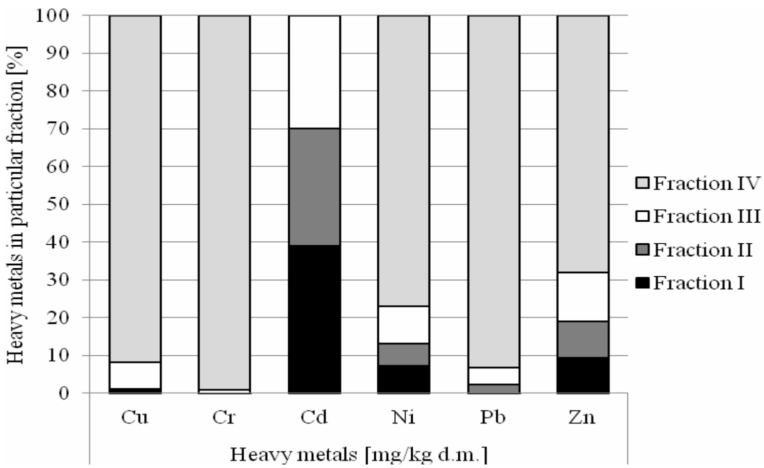

Fig. 4. The contribution percentage of heavy metals in particular fraction in sewage sludge ash from waste water treatment plant in Olsztyn

Table 2

Speciation of heavy metals sewage sludge ash from waste water treatment plant in Sitkowka-Nowiny

Speciation	Heavy metals [mg/kg d.m.]					
	Cu	Cr	Cd	Ni	Pb	Zn
FI	11.98±0.21	0.33±0.02	0.90±0.01	2.97±0.02	0.01±0.09	71.65±1.02
FII	8.24±0.08	0.08±0.08	0.74±0.01	3.81±0.04	0.16±0.18	72.96±0.35
FIII	85.42±1.26	1.49±0.13	3.76±0.05	9.92±0.02	310.89±2.02	256.21±2.82
FIV	290.99±6.40	73.92±5.29	0.00±0.00	28.90±0.05	112.47±0.97	336.85±5.49
ΣFI-IV	396.63	75.82	5.40	45.60	423.53	737.67

Table 3

Speciation of heavy metals sewage sludge ash from waste water treatment plant in Olsztyn

Speciation	Heavy metals [mg/kg d.m.]					
	Cu	**Cr**	**Cd**	**Ni**	**Pb**	**Zn**
FI	8.52±0.23	0.29±0.03	0.33±0.01	4.22±0.03	0.16±0.12	56.58±0.74
FII	1.11±0.08	0.27 ±0.05	0.27±0.02	3.34 ±0.02	0.64±0.11	58.48±1.33
FIII	58.10±1.72	0.54±0.08	0.22±0.02	5.77±0.08	1.50±0.22	78.28±0.22
FIV	757.26±16.89	110.01±10.48	0.00±0.00	44.58±0.39	31.94±0.34	410.09±5.37
ΣFI-IV	824.99	111.11	0.82	57.91	34.24	603.43

Conclusion

- The sewage sludge ash from fluidized bed incineration installation presented a high degree of mineralization. The conditions in the combustion chamber clearly influenced the incinerated sewage sludge mineralization degree.
- The incineration technology significantly influenced the grain size distribution and the size of incinerated sewage sludge ash fractions. The ash from fluidized bed installation presented minor grain size distribution whereas the grain size distribution of ash from grate furnace installation was considerably homogeneous. According to literature data the grain size distribution of sewage sludge ash fractions is an important factor influencing the choice of ash neutralization method *ie* the usage as an additive to a particular building material.
- The incineration technology of examined sewage sludge did not have a significant influence on the mobility of heavy metals from the sewage sludge ash. In the examined sewage sludge ash the heavy metals dominated in the immobile phase (FIV). Cadmium was an exception which at low concentration, especially in the grate furnace installation ash, dominated in a mobile phase (FI).

Acknowledgements

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OCENA WPŁYWU TECHNOLOGII SPALANIA KOMUNALNYCH OSADÓW ŚCIEKOWYCH NA WŁAŚCIWOŚCI POPIOŁÓW

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Abstrakt: Ilości osadów ściekowych powstających w krajowych i zagranicznych oczyszczalniach ścieków komunalnych stale wzrastają. Obowiązujące w Polsce i Unii Europejskiej normatywy prawne regulujące postępowanie z osadami ściekowymi przyczyniają się do wzrostu popularności metod termicznych. Stosowane metody termiczne obejmują między innymi spalanie osadów ściekowych w piecu ze złożem fluidalnym lub w piecu rusztowym. W pracy przedstawiono wyniki badań popiołów z osadów ściekowych pochodzących z krajowych instalacji spalania osadów ściekowych: ze złożem fluidalnym - oczyszczalnia w Sitkówce-Nowiny k. Kielc oraz z rusztem - oczyszczalnia w Olsztynie. Zbadano mobilności metali ciężkich z popiołów z osadów ściekowych. Badania przeprowadzono, wykorzystując metodykę proponowaną przez Community Bureau of Reference (BCR). Stwierdzono, że dominującą frakcją metali ciężkich w popiołach z osadów ściekowych pochodzących z obu instalacji była frakcja niemobilna.

Słowa kluczowe: popiół z osadów ściekowych, mobilność, metale ciężkie