Anaerobic Digestion of Synthetic Wastewater Dedicated for a Biochemical Waste Conversion System for Outer Space Exploration

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ABSTRACT

NASA has aimed to send humans to Mars within a decade which has prioritized R&D needs to support life on the Red Planet. The goal of treating H_2O-based wastes while producing value-added products is the main target of a biochemical waste conversion system (BIOSYS) that is being developed at the Energy Institute of Louisiana at UL Lafayette. This research aims to produce technology that has an excellent waste treatment efficiency, reasonable payload, low energy use, and ideally, can recycle generated waste into useful products to sustain life on Mars. The waste management system can treat waste not only generated in outer space as well as solve waste treatment problems here on earth. This system is designed to be both energy- and oxygen-use neutral and is capable of meeting treatment goals while producing additional life support resources. A key component of this work is the development of a highly efficient anaerobic digestion step to convert the bulk of the wastes into methane and/or hydrogen while removing over 80% of the pollutants from the wastewater stream. Food waste from the university cafeteria along with a synthetic wastewater (SWW) that mimics the wastewater generated in space was seeded (3% v/v) using anaerobic sludge from a wastewater treatment plant and anaerobically digested in a lab-scale anaerobic digester for 144 days to determine conversion efficiencies using standard digestion operational parameters. Pretreatment of the SWW using ultrasound was compared with the SWW without any pretreatments. The biogas produced was composed of 75% (v/v) methane as well as 72% tCOD removal was achieved for both the conditions. Nutrient levels for total ammonia-nitrogen, total nitrogen and total phosphorus were measured and indicated no ammonia inhibition. Use of ultrasound did not show significant improvement on the biogas production nor COD removal compared to the SWW without any pretreatment, nor did it adversely affect the digestion. Future experiments on various pre-treatment methods of SWW have been planned along with additional operational parameters for higher COD removal and biogas production.

OBJECTIVE

The main goals of conducting this research are to reduce chemical oxidation demand (COD) of synthetic wastewater by over 80% and to produce quality yield of biogas with over 75% methane composition. The reduction of COD results in lower total solids after digestion, and the high-quality biogas can be used as an energy source to power camps and transport vehicles on Mars.

METHODOLOGY

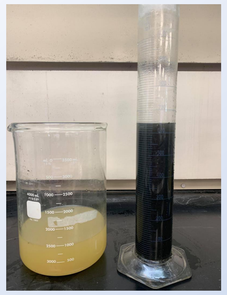

Fig 1. SWW and Sludge obtained from the anaerobic digester

Fig 2. Anaerobic bioreactor attached with Tedlar bags for gas sampling.

Fig 3. Branson Sonifier

Experimental design:

- Initial SWW tCOD- 600-800 mg/L
- Seed 3% v/v (Fig. 1)
- A total of 4 bioreactors with duplicates of 2 experimental conditions (Fig. 4)
- 2 untreated and 2 pretreated SWW
- **Treatment**: Use of ultrasound for 10 minutes at 0.5 W/mL (Fig. 3)

Fig 4. Bioreactor set-up

Reactor Conditions:

- A schedule 80 PVC pipe with a 6” inner diameter and 18” length was used to build the bioreactor
- Total Reactor Volume of 8 L and working Volume- 6.5L
- The digestion temperature was set to 37° C
- Hydraulic Retention Time (HRT) of 10 days
- ORP of -400mV and pH of 6.8-7.2
- Digestion period of 144 days

Parameters of interest:

- Headspace for biogas sampling using Tedlar sampling bags (Fig. 2)
- Biogas composition was obtained using a TCD Gas Chromatogram
- Total and soluble COD, Total Ammonia-Nitrogen, Total Nitrogen, Total Phosphorus using HACH test kits (Fig. 5)

Fig 5. TNT HACH Test kits and spectrophotometer used for analysis of effluent quality.

RESULTS

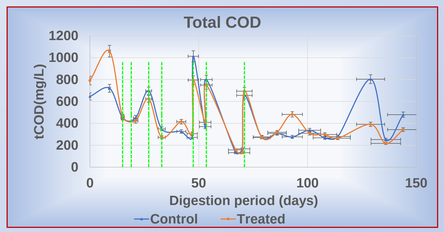

Fig 6. Total COD (Method 10236)

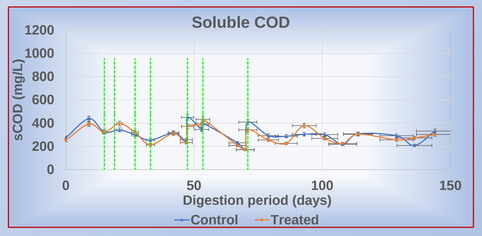

Fig 7. Soluble COD (Method 10236)

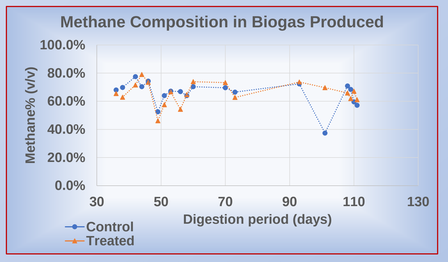

Fig 8. Methane composition in the biogas produced

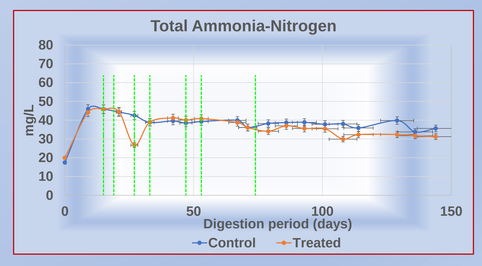

Fig 9. Total Ammonia Nitrogen levels (Salicylate Method 10205)

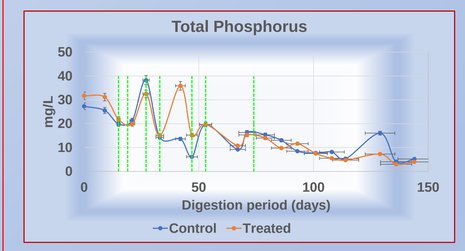

Fig 10. Total Phosphorus levels (Ascorbic Acid Method 10209)

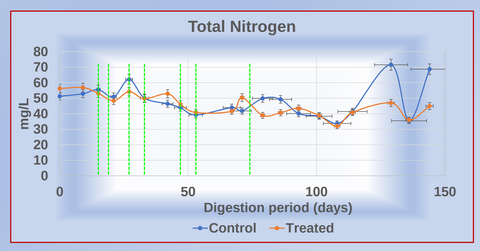

Fig 11. Total Nitrogen Level (Persulfate Digestion Method 10208)

DISCUSSION

- On average, 72% of the total COD level on SWW pretreated with ultrasound and without any pretreatment. (Fig. 6 & 7)
- Similar trend was reported on the methane composition of the biogas produced for both the conditions, with a maximum methane composition of 80% v/v. (Fig. 8)
- The methane composition declined towards the end of digestion which is possibly due to lack of substrate for microorganisms and fewer microorganisms.
- The total ammonia nitrogen level in the digester show no ammonia inhibition (Fig. 9 &11)
- The phosphorus level indicate 86% phosphorus removal towards the end of digestion. (Fig. 10)

CONCLUSION

- Pretreatment using ultrasound reported not significant result compared to the control due to the low strength of the synthetic wastewater compared to the literature which uses high strength wastewater (COD >15,000 mg/L)
- Other methods for the pretreatment of the low strength SWW prior to addition of the inoculum must be done to observe any improvement in the COD removal and increased biogas production compared to the control.

FUTURE WORK

Other pretreatment methods such as chemical and thermal will be applied to the SWW for increased COD and solids removal. Some of the pretreatment methods proven effective for COD removal [6] will be applied in the next research experiment for low loaded SWW are as follows:

- Alkaline pretreatment using NaOH has shown increase in soluble COD and is selected for the low strength SWW.
- Thermal pretreatment of the SWW has also reported in increase of quality biogas production and COD levels.

To achieve effluent COD levels of under 100 mg/L an attached growth reactor will be utilized after anaerobic digestion. The reactor will be packed with filter media which favors the growth of microorganism leading to increase in COD removal. Some of the

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