The Effect of Gas Hold-up Structure and the UV Radiation Absorbing Properties of CVOCs on the Overall Reaction Rate During OH Radical Induced Oxidation Treatment in a Bubble Column Photochemical Reactor

1. Introduction

The use of chlorinated volatile organic compounds (CVOCs) such as tri- and tetrachloroethylene (TCE and PCE) is widespread and their frequent detection in groundwater, surface waters and soil has led to the need for the development of the alternative processes for their destruction. It is well known that the OH radical initiated reactions can lead to the mineralization of CVOCs in distilled water, whereas the efficiency in natural waters is decreased due to the presence of OH radical scavengers and UV radiation absorbers. Previously we have reported that the oxidation of PCE could be efficiently led in bubble column photochemical reactor applying the UV/H₂O₂ technique, combining the mass transfer of the PCE from the gas phase followed by a free radical reaction in the reacting liquid. The performance of the reactor could be predicted based on the ratio of the apparent first order constant to the volumetric mass transfer coefficient. The proper determination of the apparent rate constant in photochemical reactors depends among other factors on the correct determination of the absorbed radiation which itself is a quite complex task. In this work we do not intend to repeat the existing rigorous models, mainly based on the theoretical assumptions, but to determine the absorbed radiation in two reactor configurations having the radiation field scattered by bubbles (using two different gas distributors) and containing the UV radiation absorbing species.

2. Experimental

The radiation absorption was measured by photolytic decomposition of hydrogen peroxide in two 50 cm tall reactors, one made of stainless steel (l=3.85 cm) and the other of glass (l=6.5 cm). Two gas distributors (ring type and porous plate) were used to determine the effect of the gas hold-up structure on the oxidation process. H₂O₂ concentration was determined by the permanganate titration, and CVOCs by GC.

3. Results and discussion

The rate of substrate degradation can be expressed as a function of the incident radiant power (I₀), quantum yield (Φ) and effective optical density (Dₑff=Iₑffαc)

\[
\frac{dc}{dt} = I₀ΦVN(1 - e^{-2.3\text{I}_\text{eff}}) \tag{1}
\]

where \( l \) is the annular space between the wall of the reactor and the protecting quartz tube, \( R_f \) reflection factor (fitted to 8.3% for glass and 24% for stainless steel reactor) and \( 10^{-D} \) transmittance of the media. The relative error of the absorbed radiation with and without taking into account the reflection from the wall of reactors was calculated from

\[
\text{Error} = \frac{I_{\text{abs,eff}} - I_{\text{abs}}}{I_{\text{abs}}} \tag{3}
\]

The error in glass reactors (solid line, reflection within 5-10%) can be usually neglected however, neglecting the reflection in stainless steel reactor will result in erroneous predictions of the radiation absorption of 20% and more.

The effect of gas hold-up distribution on the oxidation process was shown to be negligible over the range of preliminary studies (\( u_G \) of less than 1 cm/s and gas hold-up of less than 0.05). We have speculated that the good correspondence between the radiation profile and gas hold-up structure might increase the degradation rate of the pollutant, however, up to now, we could not statistically confirm the difference obtained by the two gas distributors.

The oxidation rate of PCE at high initial gas concentrations was increased, probably because of some photolytic reaction occurred also in the gas phase. Further studies are on the way.


Tel: 03-5286-3210  Fax: 03-3209-3680  E-mail: stsuneda@waseda.jp