Sonochemical Reaction Kinetics in Open Flow Sonochemical Reactor

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Most laboratory scale sonochemical reaction were finished in closed sonochemical reactor (sonoreactor) for easy to control the reaction process and create well repetition. The typical work was Suslick and Henglein groups [10]. The industrial scale sonochemical reactor, such as waste water treatment sonoreactor, considering the economic run-cost, the air was selected as saturated gas [11-12]. For supplying a batch treatment, the open-flow sonoreactor was used. The sonochemical reaction kinetic property in flow sonoreactor was firstly investigated by Hoffmann and co-workers [13]. In recent years, we investigated the sonochemical reaction kinetics in the open sonoreactor [14]. In this research, we show the sonochemical reaction property in open-flow sonoreactor by using the Humic acid and DBS degradation.

The open-flow sonoreactor was contrasted with PFR reactor, the mass balance equation was as follow [13]:

\[ \frac{\partial C_s(V,t)}{\partial t} = -Q \frac{\partial C_s(V,t)}{\partial V} + \nu r(V,t) \]  

(1)

Where, \( C_s(t) \) is the concentration of Humic acid and DBS in reservoir and in sonoreactor, \( Q \) is the volumetric flow rate mixture, \( \nu = 1 \) is the stoichiometric coefficient for the reactant Humic acid and DBS, and \( r(V,t) \) is the first order reaction rate, which is given as \( r(V,t) = k(V,t) \).

Equation (1) was expressed as:

\[ C_R(t) = C_R \exp \left[ -\left( \frac{V_s^o}{V_s^o + V_R} \right) kt \right] \]  

(2)

Where, \( C_R(t) \) is the concentration in reservoir, \( C_R \) is the initial concentration in reservoir, \( V_R \) is the volume of sonoreactor, \( V_s^o \) is the volume of sonication. Compared with the volume of sonoreactor, \( V_s^o \) is a minimal value, (2) was written as

\[ C_R(t) = -C_R \left( \frac{V_s^o}{V_s^o + V_R} \right) kt \]  

(3)

\( V_s^o \) can be expressed by follow:

\[ V_s^o = V_s^0(i) \times N \]  

(4)

Where \( V_s^0(i) \) is the one bubble contribution to the degradation.

In the sound field, the cavitation bubble amount is \( N = 1/2 \pi f A f [1/R_f^2 + 1/R_a^2] \) [15], where \( f \) is sound frequency, \( A \) is a experimental constant. In our experiment, the sound frequency is 800kHz, sound intensity is 10W/cm², we have

\[ V_s^0 = \frac{1}{2} V_s(t) \times A f (5.16 \times 10^{10} - 2.46 \times 10^4 f^2) \]  

(5)

\( C_R(t) \) can be expressed as

\[ C_R(t) = -C_R \frac{V_s(t)}{V_s(t)} \times A f (5.16 \times 10^{10} - 2.46 \times 10^4 f^2) - 2y_R \]  

(6)

Formula (6) shows that the sonochemical reaction in open-flow sonoreactor is linearly
associated with sonication time.

The experimental results are as follow:

![TOC (mg/l)](image1)

![TOC (mg/l)](image2)

Fig 1 The TOC in humic acid solution as a function of ultrasonic irradiation time

Fig 2 The DBS in solution as a function of ultrasonic irradiation time

By using the PFR model, we presented the kinetic property of the sonochemical reaction in open-flow sonoreactor. In this kind of sonoreactor, the Humic acid and DBS degradation is linearly related with sonication time.

Keywords: Open-flow sonoreactor, Reaction kinetics, DBS and Humic acid degradation

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References: