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Problematic issues of air protection during thermal processes related to the energetic uses of sewage sludge and other waste. Case study: Co-combustion in peaking power plant

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ABSTRACT

Currently, it is necessary to deal with issues related to the emissions as there is a constantly increasing interest in combusting sludge from sewage treatment plants in the boilers for wood. An analysis of the energetic importance of the combustion of sewage sludge has already been carried out, but the effects of various treatments of the sludge are not always clear, e.g. composting and subsequent combustion to the air pollution. Investments in other thermal processes of energetic utilisation of sewage sludge and organic waste are not always successfully implemented. The objective of this paper is to point out some problematic cases for acceptance of thermal processes related to energetic use of waste in terms of the air protection. The other aim is to mention the experience with solutions of such issues in Slovakia. There are mentioned first results of the operational validation experiments during the energy generation in circulating fluidized bed boiler in peaking power plant (Power 110 MW) with the addition of the so-called alternative fuel based on wood and sewage sludge to the main fuel – black coal (anthracite). And there has already been achieved the highest share of 12.4% w. (dry matter) of sewage sludge in form of compost in blend with black coal, which is technologically viable. Moreover analyzed the problems of the authorization and operation of the co-combustion of sewage sludge and of combustion of products of various kinds of pyrolysis waste - pyrolysis gas and pyrolysis oil are analyzed.

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1. Introduction

Thermal treatment of waste is still a highly topical and widely discussed theme. Today, more than 2200 waste to energy (WtE) plants are active worldwide. They have a disposal capacity of around 280 million tons of waste per year. More than 250 thermal treatment plants with a capacity of nearly 60 million annual tons were built between 2010 and 2014. We estimate almost 550 new plants with a capacity of about 150 million annual tons will be built by 2024 (Anon, 2015a; https://www.ecoprog.com/publikationen/energiewirtschaft/waste-to-energy.htm). Waste To Energy Market Outlook 2016–2026 shows very important opportunities for business (Anon, 2016). In this WtE business, issues of environmental protection issues will be present.

It is known that there is an increasing need for methods that enable a clear and uniform description of the quality of secondary fuels and of environmental aspects of their thermal application (Tubergen et al., 2005). This can be achieved by standardisation. Standardisation is a well proven concept for other secondary materials. The Directive 2008/98/EC on waste, the Directive 2010/75/EU on industrial emissions and all CEN/TC 343 statements regarding Solid Recovered Fuels since 2004 until 2012 are important to solve these issues (https://standards.cen.eu). The aim of these WI Directive is to prevent or to reduce as far as possible negative effects on the environment caused by the incineration, co-incineration and co-combustion of waste.

For principal regulations and choices in sewage-sludge utilisation methods the application of the EU Directive 91/271/EEC (Urban Wastewater Treatment Directive) and its amendment, Directive 98/15/EC are also important. The Waste Directive and the national Regulation established rules for the problem of dealing with sewage sludge. In Slovakia, a regulation of the Ministry of the Environment of the Slovak Republic No. 228/2014 Coll. was issued, which defines the requirements for fuel quality.

Combining biomass with other fuels (e.g. coal and solid recovered fuel) for energy production in existing power plants can mitigate and address technical, economic and environmental

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uncertainties, especially when biomass is sourced locally, which makes the co-firing more economically attractive (Basu et al., 2011; Iacovidou et al., 2016). Savings of carbon dioxide greenhouse gas in the amount of 42,250 tonnes were achieved by replacing fossil fuels with wood chips - biomass in fluidised-bed boilers in 2 power plants, which supplied to the Slovak republic grid 9% electricity generated from wood chips in 2015 (Anon, 2015b). Other coal blocks of heating plants have also started exploiting the co-combustion of wood. Wood is thereby becoming a low profile raw material for e.g. for the manufacture of chipboard. The question therefore arises of how to maintain the downward trend in greenhouse gas emissions from energy production. One of many possible contributions to the positive trend is the use of other resources such as sewage sludge.

The majority of biomass co-firing installations is operated at biomass to coal ratio of less than 10%, on an energy basis (Iacovidou et al., 2016). For higher co-firing ratios, however, the technical constraints can vary based on the co-firing option and technology used (Basu et al., 2011; Dai et al., 2008). A co-firing up to 3% thermal biomass content (i.e., about 10% mass) without posing any threat or major problems to the boiler operation (Basu et al., 2011).

In Slovakia, the most important and discussed secondary fuel is sewage sludge, pyrolysis gas and pyrolysis oil. In the near future we expect an increased interest in secondary fuel preparation from mixed municipal waste almost 100% of which is disposed of in landfills. Some entities try to burn secondary fuels in wood boilers and in cogenerating units. The question is whether these solutions will be accepted by society from the point of view of the air protection. Here it is necessary to distinguish between Solid Recovered Fuel (SRF), other secondary fuels prepared from waste - Refuse Derived Fuel (RDF) and biomass as a fuel.

This article is a reaction to this trend, while at the same time it analyses and applies important scientific knowledge in order to solve some problems in the energy utilisation of waste. It lists real results from the preparation and operation experiments of the energetic recovery of sewage sludge by co-combustion with black coal (anthracite). In the context of the results achieved and the efforts of energy recovery from mixed waste, we have subsequently analyzed current cases of possibilities and conditions of sewage sludge, pyrolysis gas and pyrolysis oil for co-combustion.

The European Commission's Institute for Prospective Technological Studies has published its proposals on the end-of-waste criteria for biodegradable wastes which have been subject to biological treatment processes. From the point of view of the air protection it has to be clearly stated that the fulfilment of these criteria does not mean that the product can be considered as biomass fuel. Based on our experimental findings and trends in the area of co-combustion of waste, it was necessary to conduct a theoretical environmental analysis of current cases of possibilities and conditions for co-combustion of sewage sludge, pyrolysis gas and pyrolysis oil. This analysis is based on environmental principles and legislation for air protection.

2. Variants on the energetic use of sewage sludge

The recovery of sewage sludge by its application into the soil is required as production is increasing, but it remains problematic. Thus, energetic use is an alternative under the condition of reducing the humidity of sewage sludge (Fytili and Zabaniotou, 2008). Utilisation of sewage sludge as an energy source is from the economic point of view an attractive option for energy producers and sludge producers, because it represents a new trend of sludge utilisation. The waste composition and emission diversity by year to year and location to location makes the technology selection more complicated (Fodor and Klemeš, 2011). It is necessary to develop an objective model for evaluation of emissions from co-combustion of composted sewage sludge and products of pyrolysis of wastes (Hroncová et al., 2016).

There exist many technical alternatives to reduce the humidity of sewage sludge as well as technology for energy generation (Mathioudakis et al., 2009; Werle and Wilk, 2010; Werther and Ogada, 1999; Winkler et al., 2013). The reduction in the humidity of sewage sludge can be achieved in three ways of drying which are acceptable in terms of energy consumption:

- Drying using waste heat or solar energy.
- Biodrying, de facto partial composting.
- Long-time drying of the sewage sludge in the air.

Standard technical solutions for sewage sludge drying are available in many different alternatives. Waste heat recovery and solar drying represent the best solution if there are suitable conditions for the implementation of these drying techniques. Another alternative method of reducing the humidity of sewage sludge is biodrying: short-term industrial composting aimed at fuel preparation (R&D Technical Report P1-311/TR, 2002; Winkler et al., 2013). The third alternative for reducing the humidity of sewage sludge by long-term drying in the open air is rather problematic due to the smell. Its implementation means the placement of sewage sludge in thin layers on large areas far away from houses.

The term "thermal disposal" in connection with sewage sludge refers to the incineration in mono-incineration plants (including gasification installations), and to co-combustion in coal fired power plants and cement plants, and in certain waste incineration facilities. Moreover, the search for alternative sewage sludge treatment methods has intensified in recent years (Wiechmann et al., 2013).

One of the latest alternatives is the economically interesting co-combustion of composted sewage sludge with wood and other biomass in biomass boilers. The question is whether the replacement of co-incineration by co-combustion is acceptable from the point of view of the environmental aspects, the protection of the air and of human health, too (Pikoń and Kokot, 2009; Shimizu and Toyono, 2007; Werther, 2007).

Sewage sludge can be co-incinerated at both coal and lignite fired power plants (Stelmach and Wasielewski, 2008; Werther and Ogada, 1999). The main combustion methods currently used are dust and fluidized bed combustion. As a rule, only stabilized (i.e. digested) sewage sludge is incinerated. As it is technically feasible to combust both dried and dewatered sewage sludge, most co-combustion power plants currently combust dewatered sewage sludge with total solids ranging from 25 to 35% dry residue. Some power plants in Germany only incinerate fully dried sewage sludge, while others burn this type of sludge in a mixture (Wiechmann et al., 2013). For most power plants, a sewage sludge content ranging to up to five per cent of fuel mass has proven to be a viable solution.

It is not possible to uniquely decide that the use of sewage sludge as a fuel without further measures will not lead to overall adverse environmental or human health impacts. Especially, research emission from co-combustion of sewage sludge with coal brings new insights and offers new solutions (Murakami et al., 2009; Werther, 2007). Classic combustion of sewage sludge is well-known and controllable, but because of the emissions of nitrogen oxides, heavy metals, and other harmful compounds, it raises many questions and social objections and requires large investments for the purification of flue gases (Werle and Wilk, 2010).

3. Material and methods

It is known that peaking power plant must immediately respond to variable demand for electricity. Therefore, only that

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