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SEWAGE SLUDGE AS AN ENVIRONMENTAL FRIENDLY ENERGY SOURCE

OSADY ŚCIEKOWE ŹRÓDŁEM ENERGII PRZYJAZNEJ ŚRODOWISKU

Abstract: The predominant method of the sewage sludge management in Poland is land disposal. However, since 01/01/2016, this method will be prohibited. Therefore, there is a strong need for development of thermal methods of sludge disposal. In the Polish legal system sewage sludge may be named as a biomass or waste. For purposes of determining the obligations of environmental regulations definition of the Minister of Environment should be used. When disposing of sewage sludge in an amount up to 1 % by weight of fuel, emission standards for fuel do not change. At the disposal of sewage in quantities of more than 1 %, should be conducted continuous measurement of emissions, including HCl, HF, and continuous measurements of flue gas parameters (as for the installation of waste disposal). For purposes of settlement of the share of energy from renewable sources we use the definition of Minister of Economy. In this case, in accordance with applicable law sewage sludge shall be considered as pure biomass is CO_2 neutral. The use of sewage sludge as a fuel requires the determination of fundamental combustible properties. These properties should be in accordance with the requirements put fuels as an energy source. The paper presents results of a detailed physico-chemical analysis of dried sewage sludge produced in the two Polish wastewater treatment plants. The results were compared with five representatives of biomass fuels: straw of wheat, straw of rape, willow, pine and oak sawdust. Ultimate and proximate analysis includes a detailed analysis of fuel and ash. The results clearly indicate that the sludge is a very valuable fuel similar to "traditional" biomass.

Keywords: sewage sludge, thermal treatment, combustible properties

Introduction

Sewage sludge, originating from the treatment process of wastewater, is the residue generated during the primary (physical and/or chemical), the secondary (biological) and the tertiary (additional to secondary, often nutrient removal) treatment [1–3]. Removal of sludges from *Wastewater Treatment Plants* (WWTP) represents a serious worldwide environmental problem. Not long ago, it was thought that raw sludge was a valueless material that should be discarded, and then it was disposed of in landfills and/or thrown into the ocean. But the huge amounts of sludge produced make all these options

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environmentally unacceptable. The high output of sewage sludge, which is increasing during recent years, and the limitations of the existing means of disposing sewage sludge highlight the need to find alternative routes to manage this organic material. The *6th Environment Action Programme 2002–2012* of the European Commission has been described as a major factor in reducing sewage sludge disposal by 50 % from 2000 by 2050. Moreover, European legislation prohibits the deposition of sewage sludge into landfill or water. Biomass and residues like sewage sludge are the only renewable energy sources that can provide C and H, thus it is interesting to process them by means of treatments that enable to obtain chemically valuable products like fuels. As a type of biomass fuel, sewage sludge is a renewable source and has advantage of being CO_2-neutral: no additional CO_2 is estimated into the atmosphere in the long term. The latest trends in the field of biomass and sludge management, (*ie*, combustion, pyrolysis, gasification and co-combustion) have generated significant scientific interest [4]. Those processes are illustrated in the flow-chart shown in Fig. 1.

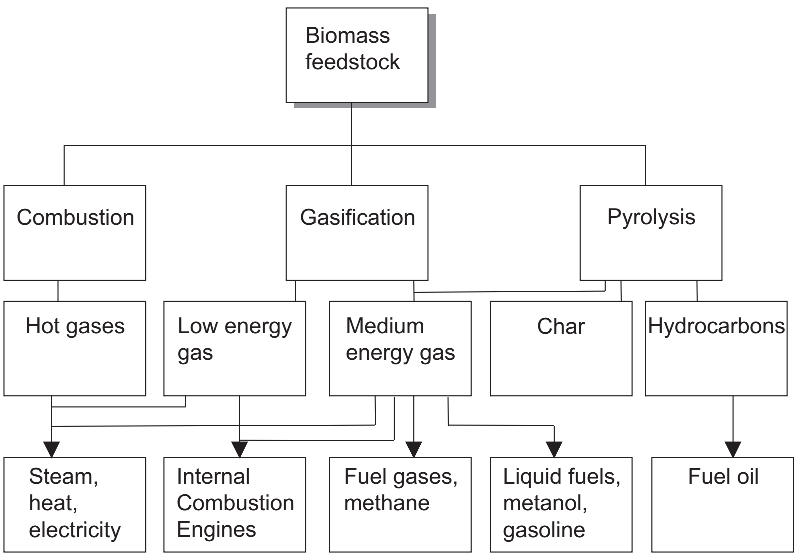

Fig. 1. Main processes of biomass conversion

Gasification is the process of converting a solid fuel into a gas by treating the solid fuel in a generator with oxygen, air, and steam or by other gasification methods [5]. The most important reactions that take place in the reduction zone of a gasifier between the different gaseous and solid reactants are given below. A minus sign indicates that heat is generated in the reaction, a positive sign that the reaction requires heat.

$$CO + CO_2 \rightarrow 2CO_2 + 164.9 \text{ kJ/kmol} \quad (1)$$

$$C + H_2 \rightarrow CO + H_2 + 122.6 \text{ kJ/kmol} \quad (2)$$

$$CO + H_2 \rightarrow CO + H_2O + 42.3 \text{ kJ/kmol} \quad (3)$$

$$C + 2H_2 \rightarrow CH_4 + 0 \text{ kJ/kmol} \tag{4}$$

$$CO + 3H_2 \rightarrow CH_4 + H_2O - 205.9 \text{ kJ/kmol} \tag{5}$$

As shown in Marrero et al, gasification of sewage sludge leads to a high-quality flammable gas that can be used for the generation of electricity or to support such processes as the drying of sewage sludge [6]. Gasification is one way of using sewage sludge and is an attractive alternative to other treatment methods. To determine the usefulness of sewage sludge as a biomass fuel for thermal transformation, it is necessary to know its basic physical and chemical characteristics. The elemental composition of sewage sludge and the contents of inorganic compounds depend on many factors, but it may be largely dependent on the country or region of origin.

The aim of the work is comparison of physico-chemical properties of dried sewage sludge produced in the two Polish wastewater treatment plants with five representatives of "traditional" biomass fuels: straw of wheat, straw of rape, willow, pine and oak sawdust. Ultimate and proximate analysis includes a detailed analysis of fuel and ash.

Results

Within this study straw of wheat and rape, oak, willow and pine sawdust and two sewage sludge samples were examined. The proximate and ultimate analysis are presented on Fig. 2.

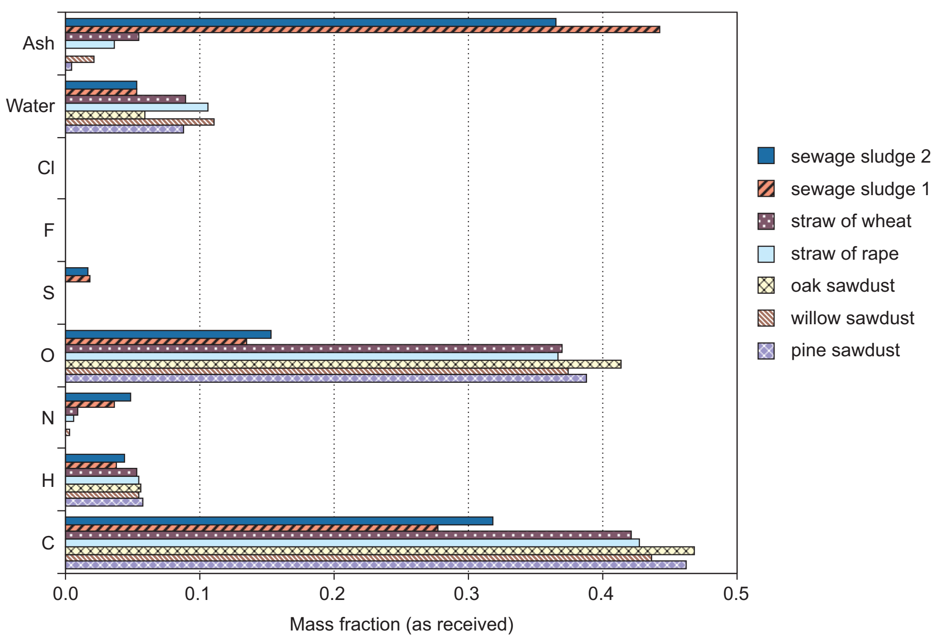

Fig. 2. Ultimate analysis and ash and water content in analysed feedstock

The moisture of the feedstock was obtained following standard PN-EN 14774-3:2010 [7]. The infrared spectroscopy analyzer was used to carry out the ultimate analysis of the sewage sludge.

The volatile matter content was determined according to standard PN-EN 15402:2011 [8]. The ash content was obtained using PN-EN 15403:2011 [9]. The calorific content was determined in accordance with standards CEN/TS15400:2006 [10].

As it can be seen from ultimate analysis, there are no significant differences in the C, H, Cl and F content. Nevertheless, taking into consideration S, N and O contents those difference between "traditional" biomass and sewage sludge is quite strong. Despite the fact that sewage sludge contains phosphorus, nitrogen and sulfur, the gasification of these components offers several advantages over a traditional combustion process. Gasification takes place in an environment with low levels of oxidizers (to prevent the formation of dioxins) and large quantities of sulfur and nitrogen oxides [11]. As mentioned above, sulfur is present in sewage sludge at low amounts; it is mainly converted to hydrogen sulfide (H_2S) during gasification [12], whereas the nitrogen is transformed into ammonia [11].

It is worth noting that the phosphorus in sewage sludge is partitioned into solid (not gaseous) residues [13] and that the volume of syngas produced from sewage sludge is low because gasification requires a fraction of the stoichiometric amount of oxygen necessary for combustion. For all of these reasons, gasification requires smaller and less expensive gas-cleaning facilities [14]. Analysing Fig. 2 it can be also seen that the sewage sludges were characterized by higher ash content than "traditional" biomass feedstock.

It can be seen in Fig. 3 that lower heating value is comparable to that of traditional biomass. Simultaneously in Fig. 4, it can be observed that volatile matter content in the sewage sludge is much lower in comparison with traditional biomass. The combination of low oxygen content and low volatile matter in sewage sludge indicates a low potential for creating large amounts of inorganic vapors during combustion and another thermal processes.

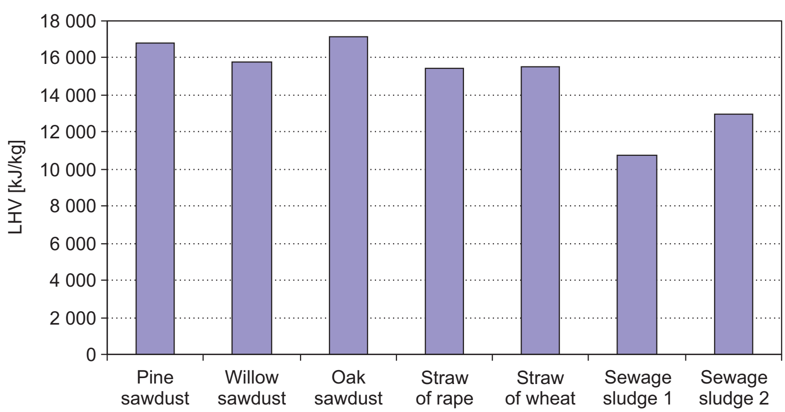

Fig. 3. Lower heating value of analysed feedstock

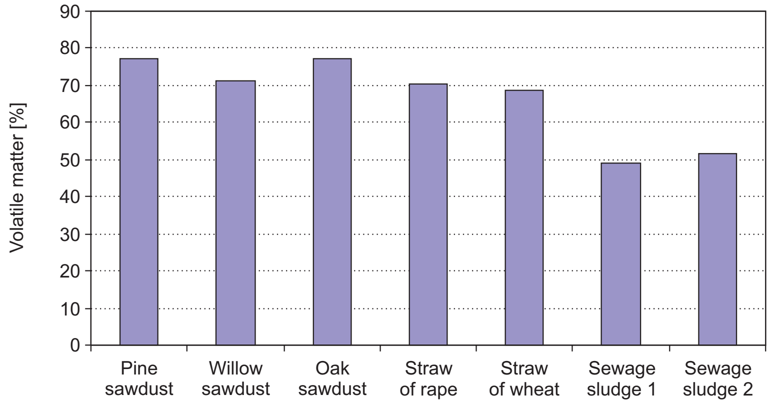

Fig. 4. Volatile matter content of analysed feedstock

The results of the chemical analyses of the fly ashes are presented in Fig. 5. The plasma spectrometer Thermo iCAP 6500 Duo ICP was used to carry out the ash analysis of the biomass feedstock.

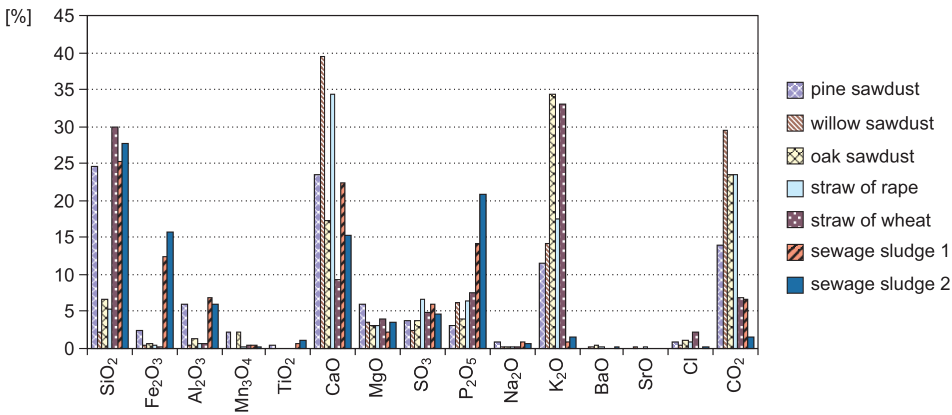

Fig. 5. Ash chemical analysis of analysed feedstock

Ash behavior and deposition tendencies were predicted through the use of empirical indices for biomass type ashes [15–17]. These indices, despite their shortcomings due to the complex conditions, which arise in boilers and their associated heat transfer equipment, are widely used and probably remain the most secure basis for decision making, if used in conjunction with pilot plant testing.

One simple index, the *alkali index* (AI) which is a parameter frequently used to describe the overall influence of catalytically active species within the ash and is defined as the ratio of the sum of the fraction of the basic compounds in the ash (CaO, MgO, K_2O, Na_2O and Fe_2O_3) to the fraction of the acidic compounds (SiO_2 and Al_2O_3) in the ash, multiplied by the ash value (eq. (1)).

$$AI = ash\% \cdot \frac{CaO + MgO + K_2O + Na_2O + Fe_2O_3}{SiO_2 + Al_2O_3} \tag{1}$$

When the AI increases slagging tendency increases.

Another index, the *base-to-acid ratio* (B/A) – eq. (2). As B/A increases, the fouling tendency of a fuel ash increases.

$$B/A = \frac{\%(CaO + MgO + K_2O + Na_2O + Fe_2O_3)}{\%(SiO_2 + TiO_2 + Al_2O_3)} \tag{2}$$

A *bed agglomeration index* (BAI) – eq. (3) has been developed, relating ash composition with agglomerations in fluidized bed reactors. BAI was calculated according to the following equation.

$$BAI = \frac{\%Fe_2O_3}{\%(K_2O + Na_2O)} \tag{3}$$

Bed agglomeration occurs when BAI values become lower than 0.15.

Analysing data presented in Fig. 6 it can be concluded that sewage sludge is characterizing by higher slagging tendency in comparison with traditional biomass (especially oak and pine sawdust). Simultaneously sewage sludge ash is characterised by lower fouling tendency than traditional biomass ash and higher tendency to create agglomerates.

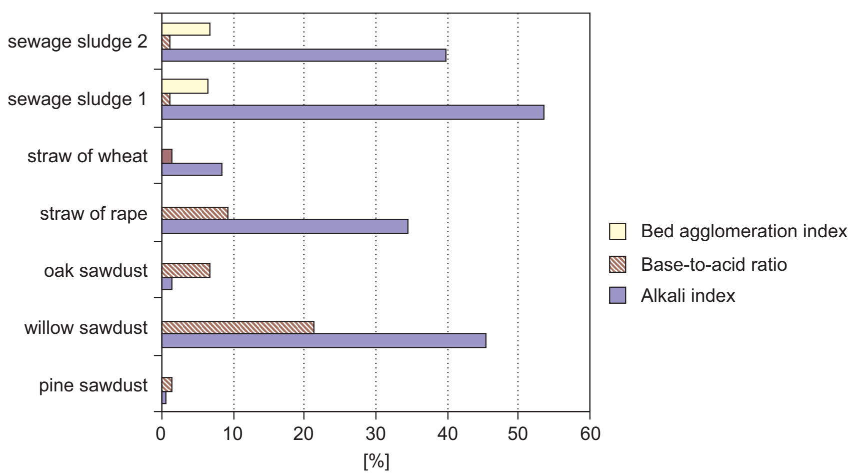

Fig. 6. Slagging/fouling indexes of analysed feedstock

Figure 7 shows the content of trace elements measured in the ashes of the studied fuels and – additionally to compare – hard coal and biomass ashes. The measurements was done by absorption spectroscopy. The measured values in all presented cases are

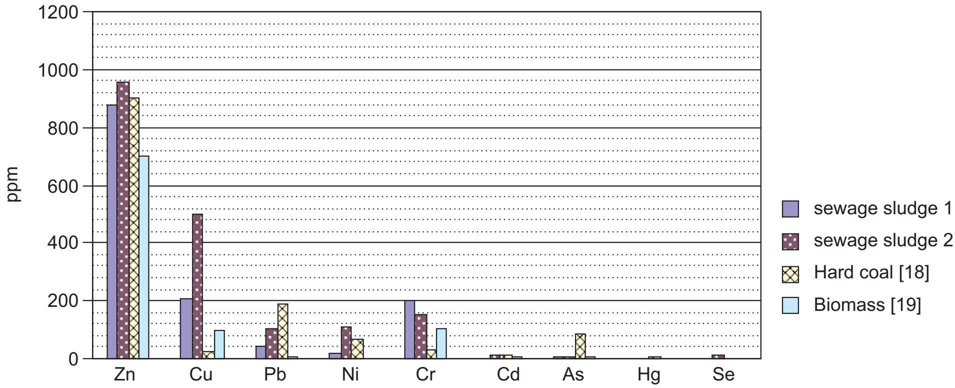

Fig. 7. Trace and selected minor elements measured in ashes

similar. It should be emphasis that sewage sludge gasification ash taking in consideration trace elements is similar to traditional biomass.

Conclusions

The analysis of various biomass materials indented to be used as supplemental fuel in fossil fuel fired power plants has shown that there is always a range of the results sometimes with a big gap between minimum and maximum. Most noticeable for the sewage sludge was the highest share of ash, nearly 50 % of the dry substance, compared with all the other fuels. Additionally it should be emphasis that the combination of low oxygen content and low volatile matter in sewage sludge indicates a low potential for creating large amounts of inorganic vapors during combustion and another thermal processes. Moreover, sewage sludge is characterizing by higher slagging tendency, lower fouling tendency and higher tendency to create agglomerates in comparison with traditional biomass.

Acknowledgements

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OSADY ŚCIEKOWE ŹRÓDŁEM ENERGII PRZYJAZNEJ ŚRODOWISKU

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Abstrakt: Dominującym kierunkiem zagospodarowania osadów ściekowych w Polsce jest ich składowanie. Jednakże począwszy od 1.01.2013 sposób ten będzie zabroniony. Istnieje zatem silna potrzeba rozwoju termicznych metod utylizacji osadów. W polskim ustawodawstwie osad może być nazywany biomasą lub odpadem. Dla celów ustalenia, jakie obowiązki wynikają z przepisów ochrony środowiska, korzystać należy z definicji Ministra Środowiska. Przy utylizacji osadów ściekowych w ilości do 1 % masy paliwa, standardy emisyjne dla paliw nie ulegają zmianie. Przy utylizacji osadów w ilości ponad 1 %, należy prowadzić ciągły pomiar emisji zanieczyszczeń, w tym HCl i HF, a także ciągły pomiar parametrów spalin (jak dla instalacji utylizacji odpadów). Do potrzeb rozliczenia udziału energii pochodzącej ze źródeł odnawialnych stosuje się definicję Ministra Gospodarki. W takim przypadku, zgodnie z obowiązującym prawem osady ściekowe uznaje się za czystą biomasę neutralną pod względem CO_2. Wykorzystanie osadów ściekowych jako paliwa wymaga określenia podstawowych właściwości palnych. Właściwości te powinny odpowiadać wymaganiom, jakie są stawiane paliwom w celu ich energetycznego wykorzystania. W pracy przedstawiono wyniki szczegółowej analizy fizykochemicznej suszonych osadów ściekowych wytworzonych w dwóch polskich oczyszczalniach ścieków. Wyniki zostały porównane z pięcioma przedstawicielami paliw biomasowych: słomy pszennej, rzepakowej, wierzby energetycznej, trocin sosnowych i dębowych. Analiza obejmowała skład elementarny paliw oraz szczegółową analizę popiołu. Wyniki jednoznacznie wskazują, iż osady ściekowe są bardzo wartościowym paliwem nieróżniącym się w zasadniczy sposób od „klasycznej" biomasy.

Słowa kluczowe: osady ściekowe, termiczna utylizacja, własności palne