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pH VALUES OF SONICATED WATER IN GAS ATMOSPHERE

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The influence of pH reduction on water disinfection processes was described. Sonication role on the pH change in the atmosphere of carbon dioxide, oxygen, argon and helium was explained. It was found that bubbling of carbon dioxide under cavitational conditions does not provide rapid decrease of pH value in suspension, comparing with CO_2 bubbling itself. The obtained results give a promising explanation for the applications of sonochemistry in water treatment.

Keywords: sonication, carbon dioxide, oxygen, argon, helium.

Introduction

Nowadays cavitational treatment is widely used in water processing for removal of not only chemical pollutants [1, 2] but also biological ones [3, 4]. Sonication has attracted great attention in water treatment due to achieving its high efficiency of micro-organisms' destruction. The ultrasonic (US) treatment, gas bubbling and simultaneous gas/US treatment for the disinfection processes of sewage, natural water and microbial suspensions were investigated in our preliminary works [5–7]. But pH value has been changed after the gas/US treatment of water, and in the same time we are interested in the estimation of pH variation during and after sonication. The influence of gases itself on the change of pH in water medium is not still understood well. Therefore, several studies were conducted by us with the aim of the more detailed consideration of this process that may be important in water technology. Hence, the objective of the current study is to investigate the pH change of suspension in the presence of gases of different nature with and without cavitation.

Experimental Procedure

The investigated water objects were the model microbial suspensions, prepared by adding microbes of Bacillus cereus bacteria type into the distilled water, where the dissolved gases were previously removed from model water by boiling for 10 minutes. Bacillus type was used as dominant microbial species identified in the natural water according to our experiments [5].

The source of ultrasonic waves was UZDN-2T generator with the frequency of 22 kHz, power of 35 W and intensity of 1.65 W/cm3. Ultrasonic vibrations were transmitted by magnetostrictive radiator, immersed into the investigated water. The pH value of microbial suspension was measured before and after the experiments using pH-673 device. Sonication of water was carried out with the following parameters: T = 298±1 K, P = 0.1 MPa, the process time (t) was 2 h. Oxygen, argon, helium and carbon dioxide were used for the effective comparison as the gases of different nature. Suspensions were desilted for a long period of time at T = 295±1 K without any light and air access.

Results and Discussion

The results show that pH value significantly decreases only in the presence of CO_2. Carbon dioxide has a high solubility in the water medium (comparing with O_2, Ar and He) and forms chemical compounds with acidic properties (i.e. carbonic acid) in the aquatic medium, which apparently led to the pH decrease. But the decrease of pH value under the simultaneous CO_2/US action was observed less pronouncedly than during the bubbling of CO_2 itself. This fact indicates that US has an influence on the gas solubility in aquatic medium. Obviously, formation of cavitational zones accelerates CO_2 allocation from the water, which forms new gas bubbles and leads to their subsequent release from the system, i.e. CO_2 degassing process occurs during sonication. That's why degassing of CO_2, as well-soluble gas, prevents rapid reduction of pH during sonication.

The pH value has not changed significantly during the bubbling of O_2, Ar or He themselves and in the US field, probably due to their inability to interact with water in chemical reactions. The close pH variations in these cases were only observed at the bubbling of O_2, Ar and He with/without US action caused by the release of destroyed internal cellular water-soluble compounds with acidic properties from microbial cells into the water medium.

It should be noted that the highest efficiency of water disinfection without US treatment has been achieved during CO_2 bubbling (degrees of water disinfection – 90.0%), comparing with other investigated gases under the same conditions. Evidently, such efficiency was achieved due to the rapid decrease of pH in the CO_2 atmosphere. Hence, these results suggest that increased acidity of the aquatic medium cause active destruction of living bacterial cells.

Increased water acidity cause denaturation of microorganisms' protein components and lead to the microbial cells inactivation. But the disadvantage of acidification is high corrosive activity of the water that will have negative effects during the subsequent processes of water purification. That's why carbon dioxide cannot be recommended for the water disinfection.

The efficiency of water disinfection under simultaneous gas/US action is close to unity (99.8–99.9 %) and pH varies slightly, regardless the nature of the gas bubbled. The slight reduction of pH in the US field has no significant effect on the rate of microorganisms' destruction. Therefore, in these cases, water disinfection is achieved due to the direct mechanical damage of the cells caused by sonication.

It was found that pH values of these water systems are almost stable during a long period of time after the previous gas/US action, moreover regardless of the nature of gas bubbled (Fig. 1, *a-e*). It could be important in the further technological processes of water purification. The dependence of pH of exposure time consists of two stages: pH change during the first 3-5 days at the first stage, and its stability during the further 25–30 days (second stage). Some points presented in Fig. 1, *a* were measured two times in the same conditions

The slight decrease of pH at keeping the water system for the first 3-5 days after the previous US action (Fig. 1, *a*) and gas/US action (Fig. 1, *b-d*) is probably due to the dissolving carbon dioxide from the air; the slight increase of pH after the previous

CO_2/US action (Fig. 1, *e*) is probably connected with the release of dissolved CO_2 from water system (i.e. degassing).

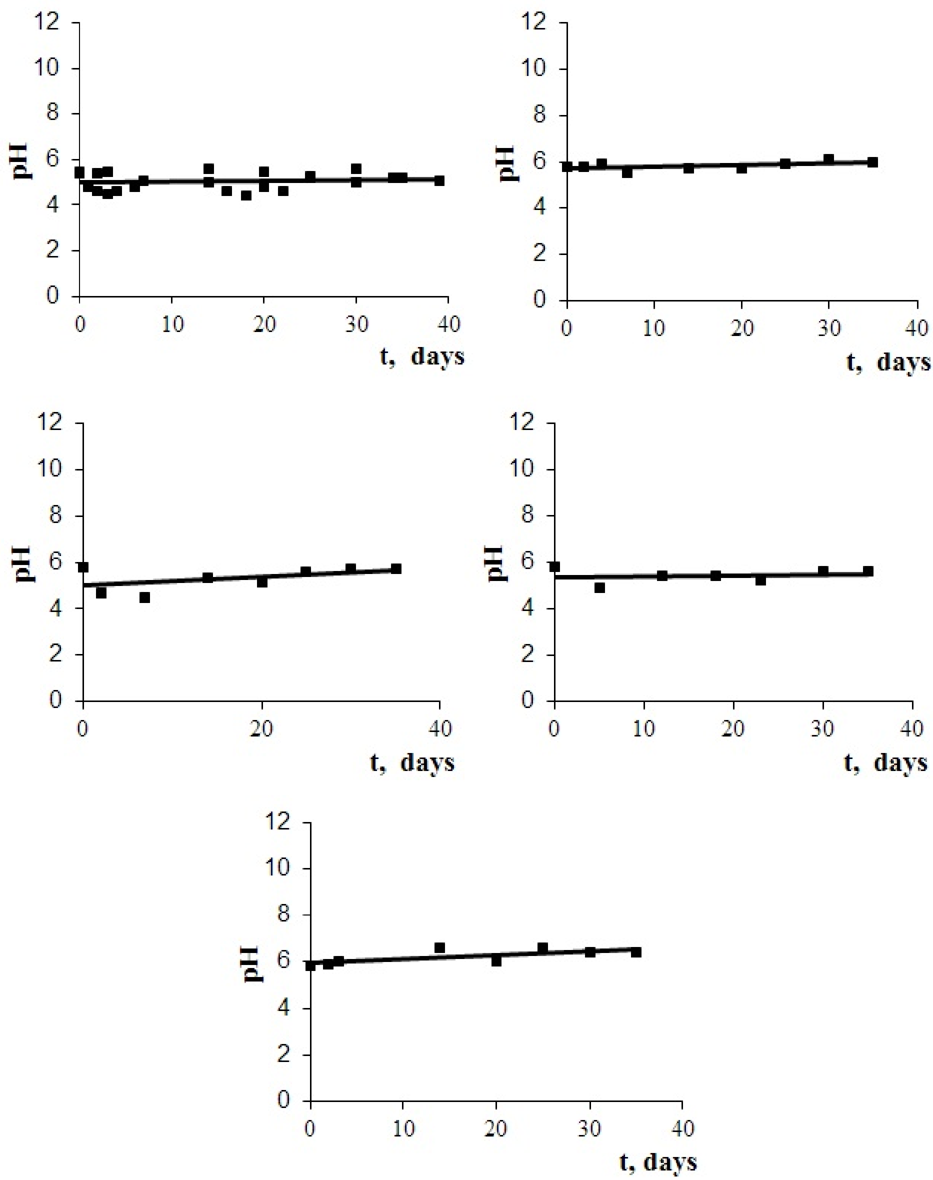

Fig. 1. Dependence of pH variation on exposure time after the previous treatments: US (a); Ar/US (b); He/US (c); O_2/US (d) and CO_2/US (e).

Conclusions

The influence of pH change regardless the gas nature bubbled through the suspension was found and explained experimentally. In the current work, slight change of pH was observed during the bubbling of CO_2 itself, while a significant pH value change was established under CO_2/US treatment, comparing with chemically inert O_2, Ar and He. The pH reduction in the CO_2 atmosphere was explained by increasing the water acidification. But our experiments indicated that pH decreasing under the simultaneous CO_2/US action does not have any significant effect on the microbial destruction in the water, which can be explained by the US ability to cause CO_2 degassing from suspension as a well-soluble gas. Therefore, under the CO_2/US treatment the pH didn't show significant variations from the initial value. The cell destruction is caused by the direct mechanical damage of the cell membranes under the US treatment. It was determined that CO_2 degassing under cavitational conditions is the main reason not leading to a rapid decrease of pH value.

Measurements have shown a slight deviation of pH during the first 3–5 days after the previous gas/US action that depends on gas nature; pH values are stable for the next 25–30 days, regardless the different nature of gases.

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РЕЗЮМЕ

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ЗНАЧЕННЯ pH ОЗВУЧЕНОЇ ВОДИ В ГАЗОВІЙ АТМОСФЕРІ

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Описано вплив зменшення pH на знезараження води. Пояснено роль озвучування на зміну величини pH в атмосфері вуглекислого газу, кисню, аргону та гелію. Встановлено, що барботування вуглекислого газу в умовах кавітації не приводить до різкого зменшення pH суспензії, порівняно з дією самого вуглекислого газу. Одержані результати несуть перспективне пояснення для застосування сонохімії у водопідготовці.

Ключові слова: озвучування, вуглекислий газ, кисень, аргон, гелій.

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