UNWANTED SOLID DEPOSITION ACCOMPANYING BIOGAS COMBUSTION IN BIOGAS-TO-ENERGY PLANTS IN HUNGARY

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Hungarian energy systems are supported by a mix of primary energy sources including fossil fuels (coal, oil, natural gas), nuclear power and renewables (biomass, solar, wind, biogas, hydro, geothermal). According to the Hungarian Energy and Public Utility Regulatory Authority (ALFÖLDI *et al*., 2019), Hungary has high energy import dependency, which was twice as much as the total primary energy production (458 PJ) in the year 2019, and most of the energy consumption (60%) was dominated by hydrocarbons (natural gas and oil products). The share of renewables within the electricity consumption in 2019 is only 9.72%. Not just in Hungary, but all around the world the renewable sources cannot yet fully replace the fossil fuels. With no doubt renewable energy would be the future of energy systems in fighting the climate change and its adverse effects to our environment, the question is just how the renewables can support current energy systems?

We are working with one of the renewables, biogas that is produced as a result of waste management, namely urban waste landfill (UWL) and wastewater treatment (WWTP). Biogas is produced through anaerobic digestion of organic-rich waste, it fuels cogeneration technology (Combined Heat and Power Systems, CHPs) to produce both heat and electricity (ISA *et al*., 2018). The electricity and heat produced is used to support the operation of the plants and the excess can be sold to the local grid. In this way, the energy produced promotes the self-sustainability of waste industry.

The main technological challenge in the biogas-to-energy industry is the solid deposition on the gas engine reaching thickness over the mm range, deteriorating engine working conditions and increasing maintenance needs. Moreover, the deposits formed in different parts of engine can get into the lubricating oil, decreasing its lifespan and increasing the oil consumption of the system. Ideally, in the combustion process CH_4 content of the biogas is converted to CO_2 and water, however, in reality, trace contaminants like H_2S and siloxanes are also involved in the oxidation process. High-temperature and constantly changing pressure conditions of the internal-combustion engines, with special flow dynamics lead to the formation of both glassy (short-range-order only; SRO) and crystalline phases.

We sampled solid engine deposits from biogas-to-energy facilities at two UWL and three WWTP sites, including the largest facilities serving the capital, Budapest, of 1.7 million population. The deposits formed multilayer crust on the piston crown and cylinder head surfaces. Physically, the crusts at the UWL are harder, resistant, and hard to remove from the surface compared to WWTP. The deposits varied in colour from whitish, greyish to brownish, some burnt parts are black. Some of the exhaust valves from the UWL are broken indicating advanced state engine failure, too.

In the UWL combustion chambers deposition of crystalline phases (anhydrite – $Ca[SO_4]$; cristobalite & quartz – SiO_2 polymorphs) beside the dominant Ca-silicate glass could be observed. The combustion chambers at the WWTP only suffered from calcium sulfate deposition, anhydrite. These findings suggest that either siloxanes are properly removed or are present in much smaller amounts at WWTP. Inside the heat exchanger compartment at WWTP the exhaust gas deposited formed large amounts of hydronium-jarosite $(H_3O)Fe_3(SO_4)_2(OH)_6^{trig}$. It shows that H_2S, converted to SO_3 during combustion, is not fully deposited as anhydrite and some escaping with the exhaust gas leads to the corrosion of Fe-bearing parts of the engines.

To develop a strategical approach in green technology development, it is important to have a proper characterization of forming deposits during biogas combustion and to understand their formation conditions and transport inside the engine, from initial input biogas and final output exhaust gas.

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