ULTRASONIC CAVITATION IN SEWAGE SLUDGE

Piotr SORYS, Ewa ZIELEWICZ-MADEJ

Institute of Water and Wastewater Engineering, Silesian University of Technology,
Konarskiego 18A, 44-100 Gliwice, POLAND

The study revealed considerable differences in the susceptibility of the sludge to preliminary treatment by two kind of mixing and expressed as changes in the initial properties of the sludge and thus conditions for the occurrence of ultrasonic disintegration in particular sludge from wastewater treatment plants G, K and Z. The susceptibility of sludge to ultrasounds which depends on the sludge properties was explained by the higher COD of dissolved matter after ultrasonic disintegration of sludge.

1. INTRODUCTION

The diversified effect of ultrasounds enables their application to the physicochemical processing of excess sludge produced during biological treatment of wastewater.

The possibility for intensifying the hydrolytic phase of excess sludge digestion which limits further processes of biochemical decomposition of organic compounds by bacteria in subsequent phases (acidogenic, acetogenic and methanogenic) has become one of the most interesting and extensively analyzed research problems in the technology of wastewater and sewage sludge treatment. It may be carried out via the preliminary treatment of the sludge by thermal, chemical and mechanical methods or a combination of those [1]. The treatment is aimed at dispersing the solid phase of the sludge and destroying microorganism cells with concomitant release of substrates and enzymes into the sludge fluid for further biochemical decomposition of organic matter. The Institute of Water and Wastewater Engineering at the Silesian University of Technology has investigated the application of ultrasounds to the disintegration of activated excess sludge for many years. Its objective was the intensification of the acidogenic and acetogenic phases of digestion to obtain short-chain organic acids (VFA) [2,3].

2. THEORETICAL ASSUMPTIONS

The majority of research staff and engineers or specialist in ultrasonic technology express the opinion that active reaction of ultrasounds in liqids is, first of all, the result of ultrasonic cavitation. The rapid implosion of the cavitation bubbles causes a local pressure...
increase and elastic shock waves [4]. Since the collapse of the bubbles is very short (a few \( \mu s \)), it is assumed that a simultaneous adiabatic compression occurs coupled with a quasi-adiabatic temperature increase of about several thousand K [5]. The occurrence of ultrasonic cavitation depends on a number of factors (temperature, surface tension, medium viscosity, hydrostatic pressure, the degree of gas saturation, gas type and others), therefore they are different for different mediums and experimental conditions. Because cavitation takes place primarily on the phase boundary, the presence of gas bubbles and the ones suspended in the medium, called the germ of cavitation, increases the susceptibility of the liquid to the process. All factors which decrease the viscosity of the liquid and break up the continuity of its structure, all solid, liquid and gaseous waste, as well as the roughness of the walls of the chambers in which ultrasonic treatment is carried out bring about a decrease in the cavitation threshold [5]. The use of ultrasounds in the aqueous environment offers a lot of technological opportunities for the treatment of water, wastewater and sewage sludge [6,7]. Local occurrence of high pressures and temperatures during bubbles collapse explains possible, deep, diversified and often irreversible changes in the structure and other physicochemical properties of sewage sludge subjected to ultrasounds [8,9]. The mechanical and sonochemical treatment of excess sludge may result in the destruction of the flocculent structure of excess sludge, increase in particle dispersion, destruction of the cell membranes of microorganisms and release of cell matter into sludge liquid [2,10-14]. The investigations carried out by us and other researchers for the last several years have shown that the disintegration of sewage sludge should be conducted using ultrasounds generated at a relatively narrow range of 16 kHz - 50 kHz.

3. OBJECTIVE, SCOPE AND METHODOLOGY OF THE RESEARCH

The research aimed at comparing the conditions for occurrence of disintegrating cavitation in several excess sludge characterized by different consistency, hydration, concentration of organic matter and different initial CODnn of the compounds dissolved in the total CODo of the sludge. They were collected in wastewater treatment plants (denoted as G, K and Z) only after the mechanical thickening process aided by introducing appropriate polyelectrolyte doses. The concentrations of the dry weight of the sludge showed that the efficiency of the thickeners differed 1.3 - 2-fold (Table 1).
Tab. 1. Parameters of sludge and sludge liquid prior to ultrasonic treatment.

<table>
<thead>
<tr>
<th>Lp.</th>
<th>Symbol of sludge</th>
<th>Parameters of sludges (aerated of mixes) before sound amplification</th>
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<td></td>
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<td>Drymass concentration</td>
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<tr>
<td>1</td>
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<td>2</td>
<td>Z</td>
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<tr>
<td>3</td>
<td>Z-aerated</td>
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<td>4</td>
<td>Z-mixed</td>
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<td>5</td>
<td>K</td>
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<td>6</td>
<td>K-aerated</td>
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<td>7</td>
<td>K-mixed</td>
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<td>8</td>
<td>G</td>
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<td>9</td>
<td>G-aerated</td>
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<td>10</td>
<td>G-mixed</td>
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The study also examined the effect of sludge preparation (preliminary mechanical or compressed air stirring) for ultrasonic disintegration on the results obtained. The preparation of the sludge prior to ultrasonic treatment involved a short (5 min) stirring of 1-litre sludge sample with a paddle stirrer (1450 rpm) or 1-h aeration with compressed air at 6 l/min. Both types of stirring were used to increase the susceptibility of the sludge to ultrasounds by dispersing of particles and introduction of gas bubbles which break up the liquid phase. The sludge were treated with ultrasounds in a laboratory employing an experimental system equipped with a WK-2000 disintegrator produced at the Silesian University of Technology (Fig.1). 300-ml sludge samples were placed in a cylindrical steel chamber of 8 cm in diameter, the ultrasound transducer head being submerged in the sludge at a depth of h=1.0 cm below the surface. The sonotrodes transmitted ultrasounds to the sludge samples at frequencies of 10, 23 and 30 kHz, changeable ultrasonic treatment time in the range of 0.5 – 10 min and constant electrical power of the disintegrator of $P_G = 450$ W. CODₙd of the liquid (the basic parameter used to monitor the effects of ultrasonic disintegration) was assayed after it had been centrifuged (20 000 rpm) and filtered through cellulose acetate membrane 0.45μm (COD of dissolved fraction showed the disintegration of microorganism cells and sonolysis) [1,2]. The extent of ultrasonic disintegration was measured on the basis of process variables:

$$k_{d1} = \frac{COD_{nd}}{COD_{nn}} \quad \text{(bw)} \quad (1)$$

CODₙd - COD of liquid phase of sludge treated with ultrasounds

CODₙn - COD of liquid phase of sludge not treated with ultrasounds
3. RESULTS

The susceptibility of sludge to ultrasounds depends on the sludge properties which are a function of its formation during wastewater treatment. The study revealed considerable differences in the susceptibility of the sludge to stirring by compressed air or mechanical stirrer expressed as changes in the initial properties of the sludge (Table 1), and thus conditions for the occurrence of ultrasonic cavitation in particular sludge. For instance, aeration substantially changed the properties of sludge G, while those of sludge Z and K remained almost unchanged. The mechanical stirring increased the amount of dissolved matter (CODnn) in sludge Z and G 4-fold and 3-fold respectively, producing no increase in sludge K. However, sludge K, not susceptible to the preliminary treatment, which might be explained by its homogenous consistency and a relatively high initial hydrolysis (CODnn/CODo) was most susceptible to ultrasounds alone, which may result from the favourable, low initial concentration of dry weight (about 4%).

Despite the different susceptibility of sludge G, Z and K to ultrasounds, an increase in ultrasonic treatment time affected ultrasonic disintegration (expressed as $kd_1$), of all the sludge. The correlations, however, are neither directly proportional to ultrasonic treatment time, and thus energy used, nor identical for all the sludge (Fig.2). Although the ultrasonic treatment time of 10 min was the most favourable for all the sludge, the effects obtained for the time of 5 min were only slightly worse and the differences did not justify the use of twice (from 125 kWh/m$^3$ to 250 kWh/m$^3$) as much of energy. The characteristic correlations between the ultrasonic treatment and the effect of aeration and stirring (for the time of 5 min and frequency of 23 kHz) are shown in the diagrams (Fig.3). Most tests revealed a favourable effect of combined preliminary stirring and ultrasonic treatment on final disintegration. Fig.4 depicts a correlation between disintegration degree $kd_1$ and ultrasound frequency typical of all the sludge. The efficiency of ultrasounds of
23 kHz proved to be the highest, which is another confirmation of the conclusions drawn by us and other authors [3,12] that the frequency of 20-25 kHz is the most favourable for ultrasonic disintegration of excess sludge.

Fig. 3. The final effect of COD\textsubscript{nd} production in disintegrated sludge.

Fig. 4. Correlation of disintegration coefficient $k_{d1}$ and ultrasound frequency at time 5 min.

4. CONCLUSIONS

1. The susceptibility of sludge (collected at the three different treatment plants) to the disintegrating effect of ultrasounds depended greatly on their initial properties.
2. Each sludge displayed too different susceptibility to the preliminary treatment of stirring or aeration, sludge K showing the most negligible effect of preliminary treatment on the final results of disintegration; the preliminary mechanical stirring is favourable for sludge Z while compressed air proved to be better for sludge G.
3. Sludge K characterized by the lowest initial COD\textsubscript{nn}/COD\textsubscript{o} and lowest concentration of dry weight (3.1%) turned out to be the most susceptible to ultrasonic disintegration.
4. The total disintegrating effect of combined preliminary treatment by mixing and ultrasonic disintegration was higher than the ultrasonic treatment alone.

5. The frequency of 23 kHz produced the most favourable disintegration effect for all the sludge.

REFERENCES