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Effects of ultrasonic disintegration of excess sewage sludge

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ABSTRACT

Ultrasonic disintegration of excess sludge is used as a process preceding the stabilization of sludge in wastewater treatment plants. It has a task of intensifying the anaerobic digestion of the organic fraction of sludge due to the fragmentation of its particles and destruction of microorganisms. Amount of energy put into process is the strongest factor determining type and intensity of disintegration. Physicochemical properties of sludge, operational variables and construction of installation have to be considered as well. The research have shown the effects of disintegration of various sludge conducted in disintegrators of varying heads and emitter structures, but at the same energy density E_V kW h m^{-3}.

1. Introduction

Sewage sludge is waste generated during wastewater treatment at WWTPs (wastewater treatment plants) and has to be treated to reduce its volume and environmental risk. One of the methods of sludge processing is biological breakdown of organic substances under anaerobic conditions known as methane digestion. Disintegration of excess sludge before digestion improves the biological decomposition of organic compounds contained in this sludge. Disintegration of sewage sludge covers a number of processes taking place in sewage sludge due to the influence of mechanical and/or chemical energy and/or heat. One of them is the rasonic energy. Main result achieved by using ultrasonic disintegration is intensification of methane digestion. Production of biogas as a source of renewable energy is an additional benefit of highly effective methane digestion. The sonication can improve production of biogas [1] and this effect correlates with improvement in solids destruction as well as with better susceptibility to dewatering of digested sludge.

The ultrasonic field with strictly defined parameters changes physical and chemical properties of sludge –structure of components, surface of solid particles and stability of its hydration layer and as consequence, its sedimentation properties, but the result of the destructive effects under conditions of acoustic waves is the most important in process of ultrasonic disintegration. The cavitation phenomenon in the ultrasonic field is recognized as the primary mechanism causing changes in sonicated sludge [2]. The ultrasound cavitation causes many effects, such as: dispergation of flocks, (sonodispergation), microorganism cells disruption (cells sonolysis), sonochemical effects, for example changes in ζ-potential of particles describing the coagulation and flocculation, rheological changes [3]. Studies conducted in laboratories and industrial scale prove that ultrasonic pretreatments of excess sludge before digestion can be carried out with low frequencies (20–30 kHz) and high intensity field ($I > 1.0$ W cm^{-2}) [2].

Destruction of microorganism cells and release of the contents of the dead cells into the sludge liquid, which results in an increase in SCOD (soluble chemical oxygen demand) as well as increase in many other substances dissolved in the liquid sludge (supernatant after centrifugation and membrane (0.45 μm) filtration) is most expected effect of ultrasonic disintegration [4].

Research carried out previously by the author proved an effect accompanying sonolysis. It was found that the ultrasonic treatment was directly followed by the release of VFAs (volatile fatty acids) to sludge liquid [5] this means that part of the dissolved organic matter, expressed as SCOD, was in sonochemical processing turned into simple organic compounds, VFAs, which are the main products of 2nd and 3rd phase of digestion. This effect, called by the author sonoacidification, was separated from the effect of the cell sonolysis. All those destructive effects of ultrasonic disintegration (named by the author sonodispergation, sonolysis and sonoacidification) are the direct effects of ultrasonic disintegration, unlike the technological effects occurring after the following steps of sludge processing such as digestion, which may be observed as increase in biogas production and improvement of quality of

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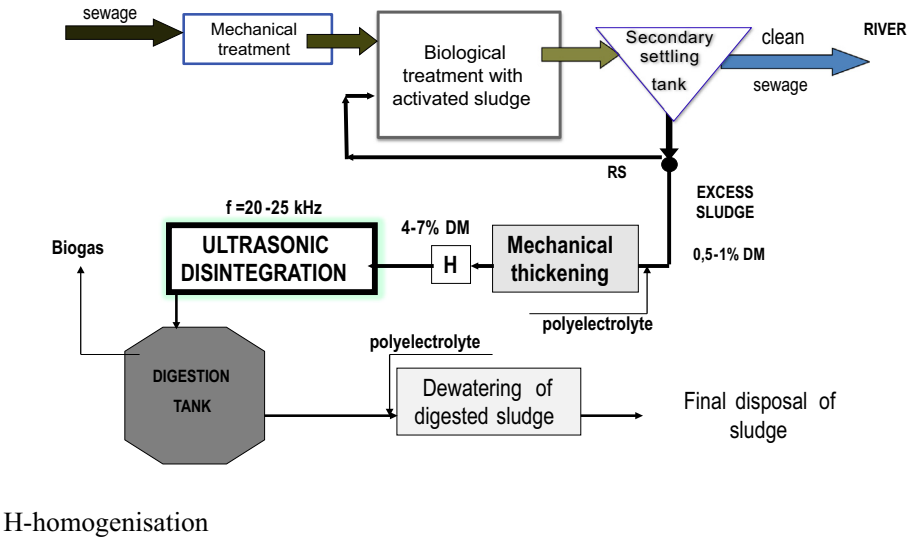

Fig. 1. The place of the ultrasound installation in WWTP.

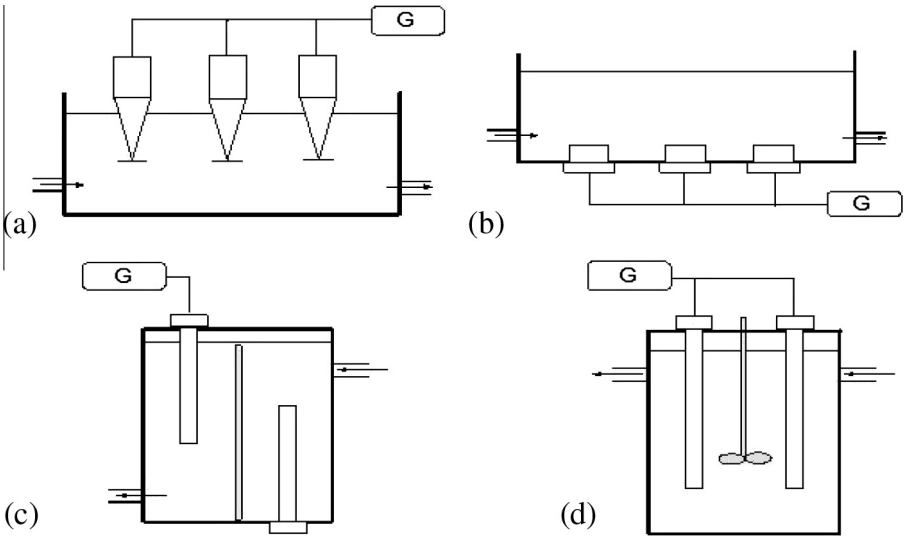

Fig. 2. Schematic of constructions of ultrasonic disintegrators: (a) continuous flow disintegrator with few horns, (b) continuous flow washer with few flat emitters, (c) disintegrator with 2 long sonotrodes and labyrinthine continuous flow (d) disintegrator of periodic cycle with few long sonotrodes and stirring.

digested sludge (a decrease in the organic compounds of the sludge and increase in its susceptibility to dewatering). In wastewater treatment plants ultrasonic disintegration is primarily used to treat excess sludge. The disintegrators should be installed after the mechanical thickener of sludge and before digestion tank. The ultrasonic disintegrator is often preceded by a mechanical homogenizer (H) of thickened sludge. (Fig. 1).

The type and intensity of the effects created as a result of disintegration depend on the characteristics of the sludge and as well as process conditions, the most important being construction parameters of the disintegrator and technological parameters of disintegration, such as frequency, output power, sonication time and temperature [6].

Fig. 2 shows some schematics of constructions of ultrasonic disintegrators used in wastewater treatment plants on industrial scale. Due to operating in dynamic conditions (disintegrators) have to ensure an appropriately long residence time of sewage sludge particles within the range of emitters' activity, their construction necessitates the hydraulic agitation of sludge (Fig. 2a–c) or they should be equipped with mechanical stirrers (Fig. 2d).

The research was carried to compare effects of ultrasonic field emitted by different constructions on sewage sludge collected at several wastewater treatment plants and finding out which of the disintegrators produced higher disintegration effectiveness, regardless of the physic-chemical characteristics of the sludge (the effect of sludge characteristics was not the aim of this study).

2. Materials and methods

Excess sludge from 6 municipal wastewater treatment plants (WWTP1–WWTP6) located in the industrial region of Poland (Silesian District) was used for this research.

All excess sludge was collected after the mechanical thickener, the concentration of dry mass (DM) in the sludge differed from around 3% to 7%. Mechanical thickening process is always supported by flocculation with polyelectrolytes, which is significant for the structure of sludge particles as well as other properties of the sludge, including their final hydration and the characteristics of the supernatant. The characteristics of excess sludge before