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THE RISKS IN THE USE OF BIOGAS AND BIOMASS IN PLANTS FOR GENERATING HEAT AND ELECTRICITY

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Abstract: The use of biomass in the world is significant not only in terms of immediate solving of the problem of the lack of energy and its high prices, but also in terms of solving the problem of environment protection. Biogas is especially convenient when it comes to using biomass as a renewable energy source. Biogas digesters use degradable organic matter, from which two useful products, fermented biogas and fertilizer can be obtained. The paper analyzes the data of the combustion products of a cogeneration biogas plant and of a boiler plant for generating thermal energy. The analysis showed thatduring the use of biomass containing lignin, the products of combustion and thermal decomposition release benzenes, which are dangerous substances for human health. In case of thermal decomposition of biogas, combustion products are significantly less dangerous for human health.
Keywords: biomass, biogas, renewable energy, risk, preventive measures.

1. INTRODUCTION

Alternative energy sources represent energy resources that can be compensated by natural processes and can be used indefinitely provided that their consumption does not exceed the capacity of their renewal. They consist of inexhaustible resources such as solar energy, geothermal energy, wind energy, hydropower, energy of sea water moving and renewable sources such as biomass and nuclear fusion. Non-renewable energy sources exist only in limited quantities on Earth; as all material in the form of non-renewable energy sources will eventually be expended, a replacement must be found for them.

Deterioration of the environment is the world's leading problem today, which requires finding of alternative sources of energy that would not have a major impact on environmental degradation [1,2]. Considering the deficit of conventional energy sources (oil and gas), the EU has reached an agreement to increase the use of the share of energy from renewable sources from 14 to 20%, striving, up to the year 2020, to reduce the total emissions by 12% compared to the year 1990 [2,3,4]. For that reason renewable energy sources are placed at the center of its development policy. A common feature of all renewable and alternative technologies includes relatively high initial investment, as well as their low operating cost. Based on the analysis of the technological cycle, it seems that their overall price is more favorable. As the renewable energy potential is huge, their continued technological advancement and application should be a priority for economic development in the Republic of Serbia as well. Renewable energy sources such as biomass gain increasing attention from governments, investors and consumers. The Government of the Republic of Serbia has set its own objective that 12% of total energy consumption must come from renewable sources by the year 2015 [3,4]. The energy potential of biomass is estimated to be at about three million tons in the crop farming, and in orchards and vineyards around 1.1 million tons. The potential of this energy from forestry is not negligible either, because the national plan provides that 31.5 percent of Serbia's territory is to be covered by forests within s two-year period [4,5]. These facts point to the importance of the renewable energy sources, especially biomass and biogas. However, how much and in which way biomass and biogas as renewable energy sources is used, should primarily depend on the information about their energy efficiency and conditions of their safe use. The formation of biogas from organic substances and the use of methane for energy purposes have been known for a long time. In recent

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past, agricultural biogas facilities were proportionally simple, with the power of less than 100 kW. These facilities based their work on the application and adaptation of existing procedures, manipulation of slurry, and the practical experiences of farms that had biogas facilities. During the last 15 − 20 years, and especially since greater importance was awarded to fermentation, technically sophisticated facilities have been developed, with higher power classes [6].

Biogas digesters use degradable substances during fermentation, from which two useful products are obtained - fermented biogas and bio fertilizer. Biogas, purified to a level of purity for the gas pipeline, is called renewable natural gas and can be used in any application where otherwise natural gas is used, which includes its distribution via pipeline to generate electricity, heating, water heating and use in various technological processes. Biogas is a high quality fuel that can replace fossil fuels. At the time when fossil fuel reserves are declining, energy costs are rising and the environment is endangered by improper disposal of waste, finding solutions to the problems of biological waste and treatment of waste organic matter, biogas production becomes an action of utmost importance, especially as the development of techniques enabled the construction of highly efficient facilities for energy production [6,7]. This paper presents a comparative analysis of biodegradation and the products of combustion of biogas in the facilities for electricity and heat generation as well as the analysis of the facilities that generate only heat by biomass combustion. The aim is to draw attention to the security aspects of the exploitation of biogas as well as the exploitation of biomass in the process of its combustion, and for generating thermal and electrical energy.

2. BIOMASS AND BIOGAS

Biomass is a renewable energy source that can be used to produce electricity and heat. According to its source, biomass can be classified into wood, nonwood and animal waste. The concept of biogas implies gas created in anaerobic fermenters and controlled conditions, i.e. in a biogas plant. The use of anaerobic treatments represents the creation of fast waste cycles, based on the principles of circulation of substances in nature.

2.1. Biomass

The composition of the biomass cell wall changes with the type of the plant, but, generally speaking, 40−45% of the mass of woody plants is made of cellulose, hemicelluloses 25-35%, 15-30% lignin while the other compounds are represented with up to 10%. The connections between the various components of woody plant mass can be hydrogen and covalent (ether, ester, glycoside). Lignin is a highly crosslinked polyphenol polymer, of molecular weight, with the degree of polymerization of more than 10000, and whose structural unit is not repeated properly and is one of the most complex aromatic organic polymer in nature. Lignin fraction of biomass is an important source of benzene, phenol and dihydroxybenzene during combustion. Of the main components of biomass, lignin presents the biggest difficulty in understanding the relationship between the structure and the mechanism of production of gaseous products during typical thermo chemical conversion processes. This feature is caused by the complexity of its structure and problems related to its isolation from the original material, and thereby not to disturb its natural structure. In any case, the combustion of lignin causes a potential hazard to human health, primarily due to the release of benzene, which is identified as a potential carcinogenic substance [8,9].

Polysaccharide components of plant cell walls are highly hydrophilic, and therefore water permeable, while lignin is more hydrophobic. Lignin is one of the slowest decomposing dead vegetation components and is the dominant source of material for the formation of humus, due to its own degradation [8]. Humic acids are the main representatives of humic substances, which are the main organic constituents of soil (humus), peat and coal [9]. From dead plants to metamorphic rocks (anthracite), it is necessary to go through the residence in the mud swamp, where anaerobic digestion happens followed by separation of volatile substances, to a permanent „breakthrough“ further into the depths of the Earth, accompanied by increasing pressure and temperature, with permanent lack of oxygen and further separation of water and volatile substances, thus increasing the degree of polymerization and the carbon content [9]. So in the case of anaerobic fermentation, it comes to the release of biogas and humic acids, which are in further degradation processes translated into a very useful humus fertilizer. Table 1 shows the lignocelluloses composition of different plant species [9].

2.2. Biogas

Biogas is formed by microbiological processes in anaerobic conditions (without oxygen). Anaerobic bacteria break down organic matter, and as a product of this process biogas is produced, as well as heat and the residue of fermentation. The process of anaerobic digestion (fermentation) is widespread in nature, wherever there are anaerobic conditions and anaerobic bacteria species. Examples are the sludge in the marshes, the seabed and the ocean, the rumen of ruminants, and the process is partially taken place during storage of manure [6,7]. Biogas is a mixture of gases, whose volume comprises about two-thirds of methane (CH_4) and one-third of carbon dioxide (CO_2). In addition to methane and carbon dioxide, the volume of biogas is constituted of other gases in a much smaller share, and an overview is given in Table 2 [5]. Volumetric shares are presented in ranges, and depend on the raw material (substrate) and the conditions in which biogas is formed.

Table 1. Content of lignocelluloses components in different plant species

Lignocelluloses material	Cellulose (%)	Hemicelluloses (%)	Lignin (%)
Grasses	25-40	35-50	10-30
Deciduous tree trunk	40-55	24-40	18-25
Coniferous tree trunk	45-50	25-35	25-35
Nutshell	25-30	25-30	30-40
Corncob	45	35	15
Foliage	15-20	80-85	0
Paper	85-99	0	0-15
Newsprint paper	40-55	25-40	18-30

Table 2. Composition of biogas

Ingredient	Chemical symbol	Volume fraction (%)
Methane	CH_4	50-75
Carbon dioxide	CO_2	25-45
Water vapor	H_2O	2-7
Nitrogen	O_2	< 2
Oxygen	N_2	< 2
Ammonia	NH_3	< 1
Hydrogen	H_2	< 1
Hydrogen sulfide	H_2S	20-20.000 ppm

Since poplar contains a lignin component (Table 3) it is highly possible that benzene is released during its thermal degradation. By analyzing the data obtained by gas chromatography, it was determined that during pyrolysis and combustion of poplar wood dust, only benzene from all BTEX compounds was formed. This result is in accordance with our previous results [11]. Since the presence of benzene was found in the products of thermal degradation (0.75 mg/m^3 during pyrolysis - incomplete combustion and 0.55 mg/m^3 during total combustion), it is interesting to compare these results with maximally allowed concentrations.

According to the British Standard MDHS, the limit value for short-term exposure at workplace is 3.25 mg/m3 (WEL). According to the American Standard OSHA, the allowed limit value for exposure to benzene PEL is 3.19 mg/m3. From the obtained results it can be noticed that the concentration of benzene is significantly lower than the limit value for short-term exposure to benzene. However, the fact that the process of combustion, especially in the pyrolysis process, releases a certain amount of benzene, suggests a possibility that in the case of small and enclosed spaces, an intensive combustion process can exceed the allowable limit (Table 4).

Table 3. Results obtained during combustion of poplar wood dust

Combustion	Sample 1	Sample 2	Sample 3
Total moisture content (%)	6.23	6.23	6.23
Volume of sampled air (l)	16.5	16.5	16.1
Maximal temperature of sample (^oC)	576	403	455
Maximal temperature of glow (^oC)	466	338	369
Mass of benzene per kilo of sample (mg/kg)	1.72	1.86	1.80
Average concentration of benzene in sampled volume of air (mg/m^3)	0.52	0.56	0.56

Table 4. The results obtained during pyrolysis of poplar wood dust

Pyrolysis	Sample 1	Sample 2	Sample 3
Total moisture content (%)	6.23	6.23	6.23
Volume of sampled air (l)	12.6	11.7	11.2
Maximal temperature of glow (^oC)	390	398	480
Mass of benzene per kilo of sample (mg/kg)	1.88	1.73	1.75
Average concentration of benzene in sampled volume of air (mg/m^3)	0.74	0.74	0.78

5. CONCLUSIONS

In this paper the security aspects of using biomass and biogas in plants for generation electrical and thermal energy are shown. In order to determine security aspects of using biogas and biomass, we especially underlined the analysis of the products of combustion of biogas in the plant to generate electricity and heat and analysis of the plant which generates only heat from the combustion of biomass.

Regarding environmental protection, the production of biogas has shown to reduce vapors of manure and other harmful biodegradable waste and that from sugar beet, fruit, vegetable processing, milk processing, production of ethanol, ethyl alcohol, etc., so that instead of disposal to the city dump this waste is thermally processed and purified in a biogas plant and returned to the ground as useful compost.

In this regard, this paper deals with some of the identified dangers and health hazards for employees during the management and maintenance of biogas plants regardless of the required technical measures that, with the very design of the equipment, have been already implemented on the equipment to work. Dangers and health hazards for employees are constantly present.

In case of biomass combustion, the importance of the presence of lignin is especially observed, the contents of which is in the range 25-30%. Combustion of lignin causes a potential hazard to human health, primarily due to the release of benzene, which is labeled as a potential carcinogenic substance.

The paper especially addressed the results of BTEX compounds in the process of pyrolysis and combustion of sawdust of poplar. The results of quantitative analyses of BTEX compounds in the process of pyrolysis and combustion sawdust of poplar showed the presence of benzene at a concentration of 0.75 mg/m^3 for pyrolysis and 0.55 mg/m^3 for combustion sawdust of poplar, which is below the permissible limit of short-term exposure of 3.25 mg/m^3.

6. REFERENCES

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РИЗИЦИ ПРИ КОРИШЋЕЊУ БИОГАСА И БИОМАСЕ У ПОСТРОЈЕЊИМА ЗА ГЕНЕРИСАЊЕ ТОПЛОТНЕ И ЕЛЕКТРИЧНЕ ЕНЕРГИЈЕ

Сажетак: Коришћење биомасе у свету има значај, не само за тренутно решавање проблема мањка енергије и њене високе цене, већ и за решавање проблема заштите животне средине. Посебну погодност у коришћењу биомасе као обновљивог извора енергије даје биогас. Биогасни дигестори користе разградљиве органске материје, од којих се добијају два корисна производа, биогас и ферментисано ђубриво. У раду је дата упоредна анализа продуката сагоревања једног коогенеративног постројења на биогас и једног котловског постројења за генерисање топлотне енергије. Анализа је показала да при коришћењу биомасе која садржи лигнин, у производима сагоревања и термичке разградње ослобођавају се бензени, који представљају опасне по људско здравље супстанце. У случају термичке декомпозиције биогаса, продукти сагоревања су значајно мање опасни по људско здравље.

Кључне речи: биомаса, биогас, обновљиви извори енергије, ризик, превентивне мере.