The Use of Ultrasounds in Improving the Sanitary Quality of Sewage Sludge †

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Abstract: The aim of this article is to study the effect of low-frequency ultrasound on the disintegration of microorganisms present in mixed sewage sludge. Initial and excessive sewage sludge were used for examinations coming from the Bialystok Sewage Treatment Plant. They were exposed to ultrasound at 20 and 40 kHz, in varying sonification times and in the case of variable operation of the ultrasonic cleaner (continuous and pulsating work). Research showed that ultrasound was demonstrating effective action with the tested microorganisms. The 30-minute interaction of ultrasounds at 20 kHz on the bacteria present in sewage sludge resulted in a significant decrease in the number of these microorganisms. The obtained results, therefore, indicate the possibility of using this method to disintegrate microorganisms in municipal wastewater treatment plants.

Keywords: ultrasounds; sanitary quality; sewage sludge; sonification

1. Introduction

Sewage sludge is an inherent product created as a result of the wastewater treatment process. Up until now it has not been worked out without wastewater treatment processes, or solutions allowing the elimination of sewage sludge from the environment. Paradoxically, the amount of sewage sludge increases with the development of more and more effective methods of chemical and biological wastewater treatment. Sewage sludge does not exceed 3% of sewage volume, however, it contains more than 50% of raw sewage pollutants [1].

Sanitary properties of sewage sludge are recognized to a lesser degree than their chemical properties. Sewage sludge is undoubtedly an environment conducive to the development of microorganisms. They are a place for living microflora and microfauna, which includes: Bacteria, fungi, viruses, protozoa and parasitic worms. The most frequent group of microbial sewage sludge pollutants are bacteria, and the most frequent are: *Escherichia coli*, *Salmonella* sp., *Shigella* sp., *Pseudomonas aeruginosa*, *Bacillus anthracis*, *Clostridium perfringens*, *Vibrio cholerae* (in tropical countries), *Listeria monocytogenes*, *Proteus vulgaris* and *Streptococcus faecalis* [2].

Sanitary properties of sewage sludge are variable and depend on many external factors, i.e., sanitary conditions, health of people, amount and type of sewage and technologies used for their treatment. The degree of danger caused by sediments formed at various stages of wastewater treatment is diversified. Although sewage sludge treatment methods are commonly used, they do not guarantee obtaining a product which will be sanitary safe [3,4].

The process of reducing or completely eliminating pathogenic organisms is called sewage sludge hygienization. Hygienization can occur to varying degrees, in various processes of deposit processing or in a separate process [1].
In recent years, there has been growing interest in ultrasound with low frequency in the range of 20–40 kHz. There are not many publications on biological issues, despite the fact that ultrasounds successfully kills microorganisms (especially filamentous bacteria) [5]. Therefore, studies of the influence of low-frequency ultrasound (20 and 40 kHz) on the disintegration of microorganisms present in mixed sludge have been carried out.

2. Materials and Methods

The research used sewage sludge (preliminary and excessive mixed in the proportion of 60:40) and Polsonic ultrasonic washers with the frequency of ultrasound 20 and 40 kHz.

The material for the research came from the Białystok Sewage Treatment Plant, which is the largest facility of this type in north-eastern Poland. Białystok Sewage Treatment Plant treats communal and industrial sewage, and receives about 15,500,000 m³ of municipal sewage and 20,000,000 m³ of industrial sewage during the year [6].

The sewage sludge, after being transported from the place of collection to the microbiological laboratory of the Department of Chemistry, Biology and Biotechnology of the Białystok University of Technology, was subjected to analyses. Each time, 2 L of mixed sludge was placed in the Polsonic ultrasonic cleaner with a frequency of 20 kHz ultrasound (tests were performed in a continuous and pulsatory mode of operation) and 40 kHz and sonicated for 30 min. Before starting sonication and after 5, 10, 15, 20, 25 and 30 min, 1 mL of sewage sludge was removed, followed by serial dilutions (ranging from $10^{-1}$ to $10^{-6}$). The samples thus obtained were transferred to an agar medium, then placed in an incubator at 37 °C and incubated for 24 h. After incubation, the number of colony forming units (cfu) grown on the plates was counted. On the basis of the obtained results, average values of cfu/mL were calculated.

3. Results and Discussion

Table 1 shows the changes in the number of microorganisms present in mixed sewage sludge treated with ultrasounds at 20 and 40 kHz, and Figure 1 shows the percentage changes in the number of bacteria depending on the time of sonication.

| Time of Sonication (min) | 20 kHz— Continuous Work | 20 kHz— Pulsating Work | 40 kHz |
|-------------------------|-------------------------|------------------------|--------|
| 0                       | $2.8 \times 10^6$       | $5.5 \times 10^5$       | $4.2 \times 10^5$ |
| 5                       | $2.7 \times 10^6$       | $3.9 \times 10^5$       | $3.9 \times 10^5$ |
| 10                      | $1.5 \times 10^6$       | $3.8 \times 10^5$       | $3.8 \times 10^5$ |
| 15                      | $1.2 \times 10^6$       | $2.8 \times 10^5$       | $2.9 \times 10^5$ |
| 20                      | $6.7 \times 10^5$       | $2.5 \times 10^5$       | $2.7 \times 10^5$ |
| 25                      | $3.8 \times 10^5$       | $2.0 \times 10^5$       | $1.9 \times 10^5$ |
| 30                      | $2.1 \times 10^5$       | $0.1 \times 10^5$       | $1.8 \times 10^5$ |

On the base of the obtained test results, there was a clear reduction in the number of bacteria present in mixed sewage sludge, both at ultrasounds of 20 and 40 kHz. Already after 5 min of ultrasound sonication at the frequency of 20 kHz (in the pulsed operating mode) was noted a decrease in the number of bacteria by approximately 29%. With time, the number of bacteria gradually decreased—after 30 min of ultrasound operation, reaching the value of approximately 2% in relation to the reference sample. The decrease in the total number of bacteria by 92.5% was also noted in the case of continuous operation of ultrasounds with a frequency of 20 kHz. Sonication in a 40 kHz washer also caused a reduction in the number of microorganisms tested, but these were not as significant (about 57% after 30 min of ultrasound), as in the case of 20 kHz.
Figure 1. Percentage changes in the number of microorganisms present in mixed sludge subjected to ultrasound (own study).

The literature indicates the confirmation of the results obtained in the presented work [1,5,7]. The presented results, therefore, indicate the effectiveness of low-frequency ultrasounds for destroying microorganisms present in sewage sludge.

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