Chemical Engineering Journal 210 (2012) 9–17

Contents lists available at SciVerse ScienceDirect

Chemical Engineering Journal

journal homepage: www.elsevier.com/locate/cej

Sonochemical degradation of estradiols: Incidence of ultrasonic frequency

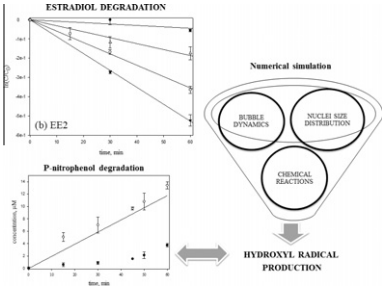
Mauro Capocelli [a,*], Eadaoin Joyce [b], Amedeo Lancia [c], Timothy J. Mason [b], Dino Musmarra [d], Marina Prisciandaro [a]

[a] Dipartimento di Ingegneria Industriale, dell'Informazione e di Economia, University of L'Aquila, Viale Giovanni Gronchi 18, 67100 L'Aquila, Italy
[b] Sonochemistry Centre, Coventry University, Priory Street, CV1 5FB Coventry, United Kingdom
[c] Department of Chemical Engineering, University "Federico II" of Napoli, Piazzale V. Tecchio 80, 80125 Napoli, Italy
[d] Department of Civil Engineering, Seconda Università di Napoli, Real Casa dell'Annunziata, Via Roma 29, 81031 Aversa (CE), Italy

HIGHLIGHTS

- Higher ultrasonic frequencies increase the removal efficiency of E2, EE2 and PNP.
- The efficiency is mainly related to hydroxyl radical production.
- The optimal frequency depends also on the bubble collapse intensity and duration.
- We model a total amount of hydroxyl radicals which agrees with experiments.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 17 April 2012
Received in revised form 10 August 2012
Accepted 23 August 2012
Available online 31 August 2012

Keywords:
Sonochemistry
Estradiol
Numerical simulation
Advanced oxidation process
Ultrasound frequency

ABSTRACT

This paper presents an experimental study of the ultrasonic degradation of organic pollutants in terms of the effect of ultrasonic frequency (40–380–850–1000 kHz). The removal efficiency of two endocrine disrupting compounds [17β-estradiol (E2) and 17α-ethinylestradiol (EE2)] is investigated using laboratory scale ultrasonic baths at low power intensities. Higher ultrasonic frequencies were found to be more effective for pollutant degradation with 850 kHz the best: 9.0×10^{-1} mg/kW h for E2 and 6.8×10^{-1} mg/kW h for EE2 at initial concentrations of 1 ppm. Additionally, the removal of p-nitrophenol was investigated under the same conditions, as a dosimetry reaction for estimating the hydroxyl radical production, key component in organic pollutant removal. In order to describe the overall phenomena occurring inside the reactor and to predict the apparent hydroxyl radical production, a simulation algorithm is proposed. It incorporates the solution of ODE systems that embodies bubble dynamics, heat and mass transfer through the bubble wall and chemical reactions in the gas–vapor phase for an initial bubble nuclei population. The experimental degradation measures of p-nitrophenol over the range of frequencies studied were found to be comparable with the model results of hydroxyl radicals produced during the sonication treatment.

1. Introduction

In recent years a number of new and complex chemical compounds have appeared in the effluent streams of wastewater processing plants as direct result of human activities; among the compounds causing most emerging concern are a group of organic pollutants such as estradiol, known as endocrine disruptor chemical (EDC). The discharge of EDCs (particularly estrogenic hormones) into the environment affects water quality and also impacts on the health of wildlife and humans [1–3]; moreover, several researchers attribute some changes observed in reproductive and developmental effects to the presence of EDCs in water [4–6]. Effluents from treatment plants are a major source of β-estradiol (E2) and 17α-ethinylestradiol (EE2) across the globe because conventional wastewater treatment is not effective in

* Corresponding author. Tel.: +39 0817685942.
E-mail address: mauro.capocelli@univaq.it (M. Capocelli).

1385-8947/$ - see front matter © 2012 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.cej.2012.08.084