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The evaluation of heat production using municipal biomass co-incineration within a thermal power plant

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A B S T R A C T

Wastewater treatment plants provide two final products, purified water and waste in the forms of liquid and solid phases. Municipal biomass from wastewater treatment plants represents a rising problem since its disposal is prohibited by a European environmental directive. Currently the more popular are municipal biomass combustion and co-combustion in power plants or waste incineration plants, because the dry municipal biomass has similar calorific value as brown coal. An addition of up to 5% of municipal biomass to the system for electricity production from fossil fuels is allowed according to the European Directives and Slovenian legislation. Following these criteria the addition of around 1730 kg/h of municipal biomass with 60% of moisture is allowed in accordance with the reference thermal power plant operational data. This paper presents analyses regarding the usages of different amounts of municipal biomass in the reference thermal power plant for which process simulation is done using the Aspen Plus programme package. Furthermore, the analysis of hazardous metals such as Pb, Hg and Cd concentrations in flue gases are determined and the economic evaluation of municipal biomass exploitation within the thermal power plant is also presented.

1. Introduction

Wastes are environmental and economic features, and during the formation process are generally sources of pollution. At the same time it is possible and necessary to process and use them for beneficial purposes, for example for electricity production, while its consumption is increasing. That is why different opportunities for electricity and more efficient heat production are searched [1–4], and on the other side, researchers are looking for different opportunities for environmental protection and decreasing the emissions of greenhouse gases [5–9].

The wastes are designated as fundamental environmental problems [10–12]. The increasing amount of waste [13], its negative influence on the environment, and the development of ecological conciseness accelerate changes in the field of waste treatment, and the results can be seen through legislation and the development of acceptable waste treatment operations. Common trends within the waste treatment area lead to the development of systems for waste recovery and to technologies for its collection, transformation, and removal.

In Slovenia, as throughout Europe, the amounts of different types of municipal waste are increasing. The increasing amounts of municipal biomass from wastewater treatment plants is one of the greater problems and due to this fact a lot of research is being done on developing alternative ways of municipal biomass handling.

The waste handling technologies follow three basic rules – Reduce, Reuse, and Recycle. This is why the main goal is to decrease the amount of produced municipal biomass. This can be achieved using microbe colonies with smaller increments and bigger conversion potentials. The processed sludge can be used again or within anaerobic digestion systems or with the process of dehydrated sludge co-combustion for energy and electricity production [14].

2. Legislation for energetic and mass usages of municipal biomass

The Directive on waste deposition introduces novel obligations regarding the characteristics of depositing municipal biomass on

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landfills [15]. Biological technologies are alternative ways of waste treatment to thermal methods all over Europe. At the same time, without using thermal treatment any novel demand for waste depositing can't be achieved.

Two different principles regarding biological treatment are recommended due to the legislation and due to the directive on waste depositing:

- anaerobic stabilisation of municipal biomass after classification, using biogas and anaerobic fermentation,
- aerobic biological stabilisation.

Products of both treatments have to fulfil the conditions for waste depositing on landfills for non-hazardous communal waste, and that is why thermal treatment is also necessary. The thermal process is the only process where the following gaols can be achieved:

- smaller volume and mass decrease (up to 90% of volume decrease, and 60–75% of mass decrease) to ensure smaller depositing places,
- complete decomposition of organic material, also resulting in the disinfection of municipal biomass,
- minimising residue amounts regarding organic carbon,
- possibilities of using produced heat and for electricity production.

The Directive on waste treatment is the basic document that regulates waste areas in Slovenia. This directive is complemented by two additional groups of regulations: the first group includes a regulation for the treatment of specific waste types (waste oil, packaging, batteries, etc.), whilst the second group regulate permits and the conditions of waste treatment plants including combustion, deposition, mechanical and biological waste treatment, etc.

3. Co-combustion of municipal biomass

The raw municipal biomass is composed of water and solid material. The solid material contains organic and inorganic compounds. The solid material ratio varies due to the ratio of the water, and has the greatest impact on the selection of suitable combustion methods. Due to the fact that the water content has to be reduced by 70%, the usage of both mechanical and thermal processes is necessary [16].

The water content influences the heating value of the municipal biomass, which is one of the more important parameters from the standpoint of suitability regarding municipal biomass usage for co-combustion. The heating value varies from 7 to 20 MJ/kg (dry material), and it strongly depends on the dry material content.

Co-combustion is an oxidation process at temperatures above 850 °C and it ensures:

- completing the decomposition of pathogenic microorganisms and the elimination of foul odour,
- decomposing and separating of micro pollutants,
- decreasing of the waste amount,
- controlling of emissions into the air,
- decreasing the municipal biomass volume to 15% of the initial volume.

Except for the combustible materials including carbon, hydrogen, oxygen, sulphur, nitrogen and chlorine compounds, the municipal biomass also contains a variety of other compounds including problematic hazardous metals and some organic impurities that can influence on efficiency of the co-combustion. The selection of a suitable unit for the co-combustion of raw municipal biomass highly depends on its composition and water content.

4. Process simulation

The simulation of the co-combustion process of municipal biomass within thermal power plant is done using the AspenPlus software package. Two thermodynamic models are used for process simulation. The main section, consisting of a combustion unit, preheat train, and mill dryer is simulated using Peng-Robinson model [17], while the STEAM model is used in turbine system section. The Peng Robinson method is suitable for gas processing, and coal and biomass gasification, meaning that its usages in these processes is reasonable [18]. Furthermore, the STEAM-TA model is suitable for processes or part of the overall process, where only steam and water are present [18].

The simplified process scheme is represented in Fig. 1. Several data and parameters, including ultimate and proximate analysis, heating values, and particle size distribution, are needed in order to simulate the process [19–21]. The more important information, for both coal and municipal biomass, is collated in Table 1.

The co-combustion process starts with mill drying, where a mixture of coal and biomass is milled and then dried to a proper moisture content (approximately three percent of moisture remains in the dried biomass). Hot drying gas is used in order to remove the appropriate amount of moisture. It is generated by mixing the flue gas from the top of the combustion unit (with temperature about 875 °C), flue gas from the bottom of the combustion unit (temperature about 290 °C), and a certain amount of fresh air. The portion of each component is chosen in such way as to obtain the drying gas temperature from 450 to 500 °C. The drying gas is in this case also used as conveyance-gas. The milled mixture of coal and municipal biomass, with temperature of approximately 210 °C, is further conveyed to a combustion unit in order to produce steam. The outlet mill dryer temperature varies with the increment of the biomass content. A more moisture is present in the biomass, the process of moisture removal requires more energy, meaning that the outlet temperature decreases as the biomass content increases. It is also assumed that the temperature difference between drying gas and drying material is approximately 10 °C at the outlet of the dryer.

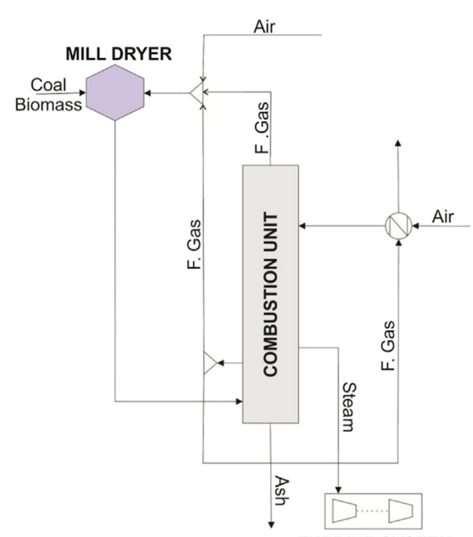

Fig. 1. Co-combustion process scheme.