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ULTRASONIC INTENSIFICATION OF AEROBIC STABILIZATION OF SEWAGE SLUDGE

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The aerobic stabilization of excess sewage sludge using low frequency ultrasound (25kHz) was investigated. The mechanically thickened excess sludge was obtained from full-scale wastewater treatment plants. The samples of sewage sludge were prepared by dissolving drinking water to obtain initial total solid concentration of 1800 mg/dm^3. Five samples were treated with ultrasound of different power per sample volume: 3,12; 6,25; 12,5; 25,0 and 50,0 Wh/l. The experiments show that ultrasonic pre-treatment with 50 Wh/dm^3 power increases the digestion of organic matter in aerobic stabilization of sewage sludge.

1. INTRODUCTION

The basic task of sewage sludge treatment is its stabilization i.e. limiting its ability to putrefy, cutting down odour and eliminating pathogens partially or completely.

The stabilization of sewage sludge can be achieved by biochemical (aerobic and anaerobic) or physicochemical (wet oxidization, liming etc.) processes. Each of them has specific kinetic characteristics which exert influence on certain factors, e.g. the capacity of reactors. The individual qualitative composition of sewage sludge which affects the susceptibility of organics to biochemical decomposition under aerobic conditions has a great impact on different results of sludge stabilization. The satisfactory stabilization of sludge is very often difficult to achieve and that imposes certain limitations on processing and final management of sludge.

Currently, preliminary preparation of sludge prior to the main process is perceived as the possibility for improvement in the effects of biochemical stabilization. Such techniques e.g. disintegration aim to change the structure of flocs or even cellular structure of micro-organisms present in the sludge which becomes more susceptible to biochemical decomposition. The preliminary preparation of sludge is carried out by thermal, chemical (ozone, acids and lye) methods as well as the techniques utilizing the high pressure, mechanical and ultrasonic energy [3]. The treatment of sludge by homogenization or ultrasounds prior to methane fermentation is also gaining in popularity. The literature shows that those techniques significantly increase the digestion of organics present in sludge and the production of biogas [7, 8, 9].

2. EFFECT OF ULTRASOUNDS ON EXCESS SEWAGE SLUDGE

One of the characteristic featurs of ultrasonic field created in water solutions by waves of low-frequency but high intensity is the process of cavitation. It generates free radicals and brings about a lot of chemical transformations as a result of local increases in temperature up to 4000°C and pressure changes to 1000 atm [2]. Cavitation can be used in many ways depending on the intensity of ultrasonic field and the amount of energy input. Low intensity and low energy input may intensify biological processes in micro-organism cultures (4, 5]. The application of low frequences (20-100kHz) but high intensity and high energy input causes the micro-organisms to disintegrate which offers the possibilities for using ultrasounds in water and wastewater disinfection, and processing of sewage sludge prior to stabilization.

An effective disintegration of sludge reduces the size of flocs [3], causes the destruction of the cell membranes of micro-organisms and releases large amounts of protein substances to sludge fluid [6], which speeds up the hydrolytic stage of anaerobic stabilization and leaves a larger part of the substrate for methane micro-organisms. This results in a considerable increase in biogas production [7, 8, 9].

3. CHARACTERISTICS OF AEROBIC STABILIZATION

Aerobic stabilization is recommended for processing small and moderate amount of sludge. It can be employed in larger wastewater treatment plants when the susceptibility of sludge to aerobic decomposition is insufficient for economic recovery of biogas. One of its advantages is a relatively low concentration of organic pollutants in the liquid phase, as a result, the sludge fluid returned to the system has a negligible effect on wastewater treatment [1].

From the biological point of view, aerobic stabilization may be regarded as a type of activated sludge system. Easily decomposed organics are biodegraded, 2/3 of their weight is converted into a new cellular substance and the remaining 1/3 is oxidized to CO_2, H_2O and NH_4^+. As the amount of substrates for exogenous respiration decreases, the endogenous respiration of the cells of micro-organisms (autooxidation) begins which stops the biomass from growing and decreases respiratory activity.

4. METHODS AND TESTS

The tests were carried out on the sludge samples collected behind the thickener of excess sludge in a municipal wastewater treatment plant which is not equipped with preliminary settling tanks. The thickened sludge contained 3.65% d.m., 71.1% of which constituted organic substances. Prior to stabilization in laboratory chambers, the sludge was diluted with tap water at a ratio of 1:1, aerated and subjected to ultrasounds (5 out of 6 samples). The ultrasonic treatment was carried out in an ultrasonic washer with a transducer installed in the bottom of the vessel. 2.5 dm^3 sludge samples were treated with ultrasounds during different times to supply different doses of ultrasonic energy per sample volume (Tab. 1). The amount of energy supplied was calculated on the basis of the power of the electric device and the treatment time employing the following formula:

$$Ev = \frac{P}{V}t$$

Ev – energy dose, Wh/cm^3
P – electric power of device, W
V – sample volume, dm^3
T – time of ultrasonic treatment, h

The sludge samples were assayed for the rate of oxygen uptake by the sludge and COD of sludge fluid prior to and after the ultrasonic treatment.
The effect of ultrasounds on the sludge was described by a disintegration factor defined by the following equation:

$$\eta_{UD} = \frac{COD_{Ci} - COD_{C0}}{COD_0 - COD_{C0}} \cdot 100\ \%$$

η_U – *disintegration factor,*
COD_{Ci} – *chemical oxygen demand in the fluid over the sludge in "i" sample after ultrasonic treatment,* mg/dm^3
COD_{C0} – *chemical oxygen demand in the fluid over the sludge in raw sample,* mg/dm^3,
COD_0 – chemical *oxygen demand in sludge prior to ultrasonic treatment,* mg/dm^3,

Table 1. Parameters of ultrasonic treatment

Sample	Amount of supplied energy [kWh/dm^3]	Time of ultrasonic treatment [h]	COD of sludge fluid [mgO_2/dm^3]	Disintegration factor η_{UD}
1	0	0	82	0,0
2	3,12	5'14''0	157	0,28
3	6,25	10'28''	234	0,58
4	12,50	20'55''	564	1,96
5	25,0	41'50''	2174	8,60
6	50,0	1h23'20''	2466	9,65

The sludge thus prepared underwent aerobic stabilization. Six parallel assays of samples whose initial volume was 2.0 dm^3 were carried in tanks made of polietthylene. The process and the ultrasonic treatment was conducted at room temperature (approx. 17°C). Aeration and stirring were performed using compressed air diffused by a porous diffuser elements fixed at the bottom of the vessels. The inflow of air supplied over 2 mg/dm^3 of dissolved oxygen. Every day, distilled water was used to compensate for the losses of water which resulted from evaporation. The samples for analysis were collected after 5, 10, 14, 20 and 25 days.

The monitoring of stabilization was based on the measurements of the losses of dry matter, organic and mineral dry matter of the sludge, COD for the sludge fluid and the rate of oxygen uptake by the sludge (respiratory activity).

The determination of dry matter, organic and mineral dry matter of the sludge was performed in accordance with the Polish Standard PN-75/C-04616/01, COD was assayed by modified dichromate technique, according to shortened mathod [11], while the rate of oxygen intake by sludge was measured according to OECD [10]. Oxygen concentration and pH were also controlled using a multi parameter instrument, type HQ 20, Hach-Lange

5. RESULTS

The ultrasonic treatment of sludge considerably affected the concentration of COD in sludge fluid and respiratory activity of activated sludge (Fig. 1). The disintegration factor and the changes in respiratory activity depend greatly on the amount of energy supplied per unit volume of prepared sludge. Samples 1, 2 and 3, characterized by a low disintegration factor, revealed a marked increase in respiratory activity, while samples 5 and 6 showed a high increase in disintegration factor but the respiratory activity decreased, dropping four-fold in sample 6 against the check sample (not treated with ultrasounds).

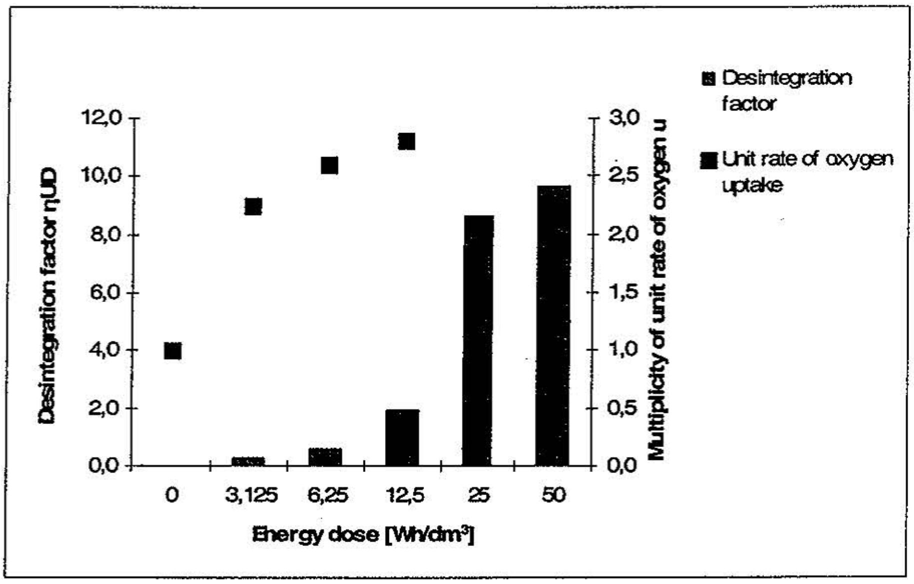

Fig. 1. Correlation between disintegration factor, rate of oxygen uptake and the amount of energy supplied after ultrasonic treatment

The results of the concentration of organic and mineral dry matter in the samples collected on successive days of stabilization helped determine a stabilization module, employing the following formula:

$$M_s = 100(1 - \frac{p_1 \cdot m_0}{p_0 \cdot m_1})$$

p_1 – *concentration of volatile substances in sludge after stabilization,* % d.w.
p_0 – *concentration of volatile substances in raw sludge,* % d.w.
m_0 – *concentration of mineral substances in raw sludge,* % d.w.
m_1 – *concentration of mineral substances in sludge after fermentation,* % d.w.

The loss of organic matter in the sludge was also determined. The effects of aerobic stabilization with respect to the amount of ultrasonic energy per unit volume of sample are shown in Figs 2 and 3.

The results enable the observation of the increase in the rate of sludge digestion with increasing amount of energy supplied per unit volume. The best effect, in which the loss of dry organic matter is the highest, was achieved for sample 6 and energy dose of 50 Wh/dm^3. The marked disintegrating action of ultrasounds in that sample, expressed as an increase in COD of sludge fluid and decrease in respiratory activity, affected the results of aerobic stabilization shown in the rise of the digestion rate of sludge organic matter.

After 10 days of stabilization, the decrease in organic matter in that sample exceeded 38%, i.e. the value EPA requires for class A sludge intended for farming. The subsequent days of measurements showed that stabilization was much slower, nevertheless, the loss of organic matter in that sample was still the highest after 25 days compared to the other samples.

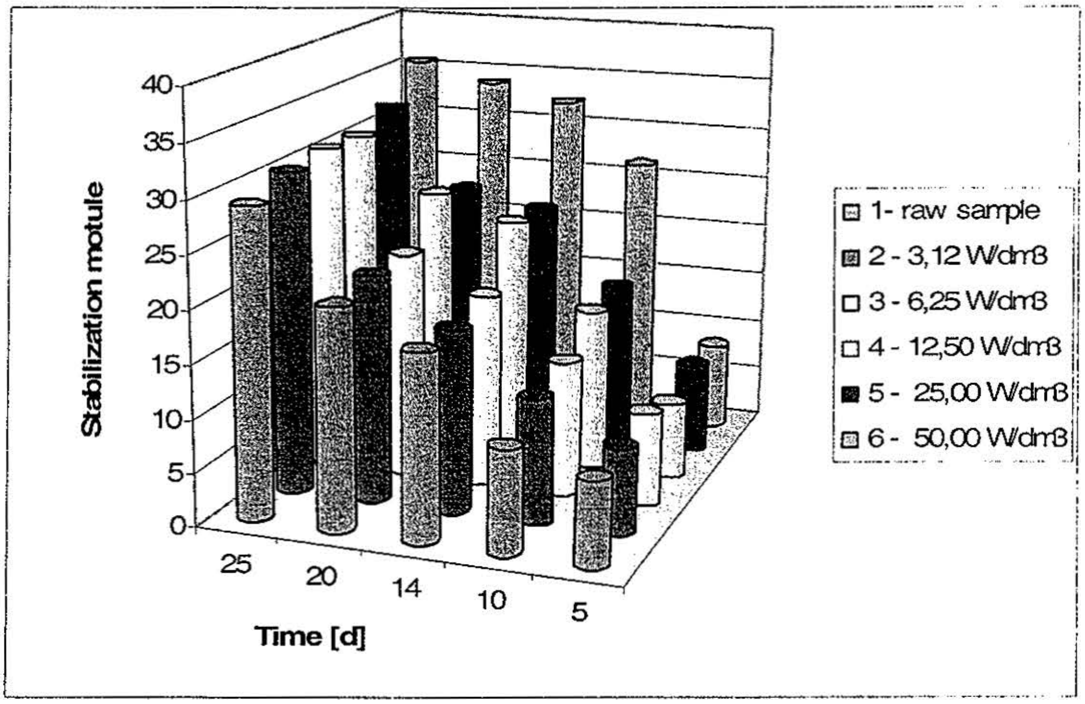

Fig. 2. Changes in stabilization module during aerobic stabilization of sewage sludge

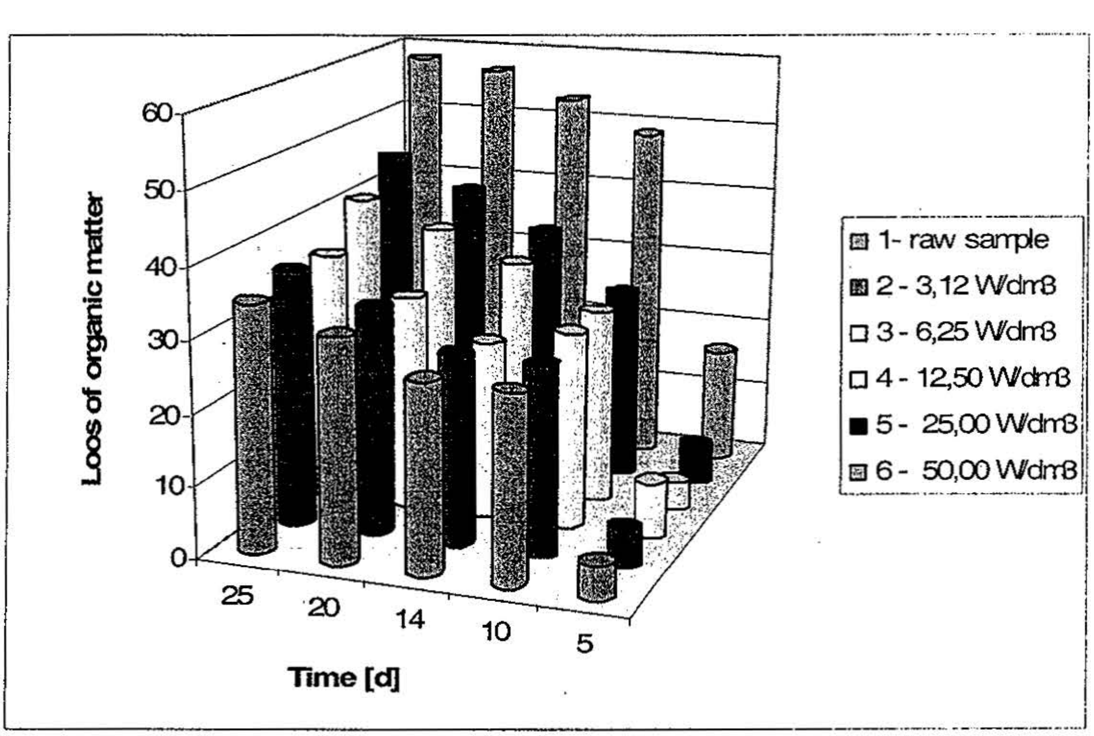

Fig. 3. Loss of organic dry matter during aerobic stabilization of sewage sludge

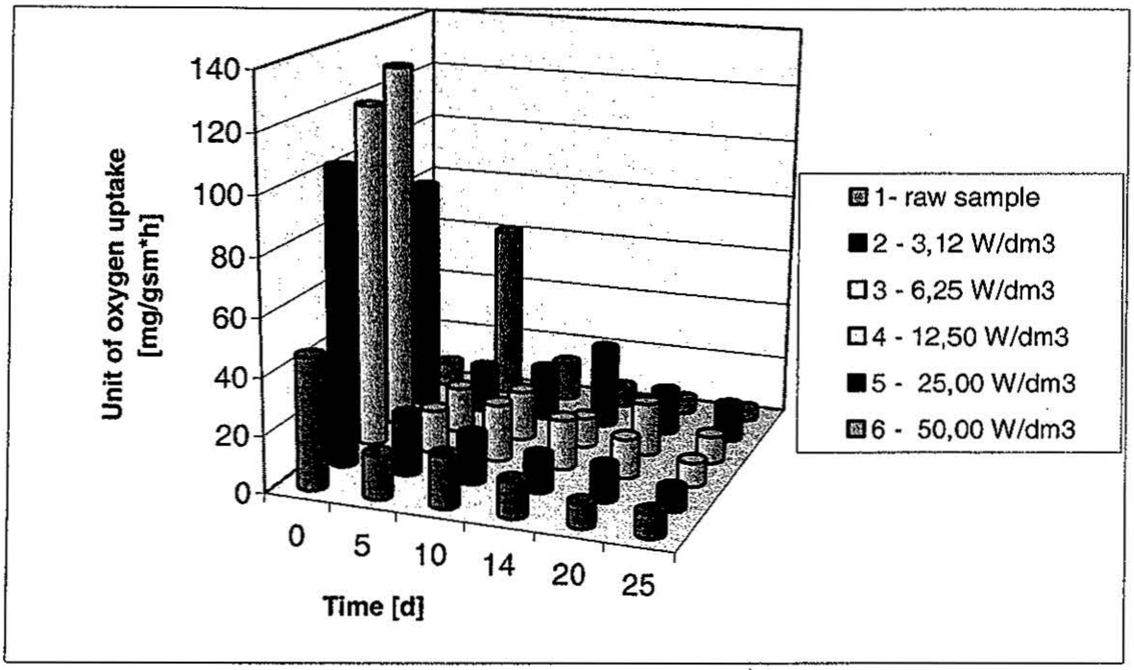

Fig. 4. Changes in unit rate of oxygen intake during aerobic stabilization of sewage sludge

Table. 2. Change in COD of sludge fluid during aerobic stabilization of sewage sludge

Sample	Time [d]					
	0	5	10	14	20	25
1 - raw sample	82	92	86	92	101	113
2 - 3.12 Wh/dm^3	157	96	97	80	105	130
3 – 6.25 Wh/dm^3	234	100	80	86	122	132
4 – 12.5. Wh/dm^3	564	113	92	80	113	147
5 – 25.0 Wh/dm^3	2174	401	109	101	126	164
6 – 50.0 Wh/dm^3	2466	1337	966	252	168	164

All the samples revealed a gradual decrease in respiratory activity, except for sample 6 which displayed an increase up to day 5 followed by a decrease to the lowest level of all samples after 14, 20 and 25 days (Fig. 4).

COD of sludge fluid also dropped rapidly (Tab. 2). The highest level was found for sample 6 reaching 164 mg/dm^3 after 25 days of stabilization.

pH had a similar value for all the samples, except for sample 6 which demonstrated a marked increase during the initial days of the process. This was probably due to the release of substantial amount of protein substances to the water phase after ultrasonic treatment, and consequently causing an increase in the concentration of ammonium nitrogen and pH. pH changes are depicted in Fig. 6.

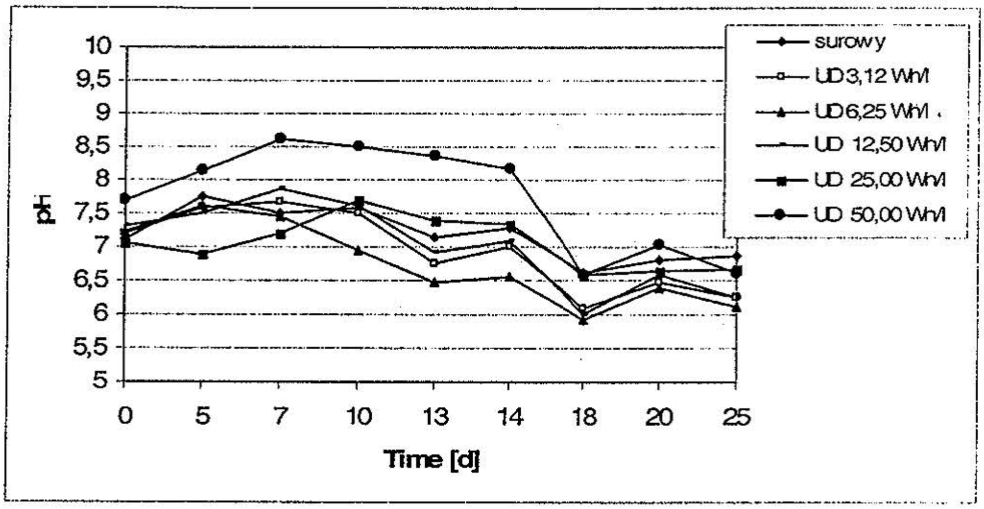

Fig. 6. pH changes during aerobic stabilization

6. CONCLUSIONS

The study revealed the possibility for ultrasonic intensification of aerobic stabilization of sewage sludge, provided the effective disintegration process is carried out which results in a marked increase in COD of sludge fluid and parallel decrease in respiratory activity of the sludge. The intensification requires a sufficient amount of ultrasonic energy.

The application of ultrasonic treatment of sludge prior to stabilization causes an increase in sludge digestion which indicates an improvement in the stability and dewaterability, and thus, resulting in smaller quantities of sludge.

The possibility for intensifying the aerobic stabilization of sewage sludge through its preliminary disintegration provides an opportunity to solve the problems with sludge in small wastewater treatment plants whose contact time in the stabilization tank is too short to ensure the satisfactory quality of the sludge so that it could be handled by nature.

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ULTRADŹWIĘKOWA INTENSYFIKACJA STABILIZACJI TLENOWEJ OSADÓW ŚCIEKOWYCH

Streszczenie

Badano wpływ wstępnej obróbki osadu nadmiernego polem ultradźwiękowym o częstotliwości 25 kHz na przebieg procesu stabilizacji tlenowej. Osad do badań pochodził z rzeczywistego obiektu biologicznej oczyszczalni ścieków. Pobrano osad zagęszczony mechanicznie a następnie rozcieńczono go wodą wodociągową osiągając koncentrację suchej masy ok. 1800 mg/l. Pięć tak przygotowanych prób poddano nadźwiękawianiu aby zapewnić odpowiednie ilości włożonej energii w objętość próby: 3,12; 6,25; 12,5; 25,0 i 50,0 Wh/l. Badania wykazały znaczny wzrost mineralizacji masy organicznej osadu przy wstępnym preparowaniu polem ultradźwiękowym dla 50 Wh/l włożonej energii.