How does presence of microplastics impact on biogas production?

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Abstract The aim of this study was to evaluate the inhibition on the biogas production caused by microplastics (MPs). Wastewater treatment plants (WWTPs) are receptors of MP. After wastewater treating, more than 90% of MP could be retained in the sludge. Anaerobic digestion of the excess sludge can help reduce its volume and operating costs of WWTPs, due to CH_4 production. Analysis with OxiTop control system could help to follow anaerobic degradation process to evaluate impact of MP on biogas production with slightly modified standard procedure by adding MP. Comparison of pressures gain of samples with added MP to control sample could determine the impact of added MP on biogas production and give the ratio of methane and carbon dioxide in biogas. Presence of MP mainly negatively affected biogas and CH_4 production. Polyamide (PA) had shown the most negative affect and reached even up to 19% less of total biogas produced, while its presence decreased CH_4 yield for up to 10% at 2.38 g L^{-1}. Polyacryl inhibited CH_4 yield up to 15% at even the lowest added concentration 0.05 g L^{-1}.

Keywords: anaerobic digestion, biogas, microplastics, wastewater

1. Introduction

Microplastics (MPs) is insoluble, solid particle, that is as anthropogenic micropollutant found in oceans, lakes, rivers, wastewaters as also in air and practically everywhere in the environment. Mainly, particles smaller than 5 mm are classified as MP and particles smaller than 1 µm as nanoplastics (NP) (Blair et al., 2019). One of main sources of MPs are wastewater treatment plants (WWTPs) that importantly contribute to releasing of MP in the environment (Kang et al., 2018). MP reach WWTPs through household wastewater or rainwater and could by the effluent continue its uncontrolled path into the environment (Ngo et al., 2019).

Removal efficiency of MP from WWTPs has shown, that efficiency depends on the type of WWTP (Sun et al.,2019). It could reach up to 99.9% (Talvitie et al., 2017; Carr et al., 2016). MP particles are partly removed in the phase of primary treatment, but the highest amount of MP remain in the sludge during secondary treatment (Sun et al., 2019; Corradini et al., 2019). Figure 1 shows removal efficiency of MP after each treating phase in WWTP. Since the most MP is retained in the sludge, it is important to understand how MP impact sludge treatment processes. Among them, anaerobic digestion is one of the most promising and common processes of waste sludge stabilisation, where anaerobic microorganisms digest organic matter and forms biogas that mainly consists of CH_4 and CO_2 and could be furtherly used to produce energy. It is highly efficient method for reducing sludge volume, unpleasant odor and presence of pathogen microorganisms (Cheng et al., 2013; Ma et al., 2018; Zhang et al., 2020). Microorganisms in this process could be inhibited by several substances. The inhibition of anaerobic microorganisms is usually determined by modified standard procedure (SIST EN ISO 11734:1999), OxiTop® method, where biogas production is measured.

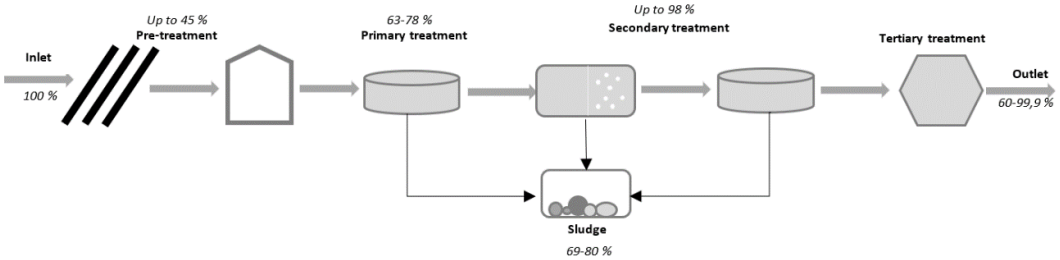

Figure 1. Removal efficiency of microplastics in wastewater treatment plant.

2. Materials and Methods

OxiTop® method was used to follow anaerobic degradation processes to evaluate biogas production in terms of increased pressure (hPa). Steps of method are shown on Figure 2. Production of biogas was measured at 37 °C for 8 days. Glass bottles were filled with mixture of anaerobic sludge (c = 1.5 g_{TSS} L^{-1}), glucose as easily biodegradable substrate (c = 0.833 mol L^{-1}), buffer solution for maintaining constant pH and MP in different concentrations, ranging from 0.05 to 2.38 g L^{-1}. Particles, size between 0,5 and 3 mm, of polyethylene terephthalate (PET), polypropylene (PP) and fibers of polyester (PES), PA and Polyacryl were added. Simultaneously a control sample with anaerobic sludge and glucose without added MP were running to determine the impact of added MP on biogas production. After 7 days NaOH (6.0 M) was added to remove formed CO_2. Biogas production was measured as pressure increase (hPa) vs. time (days). It was attributed to formation of prevailing biogas components: CH_4 and CO_2. From difference in pressure after adding NaOH, the ratio of CH_4 and CO_2 was calculated.

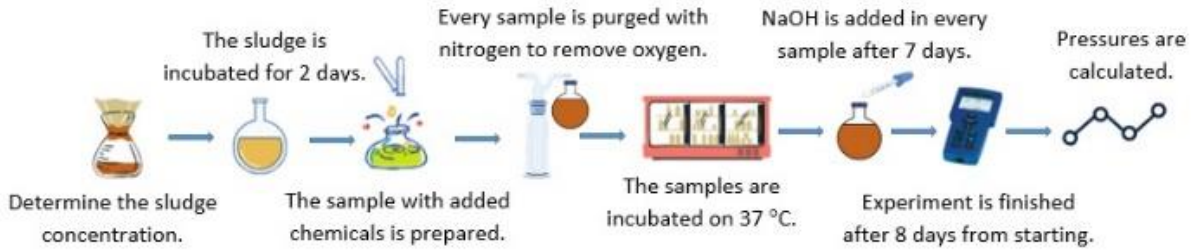

Figure 2: Steps of OxiTop® method to follow anaerobic degradation process.

3. Results and Discussion

Presence of MPs mainly decrease biogas production (Figure 3). PA at higher added concentration of 2.38 g L^{-1}, reduced biogas formation for up to 19%. PES and PET inhibited biogas formation at concentration of 1 g L^{-1} for up to 17% and at higher concentration of 2.38 g L^{-1} inhibition reduced and it reached inhibition up to 12%. Presence of MP also mainly inhibited CH_4 yield (Figure 4).

Lower concentrations (0.05 g L^{-1} and 0.5 g L^{-}) of PES and PP slightly promoted CH_4 production, while at higher concentrations, 1–2.38 g L^{-1}, inhibition of CH_4 yield was shown. PET, PA and Polyacryl inhibited CH_4 yield in all investigated concentrations, where Polyacryl at concentration 0.05 g L^{-1} had shown the highest inhibition on CH_4 production and reached up to 15%. Inhibition of biogas production in the presence of MPs was explained as a consequence of a release of different compounds adsorbed on the surface of the MPs or compounds added in the material during production (monomers, additives, colorants, stabilisers, Etc).

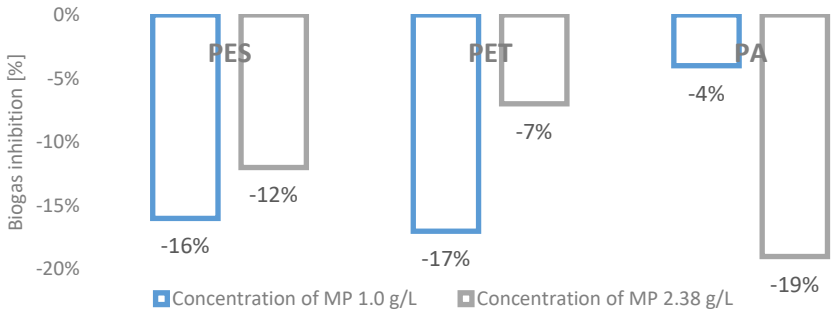

Figure 3: Inhibition of biogas production at investigated concentrations of different types of microplastics.

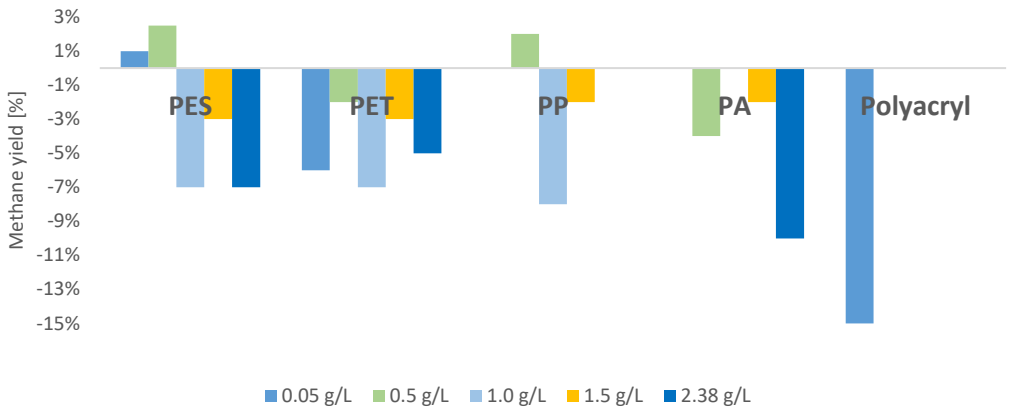

Figure 4: CH_4 yield at investigated concentrations of different types of microplastics.

4. Conclusion

The inhibition on the biogas production caused by microplastics (MPs) was evaluated. MP inhibited biogas and methane formation, due to the negative impact of MPs on the anaerobic microorganisms. Polyamide had shown the most negative affect leading up to 19% less of total biogas produced, while its presence decreased CH_4 yield for up to 10% at investigated concentrations. Polyacryl inhibited CH_4 yield up to 15%. Inhibition could be a consequence of toxic substances, adsorbed on the surface of MPs particles and released into the medium during anaerobic digestion. One of the possible sources of inhibitory compounds are also constituents of the MPs. Further work will be focused on ozonation of MPs contained sludge as one of the possible pretreatment option to improve biogas production.

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