IMPACT OF MICROWAVE DISINTEGRATION ON ACTIVATED SLUDGE

WPŁYW DEZINTEGRACJI MIKROFALOWEJ NA OSAD CZYNNY

Abstract: Microwave disintegration of activated sludge causes organic matter transfer from the solid phase to the liquid phase. This process results in an increase of the COD value in liquid by ca 614 mg O_2/dm^3 and protein concentration by ca 340 mg/dm^3. Microwave radiation positively influences the sludge volume index (SVI) decrease from 195 to 54 cm^3/g. Our research confirmed that the application of an electromagnetic wave may become a new effective way of improving sewage treatment and processing sewage sludge.

Keywords: activated sludge, microwave disintegration, COD, proteins, sludge volume index (SVI)

Destroying cell walls of microorganisms and consequently releasing intracellular substances into the surrounding liquid are conducted with the use of various disintegration methods. The most common methods of cells disintegration are: enzymatic digestion, lysis with the use of detergents and organic solvents, cutting, homogenization, sonification, grinding, differential centrifugation, shaking with glass balls, osmotic shock and freezing/defrosting.

In the recent years, some of the disintegration methods used in biotechnology have been applied in the sewage sludge processing. Among the used methods were:

- the application of thermic energy [1-3],
- the application of enzymes [4, 5],
- ozonation [6, 7],
- acidification [8],
- alkalisation [9],
- the application of high pressure [10-12],
- mechanical mincing [13],
- the application of ultrasound energy [14-16],
- the application of microwave radiation [17-20].

The most important aims of applying disintegration include:

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• releasing intracellular enzymes into the environment which cause direct decomposition of pollutants,
• exposing organic substances and making them more accessible for the remaining biomass (taking into account the disintegration of a part of activated sludge or sludge in septic tanks),
• releasing an organic substrate (surplus sludge in case of disintegration), which may be the source of easily assimilable organic carbon for the denitrification process in case of its deficiency in the sewage flowing to the bioreactor,
• a possibility of applying disintegration in sewage treatment processes to remove the foam generated in bioreactors and eliminate the foaming in septic and settlement tanks.

One of the sewage sludge disintegration methods is the usage of microwaves. Microwave radiation is a type of electromagnetic radiation with a wavelength from \( \lambda = 1 \text{ m} \) to \( \sim 0.1 \text{ mm} \) the microwave spectrum ranges from the infrared to ultra short waves, of frequency \( \nu = 3 \cdot 10^9 \div 3 \cdot 10^{12} \text{ Hz} \) [21].

Microwaves radiate in the form of mutually diffusing electric and magnetic vibrations. Microwaves vary from other electromagnetic waves in the fact that they generate the molecular move in the alternating electric field without breaking the stability of chemical bonds. The energy carried by the microwave radiation is considerably smaller than the energy of chemical bond decay.

Electromagnetic waves undergo all physical phenomena that are characteristic for wave motion. They can be transmitted or absorbed and also undergo reflection, refraction, deflection, interference and polarisation.

Microwave radiation can be absorbed by matter through dipolar polarisation (dielectric), which is responsible for the microwave heating effect, and through ionic conductivity.

A device used in generating microwave radiation is the magnetron. The magnetron uses delayed electrons, which move on a coiling spiral and radiate microwaves. In magnetrons the microwave energy is generated from electric energy. Ca 50% of energy by the frequency 2.45 GHz and 85% by the frequency 0.915 GHz undergo energy transformation.

Microwaves have a negative influence on living organisms. The basic mechanisms of the influence that the electromagnetic field has on organisms include:
• a direct influence on cell walls (membranes) which may cause their: deformation, depolarisation (a change in the electric potential of a cell’s membrane), perforation or necrocytosis;
• an influence on ions move in electrolytes (which can have negative consequences for nerve conduction);
• a direct influence on water included in tissues;
• an influence on substances included in blood (for example, hemoglobin iron).

The magnetic field has a large impact on liquids. The following elements undergo changes in solutions exposed to microwaves: molecular structure of liquid, polarisation and arrangement of molecules and electric charge. Changes also occur in the course of surface phenomena, intensification of oxidation and reduction processes, selective ionisation and in such liquid characteristics as: density, viscosity, absorption of light and absorbance of solid bodies [20]. The scatter coefficient defines the liquid ability to absorb microwaves. This
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Microwave disintegration is characterized by the dielectric loss index, or the potential of changing an electromagnetic wave into heat, and by the dielectric constant.

Microwave radiation as a source of thermal energy has been applied in environmental engineering processes as well. The process of sewage treatment generates great amounts of sludge, whose storing and later application are expensive and only to a little extent are they managed. The sewage sludge includes more than 70% of water in its mass and the microwaves can considerably influence its characteristics and structure. Moreover, numerous bacteria, protozoa, yeast, fungi and parasite ova appear in the sludge and undergo destruction on exposure to the magnetic field [18].

Microwave heating is used for:
- sludge sanitation [18],
- sludge drying [20],
- an improvement of the activated sludge work [17, 19].

Materials and methods

The material for research comprised of activated sludge from a sewage treatment plant, applying advanced processes of biological sewage treatment, which consist of simultaneous elimination of organic compounds and bonds of nitrogen and phosphorus. The treatment plant was designed for the flow of 120,000 m³/d. For the time being, the amount of flowing sewage is ca 90,000 m³/d, sewage retention time ca 14 days and concentration of activated sludge in the bioreactor 4320÷4640 mg/dm³.

In the taken samples of activated sludge the COD value was analyzed [22], the protein concentration was determined by the Lowry method [23] and also the content of suspended solids, the change of turbidity and the Sludge Volume Index (SVI) [22].

Disintegration process was carrying by frequency of microwaves irradiation 2.45 GHz and nominal power 900W. Disintegration was carried out over periods of 30, 60, 90, 120, 150, 180, 210, 240, 270, 300, 330 and 360 seconds. COD value, protein concentration and the change of turbidity was measured for samples before and after each period of disintegration. 10 series of research were conducted and the standard deviation was calculated.

Results and discussion

Microwave disintegration of activated sludge caused changes in turbidity in every research series which is presented in Figure 1. The increase of turbidity was connected with the duration period of the microwave disintegration, which considerably influenced the decay of flocks and microorganisms' cells and also releasing matter into the liquid under research.

During the research the impact of microwave radiation on sedimentation properties of activated sludge was also determined. Figure 2 presents the changes of the SVI value under research with prolonging the time of the microwave field influencing the samples.

Average values of volume index reached the 195.5÷54.1 cm³/g. As presented in Figure 2, the greatest decrease of the index value was achieved up to the third minute of microwave disintegration, obtaining a change by 136.4 cm³/g. This change showed a definite improvement on sedimentation properties of sludge because low values of the
volume index, ca 100 cm³/g., indicate a high dewatering ability of sludge. Further prolonging the operation time of microwave radiation did not influence considerably the change of the analyzed parameter.

Fig. 1. Changes in turbidity in time of disintegration

![Graph showing changes in turbidity over time](image1)

Fig. 2. Changes of SVI in time of disintegration

![Graph showing changes in SVI over time](image2)

The microwave destruction of flocks and microorganisms in activated sludge causes a release of constitutional water by which dewatering becomes faster and concentration better. The conducted research indicated that treating the activated sludge with an electromagnetic field contributes to a change in sedimentation properties of activated sludge. It means that along with prolonging the operation time of microwave disintegration, the concentration of activated sludge gradually increased. Volume limitation
of generated sludge in technical scale could have a positive impact on processing the sludge and the possibility of its management which would also give a positive reflection on economic aspects.

Microwave radiation on microorganisms in the activated sludge had a destructive influence on the release of organic substances into the over-sludge liquid, expressed in the COD and protein concentration values. As conducted research showed, the effectiveness of the applied electromagnetic field depends mainly on the amount of radiation (operation time). The most effective amount (operation time) was a 3-minute exposition of sludge to the microwave radiation (Fig. 3).

![Fig. 3. Changes of COD value in time of disintegration in liquid phase](image1)

![Fig. 4. Changes of ratio COD value/suspension in time of disintegration in liquid phase](image2)
The COD values changed on average from 58.5 mg O₂/dm³ for the actual over-sludge liquid to 712.4 mg O₂/dm³ for a sample after a 5.5-minute exposition to the microwave radiation. The greatest increase of the COD value occurred in the beginning period of exposition, e.g., in the period from 0 to 3 minutes, where the increase amounted 482.7 mg O₂/dm³ on average. Further microwave disintegration caused an increase by another 171.2 mg O₂/dm³. The largest change in the COD value was visible by the sample, which was exposed to a 3-minute microwave radiation, where the increase of the index reached 135.2 mg O₂/dm³ (between 2.5 and 3 minutes). It may indicate that this period of time has the best impact on flocks in the activated sludge and the destruction of microorganisms cells, and thus on releasing organic matter into the surrounding liquid. As a result, it can be assumed that this period of time is optimal for the disintegration method under research in terms of the COD release. This fact can be observed by analyzing Figure 4, presenting the proportion of released COD and activated sludge suspension.

Using microwaves influences the increase in the proportion of soluble COD (sCOD = soluble Chemical Oxygen Demand) to total COD (tCOD = total Chemical Oxygen Demand) which has its reflection in the elevated content of organic substances released from sludge flocks. In our research, the ratio of soluble COD to total COD increased by 12% under the influence of 5.5 minutes microwaves treatment. In the research conducted at the University of Malaysia, the sCOD/tCOD coefficient increased by 45% under the influence of a 7-minute microwave treatment [20].

For additional confirmation of the organic matter release from activated sludge during the microwave disintegration process, the protein concentration in the researched over-sludge liquid was determined. The protein concentration was increasing along with the time of conducting the microwave disintegration process, similarly to the COD value change (Fig. 5).

![Fig. 5. Changes of proteins concentration in liquid phase during disintegration process](image_url)

The protein concentration, up to the third minute of the microwave treatment, increased on average by 284.4 mg/dm³ in the proportion to the protein concentration in the actual
over-sludge liquid, reaching the level of 310.6 mg/dm$^3$. Further disintegration of samples, up to the 6-minute exposition, caused an increase of concentration only by 72.7 mg/dm$^3$ (Fig. 5).

The protein concentration changes confirmed the observation on the highest effectiveness of the microwave radiation treatment of activated sludge during the first 3 minutes.

Conclusions

The research regarding the possibilities of applying the microwave radiation for activated sludge disintegration showed that the electromagnetic field operation has a destructive influence on flocks and microorganisms in activated sludge.

Exposing the activated sludge to (electro)magnetic waves treatment causes:

- an improvement on the sludge sedimentation properties,
- a decrease of the sludge volume index from 195.5 to 54.1 cm$^3$/g,
- disunity of the homogenous sludge structure and releasing organic matter,
- releasing organic matter into the over-sludge liquid which was indicated by the increase of the COD value from 58.5 to 673 mg O$_2$/dm$^3$ and the protein concentration from 26 to 366 mg/dm$^3$.

The conducted research shows that the application of electromagnetic radiation may become a new effective method, allowing for an improvement of sewage treatment processes and processing generated sewage sludge.

References


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Abstrakt: Mikrofalowa dezintegracja osadu czynnego jest przyczyną uwolnienia substancji organicznej do cieczy nadosadowej. Proces ten skutkuje wzrostem wartości ChZT w cieczy o ok. 614 mg O₂/dm³ i stężenia protein o ok. 340 mg/dm³. Promieniowanie mikrofalowe korzystnie wpływa również na zmniejszenie indeksu objętościowego osadu (I.O.O.) z wartości 195 do 54 cm³/g. Przeprowadzone badania potwierdzają, iż zastosowanie fali elektromagnetycznej może stać się nową, korzystną metodą pozwalającą na udoskonalenie procesów oczyszczania ścierek i przeróbki powstających osadów ściekowych.

Słowa kluczowe: osad czynny, dezintegracja mikrofalowa, ChZT, proteiny, indeks objętościowy osadu