

Experimental study on ultrasonic treatment of reclaimed water

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Abstract: Through the test in the laboratory, the removing effect of ultrasonic pretreatment process on e.coli, TOC, UV₂₅₄, SUVA was studied. The experimental results show that ultrasonic has certain inactivated effect to e.coli. When ultrasonic action time is 30min and ultrasonic density is 0.75 w/mL, the removal rate of e.coli is 85%; Ultrasonic pretreatment has obvious removal effect on TOC, UV₂₅₄, SUVA. When the ultrasonic action time is 30min and ultrasonic density is 0.75w/mL, TOC, UV₂₅₄, SUVA removal rates were respectively 75%, 25%, 20%.

Introduction

The serious shortage of available water resource has already restricted the sustainable development of social economy, the recycle of wastewater becomes one of the effective ways to solve this problem. Ultrasonic technology is developed as a new water treatment technology in recent years, which combines advanced oxidation technology, pyrolysis and supercritical water oxidation. It has advantage of simple operation, mild conditions, widely applicable, clean, efficient, no secondary pollution, and has broad prospects for development^[1,2]. The main mechanism of the ultrasonic kill microorganisms and degradation of organic pollutants in thermal effects, mechanical effects and free radicals caused by cavitation^[3,4,5]. The author regard a secondary urban sewage treatment plant in jinan, China as the research object, and studied ultrasonic power and ultrasonic action time on removal efficiency of e.coli, UV₂₅₄, SUVA, TOC, looking for optimal conditions of ultrasonic processing to apply the results to engineering practice.

Materials and Methods

Materials

The test water from a sewage treatment plant in jinan, the sewage treatment plant process as follows: inflow water→mechanical coarse grid cyclone grit chamber→biological anaerobic tank pool→efficient secondary settling tank sedimentation tank→high efficiency fiber filter→disinfection→the plant effluent. Experimental raw water is the high efficiency fiber filter effluent of sewage treatment plant, raw water quality indicators are shown in Table 1.

Table 1. Water quality of test water sample

E.coli (CFU/L)	UV ₂₅₄	SUVA	NH ₄ ⁺ -N(mg/L)	TOC(mg/L)
10 ⁶ ~10 ⁷	0.224~0.240	0.8~0.861	0.5~0.7	26~30

Experimental methods

Effect factors of ultrasonic treatment efficiency include ultrasonic power intensity, ultrasonic action time and characteristics of water itself^[6]. Relevant data show the general strength of the ultrasonic power was indicated by the power by per unit volume liquid consumed that is ultrasonic density to represent. This experiment mainly study ultrasonic density and ultrasonic action time on water treatment effect. A 250 mL conical flask is filled test samples of 100 mL, using 20 KHz frequency ultrasonic respectively in ultrasonic density of 0.15, 0.3, 0.45, 0.6, 0.75, 0.9 w/mL and duration of 5, 10, 15, 20, 25, 30, 35, 40 min, ultrasonic treatment was carried out on the water under the conditions. After the sample was treated by ultrasonic, e.coli, UV₂₅₄, SUVA, TOC and other

indicators immediately were tested, then the analysis and research of the effect of ultrasonic treatment was carrying.

The experimental ways of water quality indicators (include total coliform count, UV_{254} , TOC) is based primarily on APHA "standard method for water and waste water detection"; "the reuse of urban recycling water-water quality standard for urban miscellaneous water consumption"(GB/T18920-2002) and "standards of reclaimed water quality"(SL368-2006). TOC and UV_{254} were measured by Shimadzu TOC detector and UV spectrophotometer. SUVA value is indirectly calculated by the formula, referring to ultraviolet absorption value(m) of the unit concentration DOC(mg/L), namely $UV_{254}/DOC \times 100$, while the DOC is used by Shimadzu's TOC detection analyzer.

Results and Discussion

The removal efficiency of ultrasonic treatment on e.coli

E.coli is the most important water hygiene control indicators and also the main indicators of disinfection effect. Basing on "the reuse of urban recycling water-water quality standard for urban miscellaneous water consumption"(GB/T18920-2002) and "standards of reclaimed water quality"(SL368-2006), total e.coli requirements of reclaimed water should not more than 3 cfu/L. The inactivation effect of ultrasound treatment on e.coli inactivation was shown in Figure 2.1.

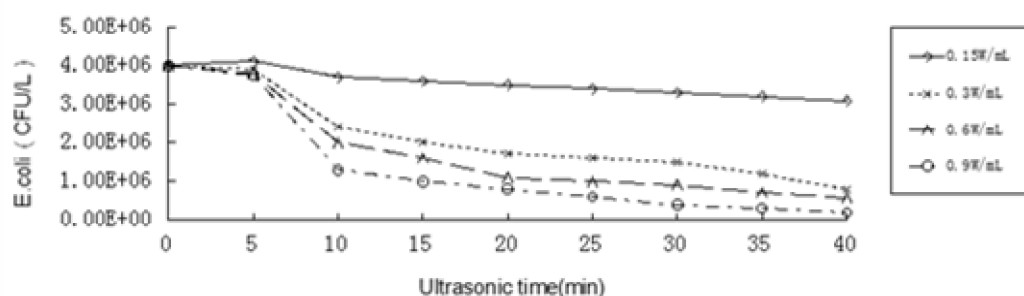


Fig 2.1 E.coli change with ultrasonic time under different ultrasonic density

Ultrasonic action time is a very important parameter, on the one hand, it decided the effect of ultrasound sterilization, on the other hand, it is the key reason for ultrasonic technology economy^[7]. The figure 2.1 shows that the ultrasonic density is 0.15 w/mL and ultrasonic action time of 5 min, e.coli number not only didn't reduce, but there are higher than the number of e.coli in the raw water; 5-10 min, the number of e.coli is rapidly declining, after 10-30 min, with the extension of time, the amount of e.coli reducing trend was slowly slowing down, until after 30 min, the number of e.coli decreased substantially longer. This shows that: when ultrasound density is small, the number of bacteria not only do not reduce but also there will be an increase trend after ultrasound treatment. That is, a small ultrasonic cavitation density does not meet the threshold, no cavitation, so it would not achieve sterilization, and the reason that only mechanical shear force play disperse bacterial groups. With the increase of ultrasonic density, sterilization rate is rising, because after reaching cavitation threshold, ultrasonic density increased with the increase of density of ultrasonic cavitation effect. Then the e.coli sterilization rate is no longer rising, the reason may be that ultrasonic density exists an optimal value, when density is more than this value, the ultrasonic cavitation effect will weaken or even disappear. Experimental results show that suitable ultrasonic density value of the research water samples is 0.75 w/ml.

After the sample was dealing with ultrasound short (5 min) process, the number of bacteria not only does not reduce, but also there will be a growing trend, which ultrasound machine dispersed some larger zoogloea into smaller zoogloea in a short period of time ultrasound, leading to an

increase the number of e.coli, so ultrasonic has no sterilization in a short little effect^[8]. Figure 2.1 shows that inactivation of e.coli was completed after ultrasonic dispersed Zoogloea and inactivation was completed within 30 min before sonication.

The removal efficiency of ultrasonic treatment on TOC

TOC is a comprehensive index number instead of organic matter, it represents the total amount of carbon-containing organic compounds in water. Since the determination of TOC combustion method, therefore organic matter can all be oxidated, it directly represents the total amount of organic matter than the BOD₅ or COD. TOC was often used as an important basis for evaluation of the degree of organic pollution of water bodies^[9].

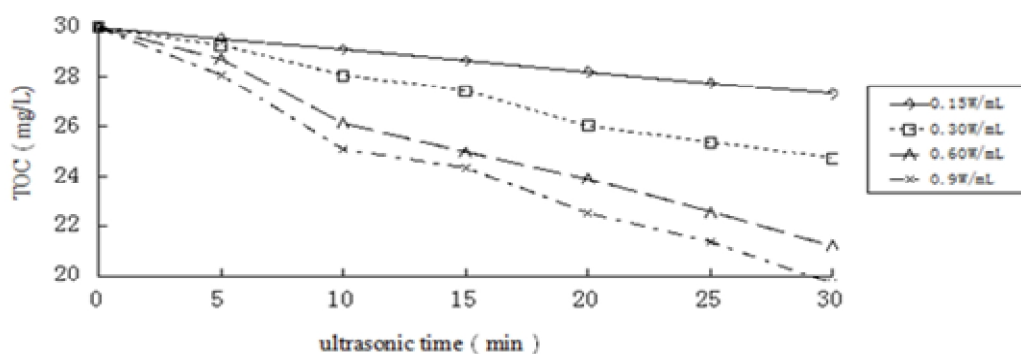


Fig 2.2 the TOC change with ultrasonic action time under different ultrasonic density

Fig 2.2 shown that the TOC was changing with the change of ultrasonic action time under different ultrasonic density. When ultrasonic density is 0.15 w/mL and ultrasonic action time within 30 min, the TOC was only reduced by 2.69 mg/L, removal rate of 8%, the TOC removal rate is relatively slow; When ultrasonic density is 0.6 w/mL, the removal rate can reach to 20%, the TOC removal rate was accelerated. But when ultrasonic density increases to 0.75 w/mL, the TOC removal curves gradually is slowing, at this point , the TOC concentration is 20.11 mg/L, and the removal rate is about 33%.

The causes of the above phenomenon is that the TOC is mainly influenced by cavitation effect process of heating and the effects of free radicals to complete, so the ultrasonic effect on the TOC is mainly accomplished by changing process of cavitation. Different water quality will have different cavitation threshold under the effect of ultrasound, when the intensity of ultrasonic power only close to or reach the cavitation threshold cavitation occurs after the reaction, so as to remove organic matter. In general, increase the intensity of ultrasonic power can make ultrasonic chemistry, but ultrasonic density increase to a certain limit, cavitation bubble is likely to grow too large, and not collapse under sonic compression, which affects the TOC removal effect.

The removal efficiency of ultrasonic treatment on UV₂₅₄

UV₂₅₄ value is the ultraviolet absorbance under 254 nm wavelength of some organic matter in water, reflecting the water containing natural macromolecular organic matter and humic type of C=C double bond and C=O double amount of aromatic compounds. A large number of experiments show that UV₂₅₄ can be used as a disinfection by-products precursor material substitution parameters, UV₂₅₄ is higher, the potential of by-products is greater^[10,11].

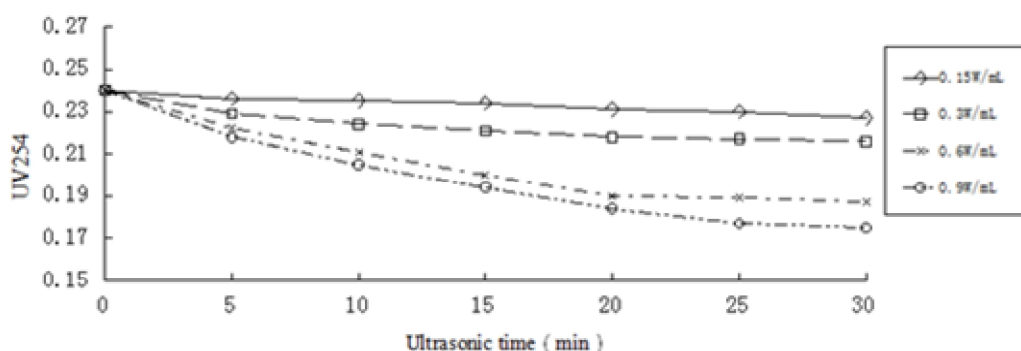


Fig 2.3 UV₂₅₄ change with ultrasonic action time under different ultrasonic density

As you can see from figure 2.3, when ultrasonic density is 0.15 w/mL, UV_{254} was slowly reducing. When the reaction time is 30 min, UV_{254} only decreased by 0.013, and the removal rate is about 5%; When ultrasonic density is 0.3 w/mL, UV_{254} removal effect is strengthened rapidly, after 0.75 w/mL, UV_{254} removal curves become gradually slowing. When ultrasonic density is 0.75 w/mL and ultrasonic action time is 30 min, UV_{254} is 0.18 and the removal rate is approximately 25%. The reasons for this phenomenon is that ultrasonic removal effect of UV_{254} was influenced by the heating effect of the cavitation process and effects of free radicals, and also will be affected by ultrasonic mechanical shearing action, the bigger the intensity of ultrasonic power, transfer the energy into the water, the higher the water molecules to vibrate more intense, the greater the hydraulic shear force, macromolecular organic matter and humic type of C=C double bond and C=O double bonds of aromatic compounds was broken down into small molecular compounds, so on the basis of an analysis of the mechanical action, the higher power intensity is, the more UV_{254} removal is. Of course, UV_{254} removal rate has same reason with TOC removal principle, and ultrasonic density increase to a certain limit, cavitation bubble is likely to grow too large, and not collapse under sonic compression, thus influencing the removal effect of UV_{254} .

The removal efficiency of ultrasonic treatment on SUVA

Specific ultraviolet absorbance (SUVA) value is the representative of the aromaticity of natural organic matter index, and it defined the unit DOC concentration (mg/L) as specific ultraviolet absorbance(m), that is $UV_{254}/DOC \times 100$. SUVA values higher raw water was usually thought that the aromatic tectonic mineralization degree is higher, and contains a lot of unsaturated bond, especially humic acid type organic matter content is higher, and humic acid type organic matter produced disinfection by-products after chlorining, thus reducing SUVA values has important significance to reduce disinfection by-products^[12,13].

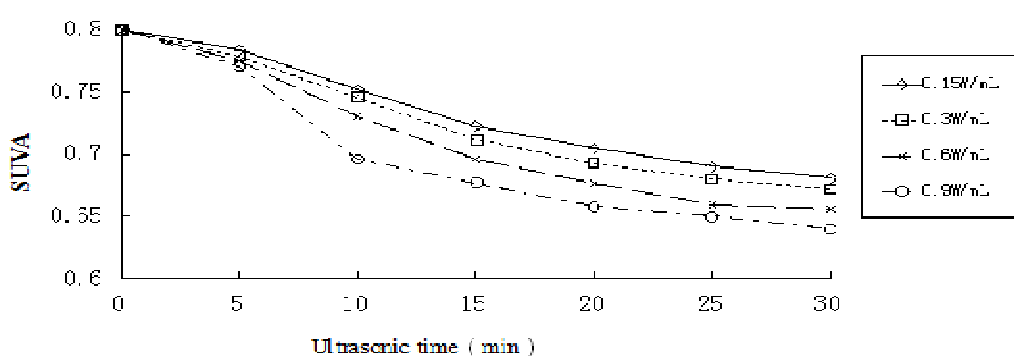


Fig 2.4 the SUVA change with the ultrasonic time under different ultrasonic density

As shown in figure 2.4, with the increase of the time, the removal of SUVA values has a overall downward trend. 0 to 5 min, SUVA values declined slowly; Between 5 and 20 min, SUVA values drop rate accelerated; After 20 min, SUVA values declined gradually smooth. when ultrasonic time is 30 min and ultrasonic density is 0.75 w/L, SUVA value reduced to 0.152 and removal rate is about 20%. The reducing reason of SUVA values may be the ultrasonic process caused by mechanical action leads to change of the DOC in water.

Conclusions

Ultrasonic pretreatment has a certain treatment effect on reclaimed water, under the best conditions of ultrasonic time 30 min and ultrasonic density 0.75 w/mL, the removal rates of e.coli, TOC, UV_{254} , SUVA were respectively 85%, 75%, 25%, 20%. Single ultrasonic treatment has a limited removal ability on e.coli and index of the organic matter, but far cannot meet the recycled water quality requirements, and from the angle of system energy, ultrasonic treatment alone is not economic. To make sure the effect of reclaimed water treatment and reduce the operation cost, ultrasonic treatment should be regard as a preprocessing method coupled with other water treatment technology, so as to strengthen the disinfection by-products precursor material removal and improve the treatment effect.

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