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INCREASING THE SOLUBLE ORGANIC MATTER CONTENT AND BIOGAS PRODUCT OF SEWAGE SLUDGE BY MICROWAVE PRETREATMENT

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Objective

A large scale development was experienced in the last few decades in the 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. The sewage sludge is the residue of the primary, secondary or tertiary wastewater management technologies. However sludge represents the major solid waste from biological and physico-chemical waste water treatment processes.

The main structure of sludge consists of an extracellular polymeric substance (EPS), other organic and inorganic matter and microbial cells which agglomerated together and formed a special type of flock structure. In the case of biological originated sewage sludge the cohesive force are greater than mineral flock, in consequence of bridging by negatively charged EPS and multivalent cations such as Ca^{2+} and Fe^{3+}. The polymeric structure originate from the compounds of raw wastewater, cell autolysis and sludge bacterial cell and the cationic content of dosed chemical. This complex flock structure of sludge is resistance to a direct aerobic or anaerobic degradation since cell walls of microorganisms and the polymeric conformation present physical and chemical barriers for microbial and enzymatic degradation. EPS is present in varying quantities in different sewage sludge often occurring as a highly hydrated capsule surrounding the cell wall of microorganisms and loose in solution as slime polymers [1].

The commonly used methods for sludge treatment are digestion, agricultural using, composting or dumping. Before following utilization sludge has to be stabilized in order to decrease environmental risk. The thermal treatments are the most commonly used process to sludge stabilization. The heat pretreatments improve pathogen destruction and dewaterability of sludge, modify the structure of sludge and transform a part of suspended organic solids into soluble compounds [2]. Result of thermal hydrolysis of macromolecules amino acids, volatile acids and simple sugars are produced, so a considerable increasing of chemical oxygen demand (COD) can be experienced in the water soluble phase [3]. Anaerobic digestion is a common way to stabilize the organic matter of sludge and this biological process has not negligible benefit, production of biogas, which is a renewable energy source.

The microwave radiation is an alternative technique for sludge treatment. Due to high water content the sewage sludge can absorb microwave energy efficiency. Because of rapid internal heating and selective heating effects, the cell walls of both dead and living microorganisms in sludge are destroyed. In consequence of non-thermal effect of microwave radiation polarizing of macromolecules could be experienced, it results breakage of hydrogen bound [4]. Therefore the microwave irradiated microbial cell shows greater damage than convective heating cells to a similar temperature. 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 [5]. However the cell liquor and extracellular organic matter within polymeric network can release into the soluble phase [5]. Hereby increase the ratio of accessible and biodegradable component and the biogas yield [6] [7].

Methods and Materials

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 after a pre-squeezing the final average water content of sludge was 58,2 w/w%.

The chemical oxygen demand (COD) was measured before and after the treatments, by the dichromate standard method, in COD tests with an ET 108 digester and a PC Checkit photometer (Lovibond, Germany). In order to determination of water soluble organic matter content before COD measurement the samples were centrifuged for 20 minutes at 6000 RCF, and the separation of water soluble phase a 0,45 μm pore size disc filter (Millipore) was used. The original chemical oxygen demand of the sludge was 398,6 kg m^{-3}.

The biochemical oxygen demand (BOD) measurements were carried out in a respirometric BOD meter (BOD Oxydirect, Lovibond, Germany), at 20 °C. To ensure the consistency of the results, standard "BOD Seed" aerobic microbe capsules (Cole Parmer, USA) were used in the measurements. The aerobic biodegradability during 5 days (BD_5%) was calculated the following equation

$$BD_5\%=(BOD_5/COD)\times 100$$

where BOD_5 is the biochemical oxygen demand (oxygen consumption) during 5 day

The microwave treatment was performed in a Labotron 500 professional microwave equipment (Buchner-Guyer AG, Switzerland) at 2,45 GHz frequency. The microwave irradiation time was 10 to 40 minutes. The applied specific microwave power level was 1, 2, 5 and 10 W/g, which was adjusted by the ratio of magnetron power and the quantity of treated sludge.

Biogas production tests were performed triplicated in batch mode under mesophilic conditions, at 30°C for 30 day, in an anaerobic laboratory digester with a pressure measuring head (Oxitop Control AN12 measurement system, WTW Gmbh, Germany). The capacity of digesters was 1000 mL, the volume of diluted sample was 200 mL, the dry content of sludge was adjusted to 6 % with sterile water. The digester was inoculated with acclimated sludge from a biogas reactor of a municipal wastewater treatment plant (Hódmezővásárhely, Hungary) in order to eliminate the possible lag-phase of anaerobic biological degradation process. For methane determination, measurements were performed in parallel in two vessels: one of them contained a CO_2 absorber, while the other measured the total biogas pressure. In addition the accurate composition of the biogas produces was measured by gas chromatographic and mass spectrometric method (Agilent 6890N-5976 GC-MS).

Results and discussion

In the first series of our experiments the effect of microwave irradiation on solublity of organic matter content of dairy originated sludge was determined.

The microwave treatments could enhance more efficiently the quantity of water soluble organic matter than conventional heat treatment at 95°C. In the case of high specific power levels (5 and 10 W/g) increasing was approximately quintuple and after 30 minutes treatments saturation values were observed (Fig. 1). This effect can be explained by the degradation of extracellular polymeric network and disruption of cell wall of dead and alive microorganisms.

By the following measurements the effect of microwave irradiation on biodegradability was examined at different specific microwave power level. The biodegradability of untreated dairy originated sewage sludge was 7%. The structure

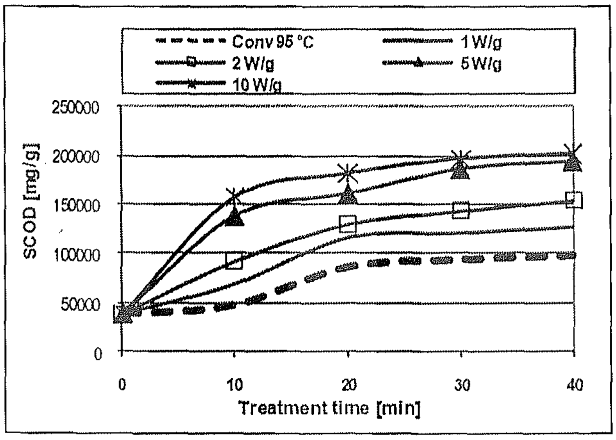

Figure 1 The changes of solubility of organic matter content after microwave and convectional treatments

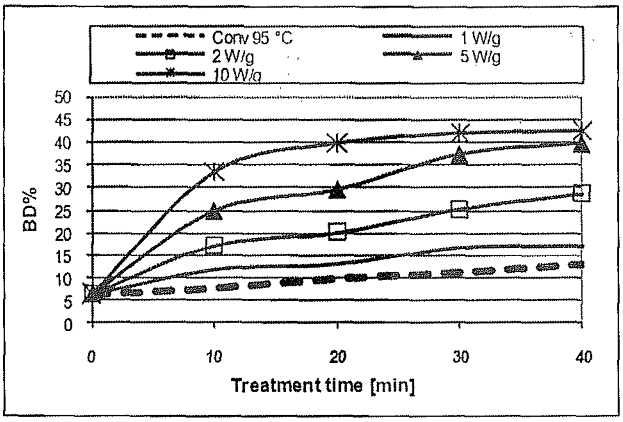

Figure 2 The effect of microwave pretreatments on biodegradability (BD%)

of sludge, formed by interaction of extracellular polymeric substance and residual chemicals, caused less accesible property for biological decomposation.

Microwave treatments at low power level (1 W/g) had small effect on the ratio of biodegradable and total organic matter, but the higher microwave power level and enhanced irradiataion time seemed to be more efficiently. Similarly to solubility of organic matter content the convecive treatment at 95°C caused increasing in biodegradability, but this effect was less effective than pre-treatment at lowest microwave power level. (Fig. 2). At highest applied power level (10 W/g) a saturation value of biodegradability was observed.

Enhancing of biodegradability may be linked to solubilization of organic matter which was indicated by the increased sCOD/COD ratio. In order to examine the effect of solubility on biological decomposation the biodegradability was plotted against the ratio of soluble and total organic matter content (Fig. 3.). The water-solubilization of organic component was characterized by the ratio of soluble COD (SCOD) and total COD.

In the case of studied microwave pretreatment a linear connection was observed between the solubilzation and the change of biodegradability. Because of thermal and athermal effect of microwave radiation the structure of sludge modified and the increased solubility of organic matter made sludge more accessible for microbial degradation.

Beside the change of solubility and biodegradability, the effect of microwave irradiation on anaerobic digestion was investigated. The digestionability was characterized by cumulative specific methane production during 30 days fermentation period.

Similar to aerobical biodegradation the microwave pretreatment could improve the performance of anaerobical digestioning and the increased irradiation time enhanced the biogas- and methane

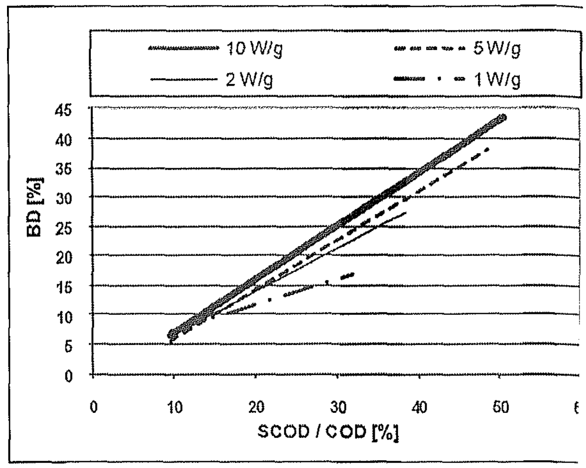

Figure 3 Connection between solubility and biodegradabilit

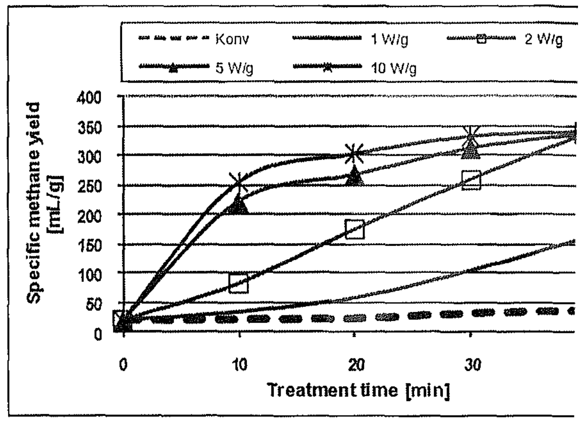

Figure 4 Specific methane yield after microwave pretreatme

production of pre-treated sewage sludge related to control non-treated control sample had a small methane productio mL), but the microwave pretreatment improved the anaerc decomposation efficiency and therefore after 40 mi treatment at 10 W/g power level the specific methane could be enhanced to 340 mL/g. The higher specific micro power caused a higher increasing in biogas productior however higher decreasing in period of lag-phase of dige. But after 40 minutes pretreatment there was no signific difference between the effect of 2, 5 and 10 W/g specific p levels (Fig. 4). By short time pretreatments the increasi microwave power level from 2 to 5 W/g caused a enhancing in methane product. In the case of methane pr was smaller difference between the effects of 5 and 10 treatment than in the case of aerobic biodegradability.

Conclusion

Our work focused on the effect of the microwave pretreat on the solubilization of organic matter, aerobic biodegrad and biogas product of sewage sludge. Our results showe the microwave irradiation could be an efficiently proc sewage sludge handling. It was observed, that orig resistant sludge after a microwave pretreatment became degradable. By applying of microwave radiation the sol of organic matter content increased and therefore the aer biodegradability and biogas product enhanced.

Acknowledgement

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