

## MICROWAVE PRE-TREATMENT FOR ENHANCING OF BIOGAS PRODUCT AND BIODEGRADABILITY OF FOOD INDUSTRIAL SEWAGE SLUDGE

### MIKROTALASI KAO PREDTRETMAN RADI POVEĆANJA PROIZVODNJE BIOGASA I BIORAZGRADIVOSTI OTPADNOG TALOGA IZ PREHRAMBENE INDUSTRIJE

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#### SUMMARY

*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. Nowadays requires of biomass based energy sources have led to the utilization of organic content of sludge for biogas producing. The controlled biological degradation of organic matters is limited by toxically matter and persistent chemical from waste water treatment technology, and however many kind of organic compound is less biodegradable. One of the possibilities of enhancing biodegradability is to transform the organic compounds into more water soluble forms by different type of pre-treatments. Our work focused on the microwave pre-treatment of food industrial sewage sludge. The aerobic biodegradability, changing of ratio of soluble organic compounds and the biogas production of the microwave pre-treated municipal and food-industrial sewage sludge were examined. 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 therefore the aerobic biodegradability enhanced and the biogas production of sludge increased also.*

**Key words:** sewage sludge, microwave pre-treatment, biogas, biodegradability.

#### INTRODUCTION

Sludge is the semi-solid residual of municipal and industrial waste water treatment processes. The sedimentable part of untreated wastewater is known as raw sludge and the residual of biological wastewater treatment is refereed as activated sludge. Fortunately, a large scale technical development of wastewater cleaning technologies was experienced in the last years, but this development has gone hand in hand with a large scale increasing of sludge production. Because of the large amount of sewage sludge the cost of the wastewater treatment process significantly has continuously raised and represents significant technical and economical challenges. In most cases the sludge handling system has been become the bottleneck of capacity of waste water treatment plants.

The municipal and food industrial sludge contains large amount organic compounds. Because of high organic and mineral matter sludge is suitable for soil conditioning and fertilizing. But there are hazardous compounds in many kind of sludge which limit the agricultural using. In many cases sludge is handled as hazardous waste on account of toxically heavy metals or pathogen microorganisms contents. Handling of this waste is difficult, and gives rise to some collateral, secondary environmental pollution often. So the amount and the environmental risk of sludge have growing whereas the disposal routes are reduced. In many instances the ocean dumping and incineration processes are mentioned the best solution of sludge problem. But in these processes the utilizable organic matter of sludge are wasted. Moreover in the case of agricultural utilization unfavorable effect was experienced with panning of soil caused by large scale decreasing of particle size of treated sludge.

Beside the processes which aim is the volume reduction of sludge the environmental friend biological sludge handling process could be favored. One of the oldest biological waste treatments is the anaerobic fermentation. The anaerobic conditions in

presence of methanogenic microorganisms lead to sludge stabilization by converting a part of organic substance into biogas. From the consideration sludge which is previously handled as hazardous waste become valuable biomass and inexpensive bio-energy source. But this theoretical opportunity raised some practical and technical difficulty. Namely carbohydrates and the lipids of sludge are easily degradable by microorganisms, while the proteins normally less accessible for biological degradation.

Moreover in most cases 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. 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 [1]. The component of polymeric sludge structure could be originated from both raw wastewater and dosed chemicals of wastewater treatment technology. Naturally the amount of biological degradable component of organic matter is a critical parameter not only in anaerobic digestion but in aerobic biological processes, for example in composting or in soil-bioremediation, also.

Among sludge handling technology the most commonly used processes are the mechanical-, thermal, thermo-chemical, enzymatic and ultrasound treatment. The pre-treating is particularly required in mesophilic biogas fermentation processes, because of less effective hydrolysis and methanogenesis. The microwave radiation is classed as thermal process, but it has so called non-thermal effects. The main advantage of microwave treatments is the rapid volumetric heating. Whereas the quantum energy of microwave radiation is too low to break the primary chemical bounds but the athermal effect of microwave irradiation could be manifested in the polarizing of macromolecules or breaking of hydrogen bounds. Therefore, for instance the microwave irradi-

ated microbial cell shows greater damage than convective heating cells to a similar temperature [2]. Certainly at higher microwave irradiation power level and at higher temperature the influence of thermal effects are more powerful than athermal effect. Due to high water content, which can be characterized by high dielectric loss factor, the sewage sludge can absorb microwave energy efficiently, so the microwave irradiation became a novel pre-treatment for anaerobic digestion too. Microwave irradiation penetrates into total mass of sludge and causes rapidly a vibration of water molecules at high frequency, and this vibration creates frictional heat and sludge heated volumetrically. In the heterogeneous chemical or biological system which contains many compounds with different dielectric properties it is possible to produce a selective heating of some areas –so called “hot-spot” - or components of material, it is known as superheating effect. In the case of microorganisms the cell wall disrupts during microwave treatment and therefore it is damaged and after disrupting of cell wall the cell liquor can be released into extracellular matter increasing the soluble organic matter content [3].

During and after the microwave heating the extracellular organic matter within polymeric network can release into the soluble phase, hereby increasing the ratio of accessible and biodegradable component [4]. Result of thermal hydrolysis of macromolecules amino acids, volatile acids and simple sugars are produced, so a considerable increasing of organic matter content -measured by increasing of chemical oxygen demand (COD)- can be experienced in the water phase [5]. So, by application of microwave treatment could be achieved flock disintegration and cells destruction to a greater extent compared to conventional heating. This effect is characterized by difference of the ratio of soluble and total COD and the increased rate of biogas production [6].

## MATERIALS AND METHODS

The dairy sewage sludge was originated from a industrial waste water treatment plant of a local dairy works (Sole-Mizo Ltd., Szeged, Hungary) and the maize canning sludge was collected from the DEKO Food Cannery, (Debrecen, Hungary).

The microwave pre-treatment was performed by a mono-mode microwave treating and measuring equipment at 2,45 GHz magnetron frequency. By this special equipment the power output of magnetron can be changed continuously from 100 to 700 W. By sludge pre-treatments the applied specific microwave power level was 1, 2, 5 and 10 W/g (depend on the mass of treated sludge and magnetron power, given by dry weight basis).

The value of biodegradability (BD) was characterized by the  $BOD_5/COD$  ratio. The chemical oxygen demand (COD) was measured according to the dichromate standard method in COD test tubes with an ET 108 digester and a Lovibond PC Checkit COD photometer. In the case of sCOD measuring the samples were centrifuged for 20 minutes at 6000 rpm. A 0,45  $\mu m$  pore size disc filter (Millipore) was used for the separation of water soluble phase. The solubility of organic matter content of sludge was given by the soluble COD and total COD (sCOD/tCOD) ratio. The biochemical oxygen demand (BOD) measurements were carried out in a respirometric BOD meter (BOD Oxidirect, Lovibond, Germany), at 20 °C for 5 days. The chemical oxygen demand and the biochemical oxygen demand measurement were performed triplicated in all cases. 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 following expression:

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

By biogas measurements the cumulative biogas digestion tests were performed triplicated 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 an operating 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.

## RESULTS AND DISCUSSION

Firstly the biodegradability of control and treated samples were measured in the case of maize canning sludge and dairy industrial sludge. The biodegradability of untreated sludge was considerably low (6,3 % by dairy industrial sludge, 4,8 % by maize canning sludge) both investigated sludge. The low biodegradability was caused particularly by the less biodegradable organic matter content, because the total organic matter content measured by COD was high. This low biodegradability is largely disadvantageous in the cases of aerobic biological decomposition and composting processes.

The ratio of biodegradable organic matter increased after conventional heating CH pre-treatment but the growth was poorly, the biodegradability ( $BD_5\%$ ) enhanced from 6,3% to 13%. The microwave pre-treatment at higher specific power level enhanced the biodegradability in a large measure, in the case of 5W/g microwave treatment the biodegradable part of organic matter increased to 40% after 40 minutes irradiation, in the case of 10 W/g microwave pre-treatment was higher (43%). By microwave pre-treatment at 10 W/g a saturation value was observed after 30 minutes irradiation in the value of biodegradability (Fig. 1).

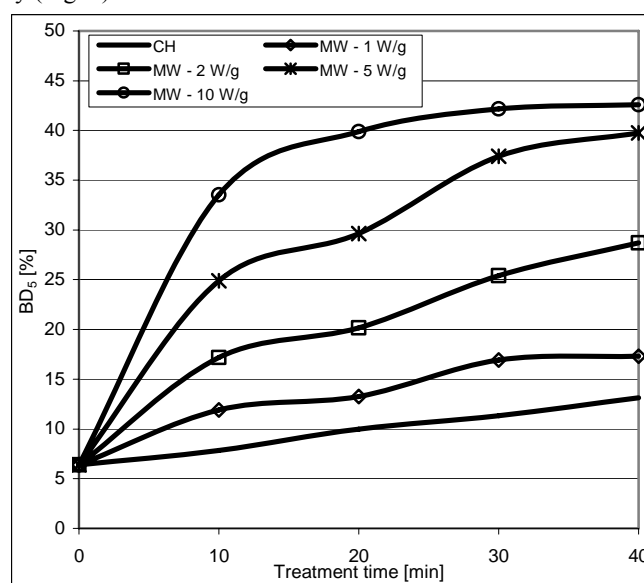


Fig. 1. Change of biodegradability of dairy industrial sludge after conventional (CH) and microwave (MW) pre-treatment  
Sl. 1. Promene biodegradacije taloga iz industrije mleka posle konvencionalnog (CH) i mikrotalasnog (MW) predtretmana

The biodegradability of non-treated maize canning sludge was also low and the microwave treatment alone could not enhance it a large measure. Whereas the main constituent of dairy industrial sludge are proteins, lactose and fats the cannery sludge contains starch in particular. The thermal hydrolysis alone could not alter the structure of starch during microwave irradiation to make it more accessible for enzymatic and microbial degradation.

The combined acidic hydrolysis (pH was adjusted by 0,5N HCl) with microwave intensification at appropriate specific power level could enhance efficiently the biodegradability. In the case of combined hydrolysis relevant difference was not observed between the effect of 2 W/g and 10 W/g microwave pre-treatment after 30 minutes continuously irradiation (Fig. 2). By applying of combined acidic and microwave pre-treatment the biodegradability could be enhanced to 31%.

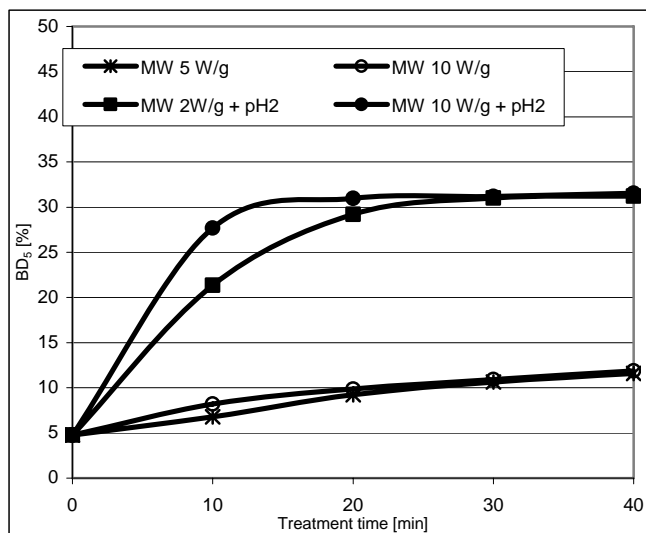


Fig. 2. Change of biodegradability of maize canning sludge after conventional (CH) and microwave (MW) pre-treatment  
Sl. 2. Promene biodegradacije taloga konzerviranja kkrzuza posle konvencionalnog (CH) i mikrotalasnog (MW) predtretmana

The ability the biological degradation of the different organic matters is linked to the water solubilisation hence the change of solubility of organic matters of sludge was examined. The amount of soluble part of total organic matter content was given by the ratio of sCOD and tCOD in percent.

Similarly to the experiences of biodegradability measurement the solubility of organic matter was enhanced after microwave pre-treatment in the case of dairy industrial sludge. But in the case of maize canning sludge combined acidic and microwave treatment was necessary to achieve a considerable increasing in the case of maize canning sludge.

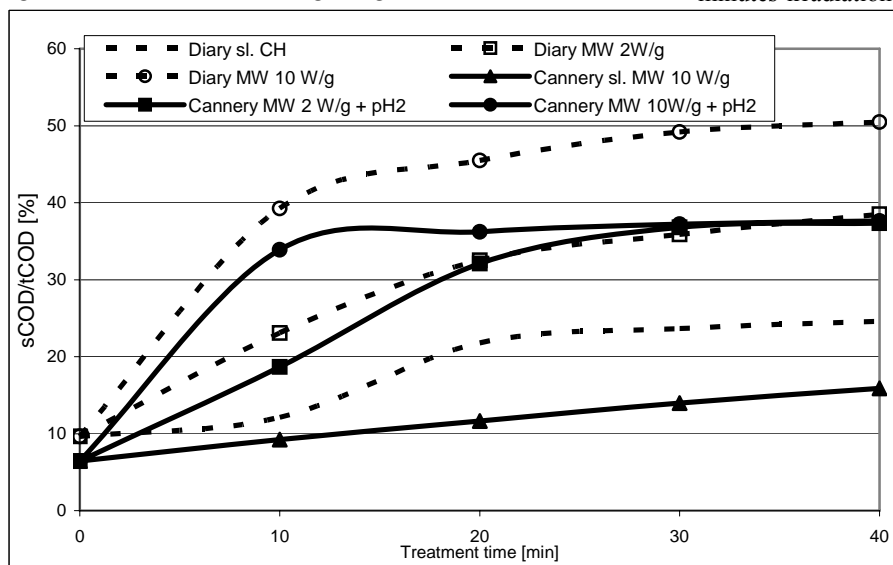


Fig. 3. Change of solubility of organic matter content  
Sl. 3. Promene rastvorljivosti organske materije

By dairy industrial sludge the sCOD/tCOD ratio increased from 9,8% to above 50% after 30 minutes 10 W/g microwave treatment. In the case of maize canning sludge the solubility of organic matter enhanced to approximately 38%. By combined acidic and microwave pre-treatments between the effects of different microwave power level considerable difference was not experienced after 30 minutes irradiation (Fig. 3).

Beside the short time biodegradability measurement the cumulative biogas product of treated sludge was investigated by anaerobic digestion.

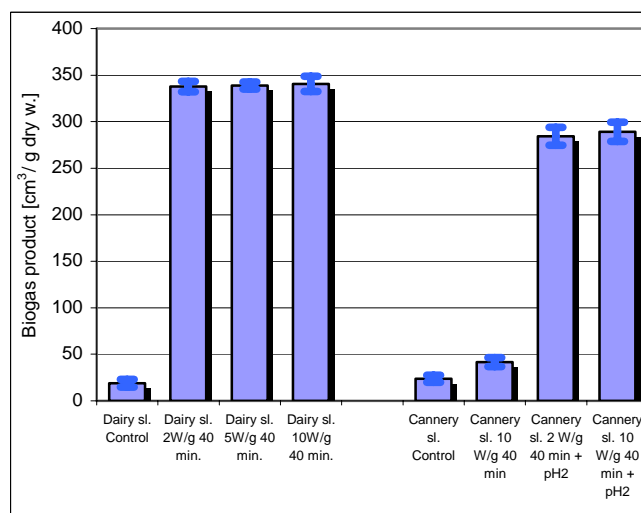


Fig. 4. Biogas product of sludge after microwave pre-treatment  
Fig. 4. Proizvodnja biogasa iz taloga posle mikrotalasnog predtretmana

During a long time (30day) anaerobic fermentation period the less degradable components are able to decompose and transform into biogas. In the case of dairy industrial sludge there was more less difference between the effects of different specific microwave power level. The microwave assisted acidic pre-treatment could enhance the biogas production of maize canning sludge more efficiently than microwave irradiation alone (from 28 cm³/g to above 270 cm³/g). After microwave treatment the cumulative biogas production of 30 day digestion of dairy industrial sludge increased from 20 cm³/g to 340 cm³/g and after 40 minutes irradiation difference was not observed between the effects of 2, 5 and 10 W/g specific power level (Fig. 4).

## CONCLUSION

In our work the effect of microwave pre-treatment was investigated on the biodegradability and digestibility of different originated sludge. For the characterization of efficiency of pre-treatments the BOD<sub>5</sub>/COD (BD<sub>5</sub>%), the solubility of organic matter content (sCOD/tCOD) and the cumulative biogas product was determined after microwave irradiation at different (1, 2, 5 and 10 W/g) specific microwave power level in the cases of maize canning originated sludge and dairy industrial sludge. Our results showed that microwave technique will be an appropriate rapid process to

enhance the efficiency of biological decomposition. In the case of examined dairy industrial sludge the aerobic biodegradability was increased above 40% and the biogas product achieved 340

cm<sup>3</sup>/g after 30 minutes microwave treatment at high specific power level (10 W/g). The microwave treatment could not increased considerably the biodegradability of maize canning originated sludge, but after combined acidic- microwave treatment the efficiency of aerobic biological degradation and the biogas production enhanced remarkably.

## REFERENCES

- [1] Neyens E., Baeyens J., Dewil R., DeHeyder, B.: Advanced sludge treatment affects extracellular polymeric substances to improve activated sludge dewatering. . Journal of Hazardous Materials, Vol. 106B, (2004) pp. 83-92.
- [2] Jones, D. A., Lelyveld, T. P., Mavrofidis, S. D., Kingman, S. W., Miles, N. J.: Microwave heating applications in environmental engineering. Resources, Conservation and Recycling, (2002) pp. 75-90
- [3] Eskicioglu, C., Terzian N., Kennedy K., J., Droste, R., L., Hamoda M.: Athermal microwave effects for enhancing digestibility of waste activated sludge. Water Research, Vol. 41, (2007) pp. 2457-2466
- [4] Beszédes, S., Kertész, Sz., László, Zs., Szabó, G., Hodúr C.: Biogas production of ozone and/or microwave-pretreated canned maize production sludge Ozone Science & Engineering Journal (2008) (in press)
- [5] Bougrier, C., Delgenes J. P., Carrere H.: Effects of thermal treatments on five different waste activated sludge samples solubilisation, physical properties and anaerobic digestion. Chemical Engineering Journal, (2007) Vol. 139, pp. 236-244.
- [6] Climent, L., Ferrer, I., Baeza M., Artola A., Vázquez F., Font X. Effect of thermal and mechanical pretreatments of secondary sludge on biogas production under thermophilic conditions Chemical Engineering Journal, (2007)pp. 273-278.

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