Comparison of the Bacteria Destruction with and Without Gas Action and Cavitation

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***Abstract* – Various branches of petroleum, chemical and food industries cause significant damage to natural reservoir; outdated and imperfect technology forms a substantial amount of harmful waste and wastewater to the environment. Mostly businesses these industries consume large amounts of water, which in some cases used directly for manufacturing processes, while others – for the support and maintenance of technology, ie for treatment products and semi-finished products, washing packing container and equipment etc.**

Key words – cavitation, water disinfection, microorganisms, gas bubbling, bacteria aggregates.

I. Introduction

Number of works is dedicated to the investigation of cavitation effect in water by the indicating of its high efficiency in the viruses, protozoa etc. But at the same time, the researchers have noticed, that cavitation is highly effective nonchemical ecological method of water purification from organic and microbial components. It is clear that the need for a long disinfecting processing doubted the feasibility of using ultrasound for industrial conditions. Obviously, it is due to the result of an inadequate study of complex phenomena, which is accompanying with the cavitation effect, together with the ignorance of basic laws of the studied process that characterize the interaction of the components of water available to it specific organisms, the impact of additional gas supplied by the action of cavitation, etc.

II. Methodology

We have conducted complex of microbiology research of natural water from the lake in the Lviv region. In this water the *Diplococcus, Pseudomonas fluorescens, Bacillus cereus, Sarcina lutea* bacterias were detected. The bacteria *Bacillus cereus* was available in a huge number that is why it was chosen as the data to create model environment. The basis was to identify not only microscopy preparations like a "crushed drop", with the fixed preparations of cells to study their morphological criteria, including Gram staining, but the study of culture and physiological reaction (oxygen) microorganisms (MO) properties identified in the examined water.

The determination of the total number of MO in the water for the purpose of bacteriological study of universal culture medium used – meat peptone agar.

Cultivation was carried investigated by the MO depth method. MO was grown in an incubator at a constant temperature (37 °C) with the duration of 48 hours.

To investigate the impact of natural gas to the cavitation effectiveness of water treatment experiments performed under argon, helium, oxygen, carbon dioxide in the ultrasound field at atmospheric pressure, temperature of 298 K, ultrasound frequency – 22 kHz. Processing time 1-120 min. US oscillation frequency of 22 kHz low-frequency generator UZDN-2T (power 90 W) transmitted via magnetostriction emitter immersed in water volume study of the initial value of the number of known microorganisms (NM). Outputs NM machining water samples were in the range NM_0 = 820 – 2090 CFU/cm^3.

III. Description

The further research aimed at studying the simultaneous effect of gas and cavitation perturbed by the rod-shaped bacteria of *Bacillus cereus* family *Bacillaceae* an insignificant microbial contamination of water (NM_0 = 8*10^2 CFU/cm^3). In the short-term action of the acoustic field under argon, oxygen, helium and carbon dioxide gas ($t_{gas/US}$ = 60÷180 s) there was a sharp increase NM. Availability of simultaneous action of carbon dioxide and ultrasound led growth in order NM (2.4*10^3 CFU/cm^3) in the first three minutes of the experiment. The further steps of gas/ultrasound processes in all cases leads to a sharp reduction of NM throughout the whole treatment process.

For detailed studying of this phenomenon the microscopy of water samples before and after the joint gas/ultrasonic action was made. As the result, in the control water samples a large number of microbial units was revealed, while after t = 180 s system was dominated mostly by the separated cells. We can therefore say that the accumulation of microbial cells on the stage of the process and due process of disaggregation. Obviously, increasing the value of NM directly proportional to the number of cells in units identified in the initial samples of water, and may affect the process of disaggregation nature of the bubbling gas. The growth of NM in the presence of carbon dioxide by 1600 CFU/cm^3, in contrast to the growth in the presence of argon (only 100 CFU/cm^3) may have an impact on the final value of the NM.

Thus, when cutting in the ultrasound field water in which existing microbial aggregates is disaggregation dominant process in the presence bubbling gases, which in turn, is characterized by a determining influence on the overall efficiency of water disinfection. Therefore, the studying of the process of disaggregation would make the process without bubbling gases only in acoustic terms.

To study the process of disaggregation, the real natural water from lake was selected in the Lviv region. Samples of water were taken during the summer period (June and July), as the water temperature is the highest and the water level is the lowest, when the oscillations of NM are maximal.

The number of MO ranged 820÷2090 CFU/cm^3, depending on many physical and chemical factors: temperature regime of a reservoir, which influences on the growth of MO, the concentration of dissolved oxygen in water, the value of pH of water and redox potential, and also temperature of the air, quantity of the atmospheric precipitations, hydrodynamic regime of the reservoir, etc.

Investigating a joint action of gas/US on the example of bacteria *Bacillus cereus* at NM_0 = 800 CFU/cm^3, and the influence of acoustic cavitation on the natural water from the lake in the Lviv region with an increased content of bacteria *Bacillus cereus* at NM_{01} = 820 CFU/cm^3 and NM_{02} = 2090 CFU/cm^3, it was found a pattern of growth of NM at the first stage of acoustic cavitation process. The difference was only at the time of sound treatment, at which the maximal values of NM were observed.

The abrupt increase of NM was observed during a short-term action of acoustic field on the bacteria *Bacillus cereus* in atmosphere of carbon dioxide during the first 60÷180 s of experiment. At the joint action of cavitation and argon or helium, although there was observed an increase in NM at the beginning of the experiment, but with much lower maxima than at the joint action of carbon dioxide and cavitation. The exception was the action of oxygen, where the increase of NM was not observed.

When lake water is treated by a sound, NM reaches its maximal value after 1800 s of experiment in the absence of gas bubbling. By microscopic examination of the water, it was discovered the aggregates of MO of different types, while the number of single cells was negligible. Energy of acoustic cavitation at this stage was spent mostly on the breaking of the aggregates to the single cells, and the dying occurs more slowly than disaggregation. A similar picture was observed during the action of acoustic cavitation on the clusters of detected bacteria aggregates *Bacillus cereus* under atmosphere of argon, oxygen, helium and carbon dioxide. The decrease of the time spent on the breaking of aggregates in the water environment, is likely due to saturation of one or another gas, because in their absence only dissolved oxygen is available in aqueous solutions.

the obtained experimental data on disinfection of aqueous solutions from bacteria *Bacillus cereus* demonstrate the effectivity of simultaneous bubbling of gases and the action of US waves on the studied water environment. The presence of a gas decreases the accumulation period of the number of MO comparing with the water treated by a sound without gases in 10 times. Thus, for the water sample 1 NM_{max} = 1500 CFU/cm^3 for 1800 s without gas bubbling; and for the sample of water with a pure culture of bacteria *Bacillus cereus* with the same initial value NM, it increased accordingly: NM_{max} = 1100 CFU/cm^3 for helium, NM_{max} = 850 CFU/cm^3 for argon, and NM_{max} = 2400 CFU/cm^3 for carbon dioxide within 60÷180 s of the experiment. As it was found that the increase of the value NM is proportional to the number of cells in the aggregates, found in the initial water samples. Thus, the process of disaggregation is also affected by the nature of bubbling gas. In the atmosphere of argon, it was achieved the highest value of the sonochemical effective death rate constant of MO $k_d = 8.92*10^{-4}\ s^{-1}$, comparing with $k_d = 7.47*10^{-4}\ s^{-1}$ for oxygen, in the presence of which the increase of NM was never observed. In the atmosphere of carbon dioxide, where the highest value of NM_{max} was observed, the process of water disinfection from bacteria Bacillus cereus proceeds the most slowly, at the value of $k_d = 6.99*10^{-4}\ s^{-1}$. Calculation of the sonochemical effective death rate constants of MO once again confirms the expediency of the gas usage (in particular, argon) to disinfect the water from bacteria *Bacillus cereus*, compared with the use of only cavitation. Without bubbling of gases under the action of cavitation waves on water samples 1 and 2, only dissolved oxygen is available in the reaction medium, the amount of which is insufficient for the formation of additional centers of cavitation nucleations.

Conclusion

It was proved that the supply of gas in the first three minutes of the process promotes acceleration of breaking of bacterial aggregates in 10 times in the water environment at acoustic conditions, comparing with the process run in the absence of gas supply, where a similar process occurs after 30 minutes, due to a formation of additional cavitation nucleations during gas supply.