Anaerobic digestion of high strength bilgewater with granular sludge: confronting salinity and investigating biomass adaptation

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Introduction

Wastewater occurring from the bilges of ships is the primary liquid pollutant produced onboard. Bilgewater can be briefly defined as saline and greasy wastewater with a high COD (> 3-15 g COD L^{-1}) that includes lubricating oil, cleaning diesel oil, oily sludge, spills from the engine room, water leaks from internal pipes, and seawater filtrations (Camarillo and Stringfellow, 2018). According to the International Maritime Organization (IMO) regulations (MARPOL 73/78) and the European directive 2000/59/EC, discharge of oil residue to marine environments is prohibited. Chemical or physical processes such as flotation, separation by centrifuge, filtration, ozonation and coagulation are the most common methods for treating bilge water and are usually applied onshore but can also be found onboard (Camarillo and Stringfellow, 2018). Noteworthy, physicochemical processes contribute substantially to operational cost, and therefore other alternatives are of great demand for companies dealing with bilge water treatment (Ahmadun et al., 2009; Camarillo and Stringfellow, 2018). Referring to biological treatment, anaerobic digestion is not widely used to treat this type of wastewater due to high salinity and recalcitrant organic compounds present in the wastewater (Morgan-Sagastume et al., 2019). This study aimed to study anaerobic digestion with the use of granular sludge and investigate the effect of salinity and adaptation potential of the biomass to enhance methane production and treatment efficiency.

Materials and Methods

Anaerobic experiments were conducted under batch mode following the same experimental set up and using the analytical methods described in a recently published work (Mazioti et al., 2020). Glass serum bottles were used (total volume 125 ml) with a working volume of 70 ml and 55 ml of headspace. Bottles were sealed and O_2 was removed by injecting CO_2. Granular sludge, collected from an industrial reactor treating cheese wastewater, was used at a concentration of 4 % w/v. Real bilge wastewater was used, sampled from a local company (Ecofuel LTD, Cyprus) collecting and treating wastewater from the marine industry. During the experiments, the wastewater characteristics were determined (pH, salinity, COD, BOD_5) as well as the performance of anaerobic digestion (gas composition of the headspace, biogas production, COD removal). For the measurement of gas composition in the headspace, gas chromatography was used (Agilent 7820A system) with a ShinCarbon ST packed column coupled to a thermal conductivity detector with argon as the carrier gas. All experiments were conducted in triplicates and necessary samples were created in order to monitor sludge activity. In preliminary experiments various approaches were used to determine the impact of salinity on the digestion process (dilution of the wastewater with i) tap water and ii) with municipal wastewater) and as a second step the adaptation of the biomass was investigated through consequent experimental cycles using the same biomass but fresh wastewater. The impact of buffer addition ($NaHCO_3$) to facilitate the digestion was also investigated. For the determination of the microbial profile of the granular sludge before and after adaptation (bacteria and archaea), the total genomic DNA was extracted with NucleoSpinDNAstool kit and was forwarded to Novogen for sequencing.

Results

The digestion process was proved faster when the initial salinity (≈30ppt) decreased by at least 40%. The cumulative production of CH_4 after 4 experimental cycles (90 days of total duration) was higher for the bilgewater diluted by 50% with municipal wastewater when normalized to the available COD load. The highest CH_4 percentage recorded in the headspace was 70% and was achieved while treating high strength bilgewater, after 29 days of treatment in the first cycle and after 14 days in the third adaptation cycle. In the fourth adaptation cycle the biogas and CH_4 production importantly declined. The average COD removal for the high strength bilgewater (COD: 9 g L^{-1}, salinity: 30ppt) was up to 50% while for the low strength bilgewater (COD: 4.5 g L^{-1}, salinity: 18ppt) up to 60%, for each experimental cycle (less than 20 days). The BOD_5/COD ratio at the beginning of the experimental cycle was close to 0.3 while at the end of the cycle close to 0.1.

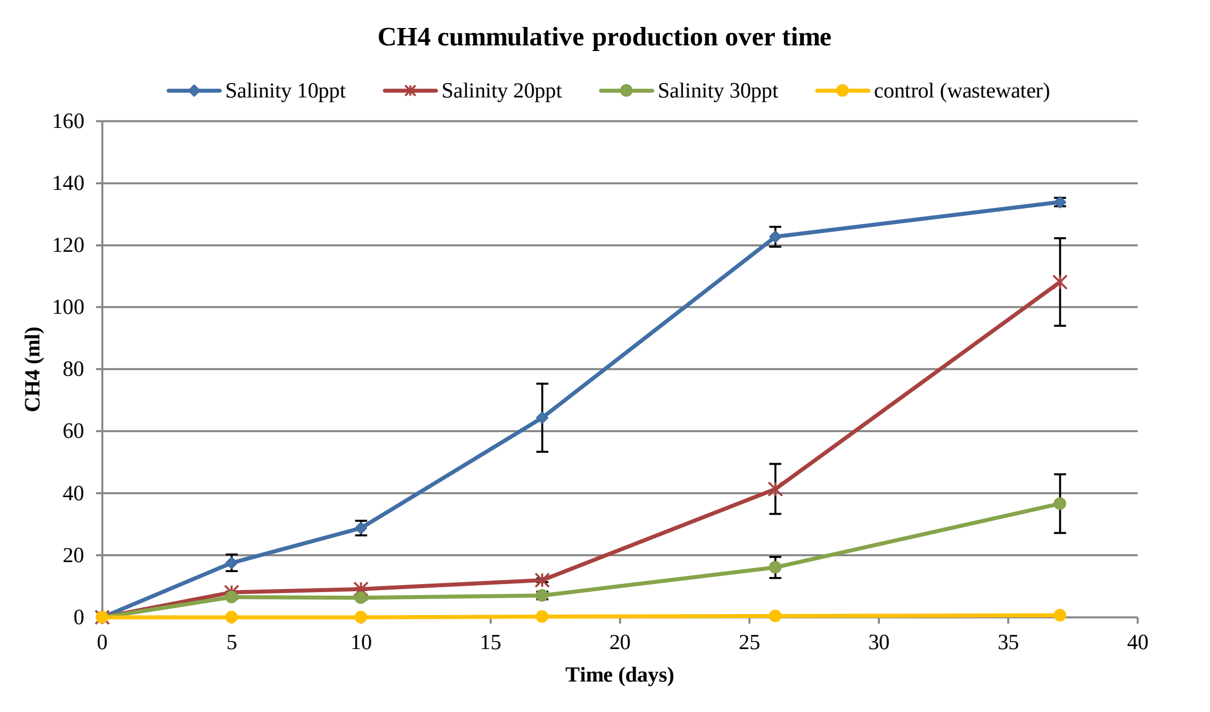

Figure 1: Cumulative production of methane over time, at three salinity levels (10, 20, 30 ppt) and with the same initial COD (≈5.000 mg L^{-1}).

In the initial granular sludge bacteria *Proteobacteria Syntrophobacter* and *Nitrosococcaceae* were highly present but over the acclimatization time *Firmicutes Peptococcaceae* and *Thermotogae Oceanotoga* presented important growth. *Archaea Methanosaeta* importantly developed over the acclimatization time (from 4% to 23%). The observed microbial diversity was compared to the community recorded in a recently published study (Mazioti et al., 2021).

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