SEWAGE SLUDGE TREATMENT BY MICROWAVE ENERGY

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ABSTRACT

This work focuses on the effect of microwave energy on sewage sludge. The vary of the chemical oxygen demand (COD), the biochemical oxygen demand (BOD), the biogas production and the moisture content of sewage sludge at different specific microwave power level were investigated. The results showed that the microwave electromagnetic field accelerated during dewatering process and furthermore increased the biogas production and the biodegradability of the sludge.

1. INTRODUCTION

The increasing environmental awareness and regulations have led to the application of improved municipal and industrial water treatment technologies. This has resulted in higher wastewater and sludge production.

The aim of sewage sludge treatment technologies is to reduce the mass it or to modify to be able for further utilization. Nowadays the commonly used methods for sludge treatment are digestioning, dewatering, incinerating or using in agriculture. It is well known, that the thermal processes give an improvement in the dewaterability of sledges (Wojciechowska, 2005). Taking into consideration, that the conventional thermal conditioning and drying are very time-consuming processes, one of the advantages of microwave treatment is short processing time.

The principle of heat transfer by microwave energy is based on the effect of electromagnetic field on molecules by ionic conduction and dipole rotation. Conduction is based on the migration of solvent ions in microwave field. The polar molecules, as water, absorb the microwave energy because of its permanent dipole momentum (Gabriel et al., 1998). The application of microwave energy in waste water treatment is very promising, because of the rapid internal heating and its selective heating effect: the cell walls of the died and alive microorganisms in sludge are destroyed organic substances due to the heat effect (Országh, Gyarmati, 2003). There are many living and died microorganisms and other cellular component in sludges. The microwave heating differently affects the different component of cell wall, because of their dielectric properties. This effect called selective heating. Hence the different heating mechanisms the cell wall are destroyed, the cells are opening and the cell fluid content of cell are releasing. During the intensive microwave heating the odorous compounds of sludge e.g. volatible fatty acids were reduced too (Neyens, Baeyens, 2003). Besides selective heating, the overheating in „hótspot" also have a strong destructive effect. The dissolved organic compounds evolved from cell fluid improve the efficiency of biological degradation processes. These experiences are similar to earlier results (Jones et al., 2002).

The municipal sewage sludge contains organic and mineral components; it is rich not only in the organic carbon, but also in hazardous heavy metals and the pathogen microorganisms as well. The sewage sludge generally contains carbohydrates, lipids and proteins. The carbohydrates and the lipids of sludge are easily degradable by microorganisms, while the proteins normally less accessible for biological degradation. The biogas product increase after a thermal pre-treating too. (Neyens, Baeyens, 2003).

The biodegradability was given by the BOD_5/COD ratio:

$$BD_5\% = \frac{BOD_5}{COD} \times 100\%, \qquad [1]$$

where COD is the chemical oxygen demand, the quantity of oxygen required oxidation by chemical oxidant, BOD_5 is the biochemical oxygen demand, the quantity of oxygen consumed by aerobic micoorganisms during the decomposition of organic matters for 5 days.

In this work the effect of microwave energy on biodegradability, drying rate and biogas production of sewage sludge was investigated.

2. MATERIALS AND METHODS

Putrefected communal sewage sludge was used from municipal sewage sludge system for our experiments. The microwave treatments have been carried out in a single mode cavity resonator, at 2,45 GHz frequency. The power of magnetron is changeable continuously 100-700 W by toroidal-core transformer. Our experiments continuous 700W power level was used, with different sample quantity. The wet sludge was put into the cavity resonator in a poly-tetrafluor-ethylen (PTFE) vessel. The temperature of samples was measured by infrared (IR) thermometer.

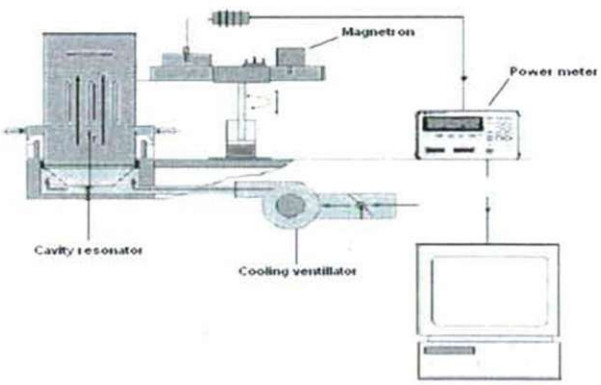

Fig. 1.: The scheme of microwave equipment

The moisture content of the sludge was determined by drying at 105 °C for 24 h. The COD and BOD_5 was measured by Secomam Pastel UV equipment (Secomam, France) by applying the manufacturer's calibration for waste water. The biogas production within a 30 day period was measured by anaerobic fermentation process with methanogen bacteria at 30 °C. The methanogen bacteria culture was selected in University of Szeged, Department of Biotechnology.

3. RESULTS AND DISCUSSION

In the first series of experiments the dewatering efficiency of microwave drying was investigated. The mass of the treated sludge changed between 20-150 g, the microwave power level was continuosly 700W.

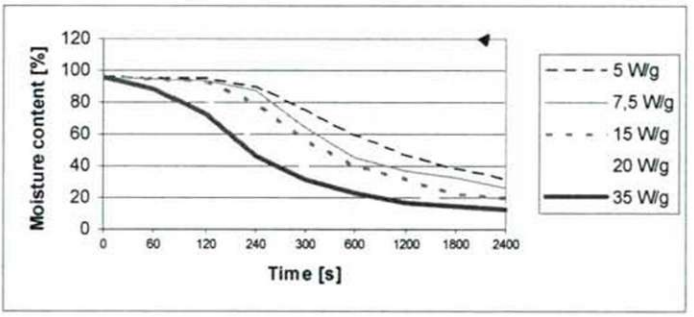

Fig. 2.: Drying curves of dewatering sewage sludge process by microwave treatments of different quantity of sludge samples at 700 W microwave power

It was observed, that the water can be rapidly removed by microwave heating. After 40 minutes treatment it reduced to 20-35 % depending on the specific power level.

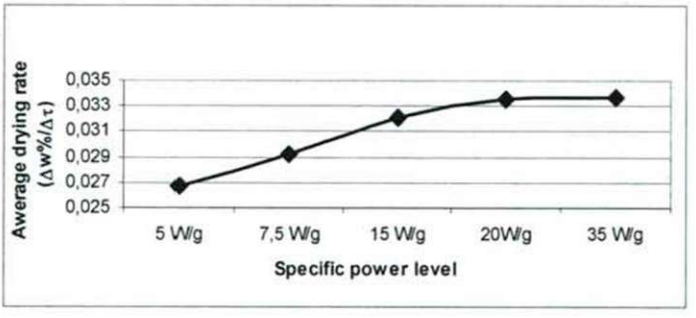

Fig. 3.: Influence of applied specific microwave power on drying rate

The average drying rate increased about linear by the added microwave power between 5 W/g and 20 W/g specific power level. Over 20 W/g the curve has a saturation point *(Fig. 3.)*.

In the next series of experiments the treated samples were diluted back to their original mass to ensure the accurate biodegradability values and the data could be comparing to the original data.

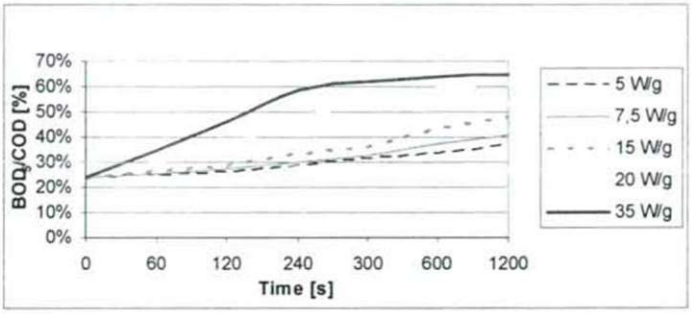

Fig. 4.: Influence of microwave treatments on biodegradability

It was found, that biodegradability was increased with increasing specific microwave power. After 20 minutes at least 50% enhancement of biodegradability was observed, but over 20 W/g specific microwave power the biodegradability increased about 300%.

In an other series of experiments the changes of biogas production of the sludge were examined, just to measured the energy balance. The microwave treatment time was 15 min.

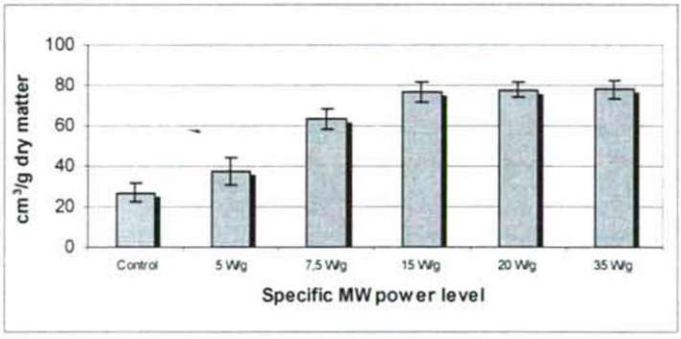

Fig. 5.: The biogas production after 30 days fermentation of microwave treated sludge samples

It was found, that the biogas production increased with increased the specific microwave power. The biogas production was increased up to 70 cm^3 biogas/g dry matter in the case of 15 W/g sample, the pre-treating. Enhancing specific microwave power over 15 W/g the biogas production trends to a saturation value.

To calculate the Net Energy Product (NEP) we introduce an Equation [2] since the calculation of energy balance is essential for the applicability of the method. Considering, that the produced biogas contains average 70% CH_4, the net energy product (NEP) can be calculated by the equation:

$$\mathbf{NEP} = \mathbf{q}_{\mathbf{comb}} \times \mathbf{m}_{\mathbf{sludge}} - \mathbf{P}_{\mathbf{m}} \times \tau \qquad [2]$$

where the, q_{comb} the combustion heated, m_{sludge} the mass of the treated sludge, P_m the power of MW magnetron, τ the time of treatment.

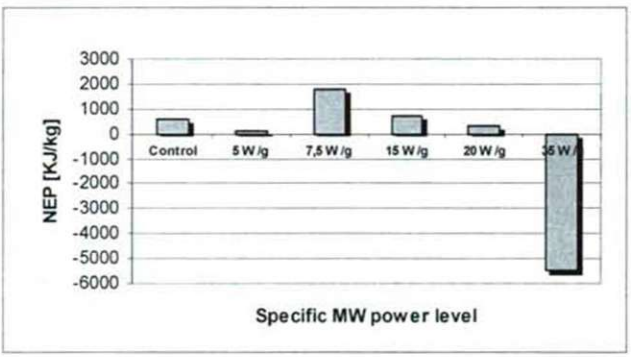

Fig. 6.: The net energy product by anaerobic fermentation

Our calculations based on Eq 2. show (Fig. 6.), that there is optimal specific microwave power levels which produces positive energy balance. It means that the microwave pre-treatment not only enhances the biogas production, but this may profitable too.

4. CONCLUSION

Application of microwave energy accelerated the dewatering process of sewage sludge. Furthermore the normally less degradable components become accessible for biological degradation, hence the biodegradability and the biogas product of anaerobic fermentation increased. If appropriate treatment parameters are chosen the microwave method accelerates sewage sludge management and the energy utilization can be optimalized as well.

5. ACKNOWLEDGEMENTS

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