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High intensity ultrasound for the enhancement of water purification

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A B S T R A C T

The last stage of water purification process is advanced oxidation process which uses oxidation-reduction reaction. Chlorine and ozone is used for advanced oxidation process. Ozone is not well used even though it has strong oxidative power because of its low efficiency. We use cavitation of ultrasound to enhance the efficiency of ozone treatment in advanced oxidation process. To treat ozone with ultrasound in Bromophenol blue sodium salt (3',3",5',5"-Tetrabromophenolsulfophathalein sodium salt) solution, we made ozonation system, which is composed of acrylic tube, six ultrasound generators, and ozone generator. Results of UV spectrophotometer and mass spectroscopy demonstrated that carbon double bond in salt is degraded by oxidized ozone which support our expectation. This research provides starting point of further research on the degradation of other organic materials in water solution which will help humanity to deal with water pollution.

Key words: water purification, ultrasound, cavitation, ozone

1. Introduction

Water purification involves physical treatment, biological treatment, and advanced oxidation process, which decomposes residuals after physical and biological treatment. Since ozone has strong oxidation and high ability of sterilization, it is often used in advanced oxidation process. However, higher cost and low efficiency of ozone makes the quantity of it consumed lower than that of chlorine. As a solution for its low efficiency, we focused our research on high intensity ultrasound.

High Intensity ultrasound is accompanied with cavitation and streaming in the medium. High energy of ultrasound is used for direct reaction to matters or production of OH radical, which work as a strong oxidizer. We expected that the efficiency of ozone treatment in advanced oxidation process will be increased by cavitation. In addition, the molecular motion of fluid and ozone is activated, and it causes the rate of reaction between molecules increasing. What it means is that the ultrasound serves as a catalyst of chemical reaction.

In previous research, they treated advanced oxidation process using ozone on pharmaceuticals such as CBZ and enhance the efficiency of the process with ultrasound for application in industrial area [1]. Also, there is a precedent that applies the cavitation to 1,4-dioxane [2]. However, both of the research didn't reveal the exact mechanism of the reaction and showed only the result that the rate of reaction is influenced positively by the cavitation. Furthermore, they measured only BOD and COD to compare the effect of ultrasound on ozone molecules.

As they used specific organic molecules in their research, our research is focused on Bromophenol Blue Sodium Salt, which is also named as 3',3",5',5"-Tetrabromophenolsulfophathalein sodium salt.

In present work, we measured not only COD but also UV spectroscopy, mass spectroscopy and NMR spectroscopy to find out the exact mechanism of the degradation of dye samples and the effect of cavitation on ozone molecules.

2. Materials and Methods

2.1. Materials

To get more objective results, enhance reliability of experiment and figure out the oxidative reaction ozone exactly, we specified the object of study on certain dye, Bromophenol Blue Sodium Salt (3',3",5',5"-Tetrabromophenolsulfophathalein sodium salt) which is water soluble and has carbon double bond that can be decomposed by oxidized ozone [1]. It has maximum absorption spectrum in 383nm and 589nm.

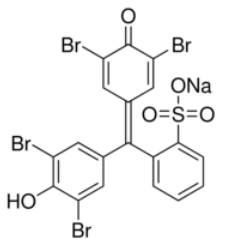

Fig 1. The structure of Bromophenol Blue Sodium Salt

2.2. Apparatus

A graduated cylinder with ultrasound generator was used for simple qualitative experiment. PVC tubes were for a transfer of ozone from ozone generator

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to dye solution. For more sophisticated experiment, we made an ozonation system. It is composed of two 2-liter water tanks, an acrylic tube, an ozone generator and six ultrasound generators. The ozone generator is made from Ozonetech where the ozone generator is named as OZT-1207PWR. The amount of production of ozone is 36.3mg/hr. The ultrasound generator is made from Kodo technical research company and its technical name is U-sonie generator NXGD-3F. Three different frequencies are allowed – 28kHz, 45kHz and 100kHz. The acrylic tube is 60cm long which has six holes on its one side and six ultrasound generators on the other side. It is manufactured as following blueprint below.

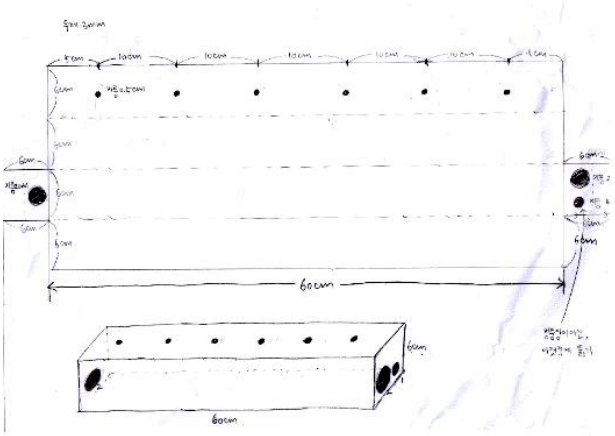

Fig 2. The blueprint of acrylic tube

For analysis, we can use COD, mass spectroscopy, UV spectrophotometer and NMR spectroscopy. We can use COD kit that is made from Dongchun chemical which is named Eco Watch COD measurement kit.

2.3. Experiment using a graduated cylinder

We prepared $1x10^{-5}$M Bromophenol blue sodium solution in graduated cylinder, and provided ozone and ultrasound directly into it using PVC tube. Then, we checked the color change per minutes. We can put samples into UV spectrophotometer and checked changes of the wavelength that has maximum peak in absorption spectrum for all samples.

2.4. Experiment using the ozonation system

We prepared $1x10^{-5}$M Bromophenol blue sodium salt solution 3 liters in water tank. PVC tube connected the water tank and the acrylic tube. We flowed Bromophenol blue sodium salt solution into acrylic tube as flowing ozone in the same direction at the same time by controlling three variables - time, frequency, and addition or rejection of ultrasound. We collected samples from each six holes at the same time. We observed the difference of color and COD of each samples. We can figure out the mechanism by mass spectroscopy, UV spectrophotometer and NMR.

3. Result

3.1. Color change

Following figure is the color change in graduated cylinder. Each square is a part of the picture of the graduated cylinder that is taken per minutes. We can observe that the color of Bromophenol blue sodium salt get fainter as time goes. Our result shows that the component of solution is changed due to ozone treatment with ultrasound which means the degradation of Bromophenol blue sodium salt.

Fig 3. The color change of dye solution

4. Discussion

Our result shows that the degradation of Bromophenol Blue Sodium Salt is increasing as more ultrasound is provided by the color change which is measured by naked eyes. It highly supports our expectation that the reactivity of ozone molecules is increasing due to ultrasound treatment. Here, to consider more variables related to ozone reactivity and cavitation, we will do on experiment on the ozonation system. By analyzing the result with highly accurate experimental device, such as mass spectroscopy, we will be able to support our research quantitatively, and find out exact mechanism of reaction between ozone molecules and Bromophenol Blue Sodium Salt.

5. Conclusion

In conclusion, by treating ozone with high intensity ultrasound, we can enhance the oxidation of ozone, thereby increase the amount of the decomposition of the organic material, Bromophenol Blue Sodium Salt. We expect further research on the exact condition that can maximize the effect of cavitation on ozone to deal with other organic materials and water purification.

Acknowledgment

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References

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