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EXAMINATION OF THE EFFECT OF MICROWAVE HEATING ON THE BIODEGRADABLE AND SOLUBLE FRACTION OF ORGANIC MATTER OF SLUDGE

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Abstract

Because of the high industrial wastewater output the quantity of sludge has been increased. The efficiency of biological sludge handling process was limited by the non-soluble and non-degradable component. Among sludge handling processes the thermal treatments are known as more utilizable methods because of pathogen destruction and digestion effect. In the case of microwave treatment the biodegradability is increased. In our work the effect of microwave irradiation on biodegradability and anaerobic digestionability of dairy originated sewage sludge was investigated. our results showed that microwave pretreatment is appropriate to enhance solubility of organic compounds thus the biodegradability and biogas product increased.

Keywords:

sludge, microwave pre-treatment, solubility, biodegradability, biogas

1. INTRODUCTION

The drinking water supply has been turned into the most urgent problem for assuring healthy human being in the world. A large scale development was experienced in the drinking water and waste water management technology and hereby the cleaning efficiency could be in a large measure improved, but simultaneously the quantity and the environmental risk of emitted sewage sludge increased. Generally, the solid phase of waste water is named sewage sludge.

Depending on the processed raw material the sludge may be rich in carbohydrates, lipids or proteins. In most cases the sludge handling system has been become the bottleneck of capacity of waste water treatment plants. The most common alternatives of sewage sludge handling are landfill, cropland application, incineration and in the last resort conditioned dumping as hazardous waste.

Waste management has become an acute problem in many countries. Management options require extensive waste characterization since many of them may contain compounds deleterious for the ecosystem, such as heavy metals, organic micropollutants and other persistent and less biodegradable compound. Beside the general characterization and testing of waste sludge the digestion and biodegradability testing give more utilizable information for planning of composting and biogas producing. The main structure of municipal and food industrial sewage sludge consists of extracellular polymeric substance (polysaccharides, proteins, lipids, nucleic acids), multivalent cations, other organic and inorganic matter and microbial cells which compose a special flock structure [1]. This agglomerated complex flock structure is resistance to a direct anaerobic degradation since cell walls and polymeric conformation present physical and chemical barriers for microbial and enzymatic degradation.

Extracellular polymeric substance are present in varying quantities in sewage sludge, occurring as highly hydrated capsule surrounding the cell wall and loose in solution as slimy polymers and it is able to retain a large volume of water within the sludge matrix by electrostatic interactions and hydrogen bounds. The non-biodegradable polymeric structure does not only originate from cell autolysis and sludge bacterial cell but also originates from the compounds of raw wastewater. So besides the cationic content of dosed chemical and organic content, the efficiency and specific removal capacity of applied waste water treatment technology (chemical, biological or combined) have effect on biodegradability of sludge [2].

There are many possibilities to improve the digestibility and aerobical biodegradability of sludge. Mechanical, thermal, ultrasound, chemical, thermo-chemical and enzymatic pre-treatment methods can enhance the extent and the rate of biological degradation [3, 4]. It is verified the thermal pretreatments improve pathogen destruction and dewaterability process of sludge, too [5].

Microwave heating is used as a popular alternative to conventional heating mainly due to considerable reaction time reducing effect. The microwave equipment generally uses 2450 MHz

frequency with a 12,24 cm operating wavelength. The microwave magnetron with 900 MHz operating frequency is used for industrial scale heating and drying of solid and low water content matter on the ground of larger penetration ability. Applications of microwave-assisted techniques in many fields of analytical methods, such as sample drying, moisture measurements and extraction processes are used [6]. The microwave irradiation has thermal and athermal effect. The thermal effect can be attributed heat generation in the matter due to rotation of dipole molecules or ionic conduction. Ionic conduction is the electrophoretic migration of ions when an electromagnetic field is applied. Dipole rotation means realignment of dipoles with the applied fields, for example at 2450 MHz the dipoles align and randomized $4{,}9\times10^{9}$ times per second and this forced molecular motion results heat. In many applications these two mechanisms have been applied simultaneously. Due to high water content the sewage sludge can absorb microwave energy efficiency. Although the quantum energy of microwave radiation is too low ($1{,}05\times10^{-5}$ eV) to break the chemical bounds but some structures can be altered by the energies carried by microwaves. For example the athermal effect of microwave radiation is caused by polarized parts of macromolecules, it results breakage of hydrogen bound. The intensive microwave heat generation and the different dielectric properties of compounds of cell wall lead to a rapid disruption of extracellular polymer network and residue cells of sludge [7, 8]. However the cell liquor and extracellular organic matter within polymeric network can release into the soluble phase, hereby increase the ratio of accessible and biodegradable component [9, 10].

2. MATERIALS AND METHODS

The sewage sludge was originated from a industrial waste water treatment plant of a local dairy works (Sole-Mizo Ltd., Szeged, Hungary). In the case of dairy industrial sewage sludge a phyico-chemical waste water technology was applied and the final water content of sludge was 58,2 w/w%.

The microwave pre-treatments were performed in a self-developed monomode microwave treating and measuring unit, at 2,45 GHz frequency, at 50 to 700 W microwave power. The microwave irradiation time was 10 to 40 minutes. The applied specific microwave power level was 1, 2 and 5 W/g, which was adjusted by the ratio of magnetron power and the quantity of treated sludge. The sludge samples were placed invariably in 2 cm layer because of penetration depth of microwave radiation. Poly-tetrafluor-ethylene (PTFE) vessels were used on account of efficient microwave penetration and absorption. Cover was applied to prevent the evaporation during the irradiation. The surface temperature of sludge an Infracam (FLIR InfraCAM-SD, Sweden) was determined after microwave irradiation

As comparing method convective heat-treatments were performed. The convective heat-treatment was performed in automatic temperature controlled laboratory heater equipment (Medline CM 307, UK) at 95 °C.

The value of biodegradability (BD) is commonly characterized by the BOD/COD ratio. COD is the chemical oxygen demand; the quantity of oxygen required oxidation by chemical oxidant. The soluble COD (sCOD) indicate the water soluble part of COD. BOD is the biochemical oxygen demand, the quantity of oxygen consumed by aerobic microorganisms due to carbonaceous oxidation at a standard temperature (20°C).

COD was measured according to the dichromate standard method in COD test tubes with an ET 108 digester and a Lovibond PC Checkit photometer. Before sCOD determination the samples were centrifuged for 20 minutes at 6000 RCF. The separation of water soluble phase a 0,45 μm pore size disc filter (Millipore) was used. The biochemical oxygen demand measurements were carried out in a respirometric BOD meter (BOD Oxidirect, Lovibond, Germany), at 20°C. To ensure the consistency of the results BOD microbe capsules (Cole Parmer, USA) were used for measurements. Biodegradability during 5 days (BD_5%) was characterized by the (1) expression:

$$BD_5\% = \frac{BOD_5}{COD} \times 100\% \quad (1)$$

The anaerobic degradability batch mesophilic biochemical methane potential (BMP) tests are used with applying of acclimated inoculums of methanogenic bacteria at mesophilic temperature range (25-45 °C). By our measurements the cumulative biogas production tests were performed in batch mode under mesophilic conditions, at 40°C for 30 day, in a temperature controlled anaerobic digester with Oxitop Control type pressure mode measuring system (WTW Gmbh, Germany). The digesters were inoculated with an acclimated anaerobic sludge from a biogas reactor of municipal wastewater treatment plant (Hódmezővásárhely, Hungary) in order to eliminate the possible lag-phase of biological degradation process. After inoculation nitrogen gas was flowed through the reactor to prevent exposure to air.

3. RESULTS AND DISCUSSION

The surface temperature of samples was measured by infracam, and the average temperature and standard deviation were represented in the following table.

Table 1: The surface temperature of microwave irradiated sludge after treatments

MW Power level	Surface temperature [°C]			
	10 min.	20 min.	30 min.	40 min.
1 W/g	75,7 ± 2,9	83,5 ± 1,8	89,2 ± 1,6	90,2 ± 1,3
2 W/g	79,3 ± 2,2	86,7 ± 1,4	89,6 ± 1,1	91,7 ± 0,7
5 W/g	83,6 ± 0,8	89,1 ± 0,9	90,8 ± 0,3	92,8 ± 0,4

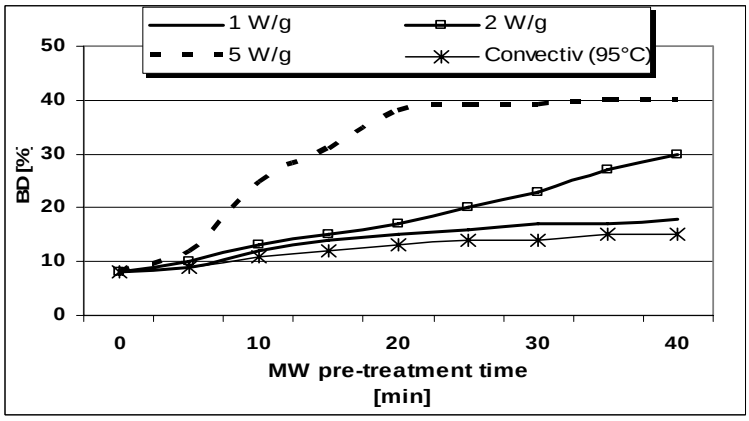

Fig. 1. Biodegradability (BD%) of dairy sewage sludge after microwave and convective pre-treatments

In the first series of our experiments the effect of microwave irradiation on biodegradability of sewage sludge was investigated at different specific microwave power level. Besides the specific power level the effect of irradiation time was studied too. It was found that without pre-treatment the dairy industrial sludge was less biodegradable because the biodegradability of untreated dairy sludge was 8%.

The biodegradability of dairy sewage sludge was 8% and however it was find that without pre-treatment the sludge was in a large measur resistant to aerobical biological degradation. The structure of dairy sludge, formed by interaction of extracellular polymeric substance and applied chemicals, caused less accesible property for biological decomposation.

Microwave irradiation at low power level (1 W/g) had slightly effect on biodegradability, but the higher microwave power level and enhanced irradiataion time seemed to be more efficiently. By higher applied power level (5-10 W/g) a saturation value of biodegradability was observed. The ratio of biodegradable component of dairy originated sludge was enhanced from 8 % to 40 % after 30 minutes microwave irradiation at 5 and 10 W/g (Fig. 1).

The following measurements the effect of microwave irradiation on solubility of organic matter content of dairy originated sewage sludge were examined. The water-solubilization of organic component was characterized by the ratio of soluble COD (sCOD) and total COD.

It was found that the microwave pre-treatment could increase the quantity of water-soluble part of organic matter. Similar to biodegradability in the case of solubility of organic matter content saturation values were observed at 5 and 10 W/g specific microwave treatment level, but the differences in values of solubilisation were more considerable (from 10% to 50%) than values of biodegradability (Fig. 2). But the efficiency of increased microwave power level was slighter than the difference by biodegradability. Enhancing of biodegradability may be linked to solubilization of organic matter which was indicated by the increased sCOD/COD ratio.

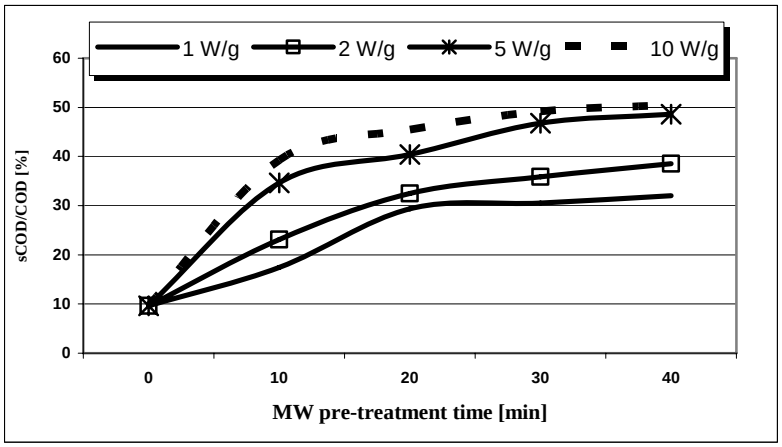

Fig. 2. The effect of microwave pre-treatments on solubilization (sCOD/COD ratio) of organic matter content of sludge

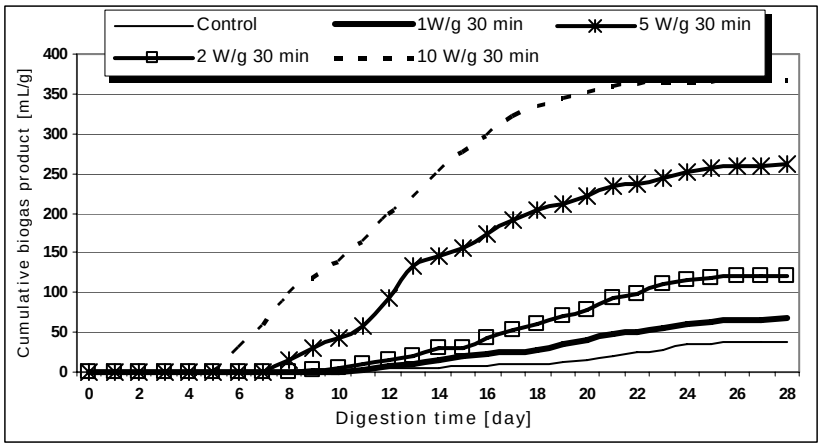

Fig. 3. Cumulative biogas product of microwave pre-treated sludge

Besides the change of biodegradability and solubilization the effect of microwave irradiation on anaerobic digestion was investigated also. The digestionability was characterized by cumultive biogas production. Similar to aerobical biodegradation the microwave pre-treatment improved the efficiency of the anaerobical decomposation. The untreated control sample had a small (40 cm^3/g) biogas production, and after a pre-treatment at 2 W/g for 30 minutes enhanced the methane product up to 120 cm^3/g and by 10 W/g microwave treatment the biogas product could reach the 350 cm^3/g value. The applied microwave treatment could decreased the lag-phase period of anaerobic digestioning process. The higher specific microwave power caused higher increasing in biogas production and however higher decreasing could have measured in period of lag-phase. Increasing power level of microwave treatment from 5 to 10 W/g caused a great enhancing in biogas product but not in the solubilization or aerobic biodegradability (Fig. 2, 3).

4. CONCLUSION

Our results showed that the microwave irradiation is successfully adjustable and utilizable technique in sewage sludge handling. Applying of microwave pre-treatment the solubility of organic matter content increased and it enhance more efficiently the aerobical biodegradability and biogas yield than the convective heat pre-treatments.

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