BIOGAS PRODUCTION POTENTIAL OF THE MICROWAVE, $\text{H}_2\text{O}_2$/MW AND $\text{S}_2\text{O}_8^{2-}$/MW PRETREATED WASTEWATER SLUDGES

Ece Özön, Ayşen Erdinçler

Prof.Dr.Ayşen Erdinçler

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Introduction

- The sewage sludge production increases with gradual growth of human population.

- Sewage sludge production after treatment operations of wastewater in Turkey was 299 ktons (on dry basis) in 2017.

- Expected to reach 911 ktons by year 2040.

- To solve the problem: Sludge stabilization is essential, and anaerobic stabilization of sludges improves the energy efficiency.
Introduction

**Sludge Stabilization and Aneobic Digestion**

- Sludge volume reduction
- Organics and pathogens removals
- Odor problems elimination
- Renewable energy production in terms of biogas and methane
- Lower capital cost
Anaerobic Digestion

**Process Input**
- Energy Crops
- Manure
- Industrial waste
- Source separated organics (SSO)/Municipal Solid Waste (MSW)
- Restaurant/Food Industry Waste
- Wastewater Treatment Plant Sludge

**Anaerobic Digestion**

**Process Output**
- Electricity
- Biogas
- Renewable Fuel
- Biofertilizer
- Reusable water
- Compost

http://www.theecoambassador.com/Biogas.html
Aim of this Study

to investigate the effects of:

- combined hydrogen peroxide/microwave (H₂O₂/MW),
- combined persulfate/MW (S₂O₈²⁻/MW) and
- microwave (MW)

sludge pre-treatment methods on the anaerobic digestion efficiency and the biogas production potential of wastewater sludges.
Materials and Methods
Sewage Sludge (SS)

- from the recirculation line of an advanced biological WWTP in Istanbul
- TS = 13.6 g/L
- VS = 8.4 g/L

Inoculum Sludge

- from the anaerobic digesters of an advanced biological WWTP in Istanbul
- TS = 45 g/L
- VS = 21 g/L
## Sludge Characteristics

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<th>Parameter</th>
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Pre-treatments

- Microwave (MW) Pre-treatment
- Combined Hydrogen Peroxide and MW (H₂O₂/MW) Pre-treatments
- Combined Persulfate and MW (S₂O₈²⁻/MW) Pre-treatments
MW Pre-treatment

- at 160ºC for 15 minutes by using Berghof, MWS-3+ Digestion System
Combined Hydrogen Peroxide and MW (H$_2$O$_2$/MW) Pre-treatments

- Pre-heating stage at 120°C for 15 minutes
- 1 g H$_2$O$_2$ / g TS
- MW treatment at 160°C for 15 minutes (H$_2$O$_2$/MW)
Combined Persulfate and MW (S$_2$O$_8^{2-}$/MW) Pre-treatments

- 1 g S$_2$O$_8^{2-}$/g TS

- MW treatment at 160°C for 15 minutes (S$_2$O$_8^{2-}$/MW)
Steps in Anaerobic Digestion

1. **Phase 1: Hydrolysis**
   - Complex biopolymers (proteins, polysaccharides, fats/oils) are broken down by fermentative bacteria.

2. **Phase 2: Acidogenesis**
   - Broken down monomers and oligomers (sugars, amino acids, peptides) are converted into propionate, butyrate, etc. by fermentative bacteria.

3. **Phase 3: Acetogenesis**
   - Propionate, butyrate, etc. are further broken down into acetate and hydrogen ($H_2$) by fermentative bacteria.

4. **Phase 4: Methanogenesis**
   - Acetate is converted into methane ($CH_4$) and carbon dioxide ($CO_2$) by acetoclastic methanogens. The hydrogen ($H_2$) and carbon dioxide ($CO_2$) are also converted into methane ($CH_4$) and carbon dioxide ($CO_2$) by hydrogen-$H_2$ producing and hydrogen-$H_2$ consuming acetogens.
Preparation of the Reactors

- Serum bottles were flushed with \( \text{N}_2 \) gas.
- 6 parallels for each reactor.
- \( S:I \rightarrow 1:1 \) (VS basis)
- 80 mL active volume.
- Initial pH values = 7-7.2.
- Initial alkalinities = 3000-4500 mg/L as CaCO\(_3\).
- Serum bottles were flushed with \( \text{N}_2 \) gas.
Anaerobic Digestion Period

- Mesophilic conditions at 37°C (in water baths).

- 40 days of digestion period.
BMP Tests

Daily gas productions
- Lutron PM-9107 Electronic Manometer

The biogas compositions
- Agilent HP 6850 Gas Chromatograph (each week)
Results and Discussion
VS Variations

Removal rates in reactors:

- $\text{H}_2\text{O}_2/\text{MW} >> 59\%$
- $\text{S}_2\text{O}_8^{2-}/\text{MW} >> 45\%$
- $\text{MW} >> 42\%$
- Control $>> 24\%$

18-35% increase in VS removal
Removal rates in reactors:

- **MW** >> 58%
- **H₂O₂/MW** >> 55%
- **S₂O₈²⁻/MW** >> 41%
- **Control** >> 18%
Removal rates in reactors:

- MW >> 74%
- $\text{H}_2\text{O}_2$/MW >> 68%
- $\text{S}_2\text{O}_8^{2-}$/MW >> 8%
- Control >> 14%
Cumulative Biogas Production

Cumulative biogas production (mL/day)

Time (day)

Cumulative biogas production (mL)

control  
MW  
S2O82-/MW  
H2O2/MW
Conclusions

- The pre-treatments applied prior to anaerobic digestion speeded up the hydrolysis step and improved the biodegradability of the organics in sludge by increasing their solubility.

- The potential of the biogas and the methane productions at the end of the AD process was enhanced by the applications of microwave and \( \text{H}_2\text{O}_2/\text{MW} \) pre-treatments.

- Biogas yields increased as 52% and 13%.
Conclusions

✓ The residual $\text{H}_2\text{O}_2$ or its byproducts limited the activity of methanogens, and decreased the biogas production and the yield.

✓ The $\text{S}_2\text{O}_8^{2-}$ concentration applied to the sludge samples eliminated the biogas and methane productions by creating an inhibition effect on the survival of the methanogenic bacteria.
THANK YOU!