Original Articles

Application of Acoustical Processor Reactors for Degradation of Diazinon from Surface Water

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Abstract

Background: Since organophosphorus pesticides are widely used for industry and insect control in agricultural crops, their fate in the environment is very important. Pesticide contamination of surface water has been recognized as a major contaminant in world because of their potential toxicity towards human and animals. The objective of this research was to investigate the influence of various parameters including the influence of time, power, and initial concentration on degradation of diazinon pesticide.

Methods: The sonochemical degradation of diazinon was investigated using acoustical processor reactor. Acoustical processor reactor with 130 kHz was used to study the degradation of pesticide solution. Samples were analyzed using HPLC at different time intervals. Effectiveness of APR at different times (20, 40, 60, 80, 100, and 120 min), concentrations (2, 4 and 8 mg/L) and powers (300W, 400W, 500W) were compared.

Results: The degradation of the diazinon at lower concentrations was greater in comparison to higher concentrations. There was also direct correlation between power and diazinon degradation. In addition, when the power increased, the ability to degraded diazinon increased.

Conclusion: The sonodegradation of diazinon pesticide at different concentrations and powers was successfully provided. It has been shown that APR can be used to reduce the concentration of dissolved pesticide using high frequency.

Keywords: Diazinon, acoustical processor reactor, initial concentration, power, time

Introduction

Pesticides are known to be carcinogenic, mutagenic, teratogenic and simultaneously resistant to destruction in environment. Organophosphorus pesticides are extremely toxic, acting on acetyl cholinesterase activity (Safi 2002). Diazinon [O, O-diethyl-O- (2-isopropyl-6-methy-4-pyrimidinyl) phosphorothioate] is a commonly used insecticide in the organophosphate chemical family. Diazinon decomposes above 120° C and is susceptible to oxidation. It is stable at pH 7.0 and can persist in the environment for as long as six months (US EPA 1986, WHO 1998).

Many reports for sonochemical treatment of water and wastewater plants have been considered (Krueger and Seiber 1984, Norwood 1990, Somich 1990, Benito et al. 2005, Dehghani et al. 2006, 2007a, 2007b, 2008, Asakura et al. 2008). Mahvi et al.

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2009). A variety of physical and chemical methods are employed for the removal of aqueous pesticides. Several techniques to eliminate pesticides have been so far considered, like ozonation (Legube 1987, Benitez 1995, Asakura 2005,), adsorption by activated coke (Battaglia 1989, Richard 1991, Mason and Lorimer 2002,), ultraviolet irradiation and hydrogen peroxide (Peterson et al. 1988, Raha and Das 1990, Battacharya 1994, Baron et al. 1994, Benitez 1995 b, Bellobono et al. 1995, Boisdon and Cacite´ de la 1995, Bourgine et al. 1995, Mansour et al. 1997, Huston and Pignatello 1999, Bachman and Patterson 1999).

Acoustical Processor Reactor (APR) has been used to induce or accelerate a variety of reactions. These reactors have a board range of industrial applications, including water and wastewater treatment (Suslick 1994, Suslick and Crum 1997, Suslick and Price 1999, Joyce 2002, Gogate et al. 2003, Dehghani et al. 2008, 2010). Since 1990, there has been increasing interest in the sonochemical degradation of aqueous solutions both in water and wastewater decontamination (Laborde and Bouyer 1998, Destaillats et al. 2001,). The chemical effects of APR of aqueous environment are believed to be related with acoustic cavitations Ultrasound irradiation enhances chemical reactivity through cavitation, the formation of gas bubbles in a liquid, which rapidly expand and implode. The chemical aspects are realized during and immediately after collapse of a vapor-filled cavitation bubbles. Bubble collapse induced by cavitation produces intense local heating, high pressures (Hung and Hoffmann 1999, Beckett and Hua 2001,Wayment and Casadonte 2002, Mason et al. 2004, Hua et al. 2005, Dehghani and Changani 2006, Arrojo and Benito 2008,). These hot spots have temperatures of roughly 5000 K, and pressures of about 500 atm as well as the production of free radicals. These conditions provide several possible pathways of degradation, such as free radical attack. (Mason 1991, Hua et al. 1995, Hua and Hoffman 1997, Mason and Lorimer 1998, Crum et al. 1999, Hua and Pfalzer-Thompson 2001, Asakura et al. 2008).

The present research deals with the sonochemical degradation of selected diazinon pesticide in the APR. The objective was to determine the potential of batch reactor for degradation of diazinon in different conditions such as power, concentration, and degradation time.

Materials and Methods

Procedures

Sample was prepared by dissolving a measured volume of pesticide with 95% concentration in 1000 ml of distilled water in a volumetric vessel. All organic solvents (acetone, hexane) were of analytical reagent grade, supplied by Merk Company. Homogenized samples were pretreated at 18–20º C and then were placed in reactor. Reactor temperature was controlled with the help of condensation water surrounding the reactor. Therefore, temperature did not exceeded 18-20º C in all experiments. Diazinon pesticide samples were exposed to a fixed frequency of 130 kHz. Characteristics of the reactor and experiment conditions presented in Table 1 and 2 respectively. All sonicated solutions were analyzed for diazinon and degradation operation by HPLC at different time intervals. Characteristics of the HPLC system were as following (Table 3).

All the analyses were performed according to the procedures outlined in standard methods (APHA 2005).

Calculation method

The definition of diazinon degradation percentage (DP) was as follows:

$$DP = (C_1 - C_2) / C_1 \times 100$$

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Where DP (%) is the degradation percentage of the reactor,
C_1 is the initial concentration of diazinon (mg/l),
C_2 is the concentration of diazinon (mg/l) after reaction for (t) time

Statistical analysis

The degradation of diazinon using APR was analyzed statistically by SPSS 11.5 and Excel software. The data were analyzed using one way ANOVA, Post-hoc test and multiple regressions. The variables were degradation time, concentration and power. Degradation was depended variable.

Results

An aqueous solution of diazinon was sonicated in a batch reactor at different concentrations, powers, fixed frequency, and different times. During the sonochemical degradation, the concentrations of diazinon were determined and the ultraviolet absorption spectra of the aqueous solution of diazinon were measured.

Effect of initial concentration

The effect of initial diazinon concentration on the removal percentage is shown Fig.1, 2 and 3. Different initial concentrations resulted in different removal percentage. The removal percentage decreased with increasing initial diazinon concentration in the range of 2 mg/l(Mean= 95.3422 and SD= 3.40735), 4 mg/l (Mean= 91.6033 and SD= 2.84080) and 8 mg/l (Mean= 83. 8294 and SD= 5.89949) under sonication after 120 min. Clearly, the rate of sonochemical degradation was slow in the presence of high concentration of diazinon. On the other hand, the increase of diazinon concentration in the solutions significantly decreased the rate of diazinon degradation after 120 min. As expected, the degradation percentage is the highest for the lowest concentration. The best status for pesticide degradation was 2 mg/l under sonication after 120 min. One way ANOVA and Post Hoc test indicated that mean difference is significant ($P < 0.05$).

Effect of time

The effect of time on the degradation of diazinon was shown in Fig. 1, 2 and 3. The degradation percentage of diazinon was 90.83% (2 mg/l), 86.11% (4 mg/l) and 76.99% (8 mg/l) for 300 W (Fig. 1). In addition, degradation percentage was 96.11 % (2 mg /l), 90.95% (4 mg/l) and 84.54% (8 mg/l) for 400 W (Fig. 2). However, degradation percentage was 98.44% (2 mg /l), 94.07% (4 mg/l) and 88.98 % (8 mg/l) after 120 minutes for 500 W (Fig. 3). According to regression analysis using backward method, the mean difference is no significant. On the other word, degradation time is excluded variables.

Effect of pH

The results showed that sonolysis had no considerable effect on pH (6.8-7) of pesticide samples, and the minor change occurred were no significant.

Effect of temperature

In this study, the reaction temperature was controlled with condensation water surrounding the reactor bath. Therefore, experiments showed that temperature increase of pesticide samples during sonication had no considerable effect on degradation of pesticide.

Effect of acoustic power

The effect of power on the diazinon degradation was also studied for 300 W (Mean= 85.4694±6.14753), 400 W (Mean= 90.4689±5.61704) and 500 W (Mean= 94.8367±3.41482). One way ANOVA and Post Hoc test showed the mean difference is significant between removal efficiencies at

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0.05 level, when the power rose from 300 W to 500 W

According to statistical analysis, linear relationships equations were as follows:

Degradation ratio= 80.495 -1.922 concentration + 0.047 power

In addition, determination coefficient (R square) for above model showed that highest changes related to degradation efficiency depends upon concentration and power (R square= 0.937).

Table 1. Characteristics of acoustical reactor

Parameter	Characteristics
Power	300 W, 400 W, 500 W
Frequency	130 kHz
Reactor type	Basin
Flow type	Batch
Capacity	1.5 L

Table 2. Experimental conditions for degradation operations

Frequency (kHz)	Power (W)	Sonication time (min)	Initial concentration (mg/L)	Sample volume (mL)	Temp (ºC)	pH
130	300, 400 , 500	20, 40, 60, 80, 100, 120	2, 4, 8	200	18–20	6.8–7

Table 3. Characteristics of HPLC system

Column Inertsil	Mobile phase	Temperature	Detector UV	Flow rate
ODS – 2	CH_3CN/H_2O (65:35, V:V)	40 ºC	wavelength 210 nm	1mL/min
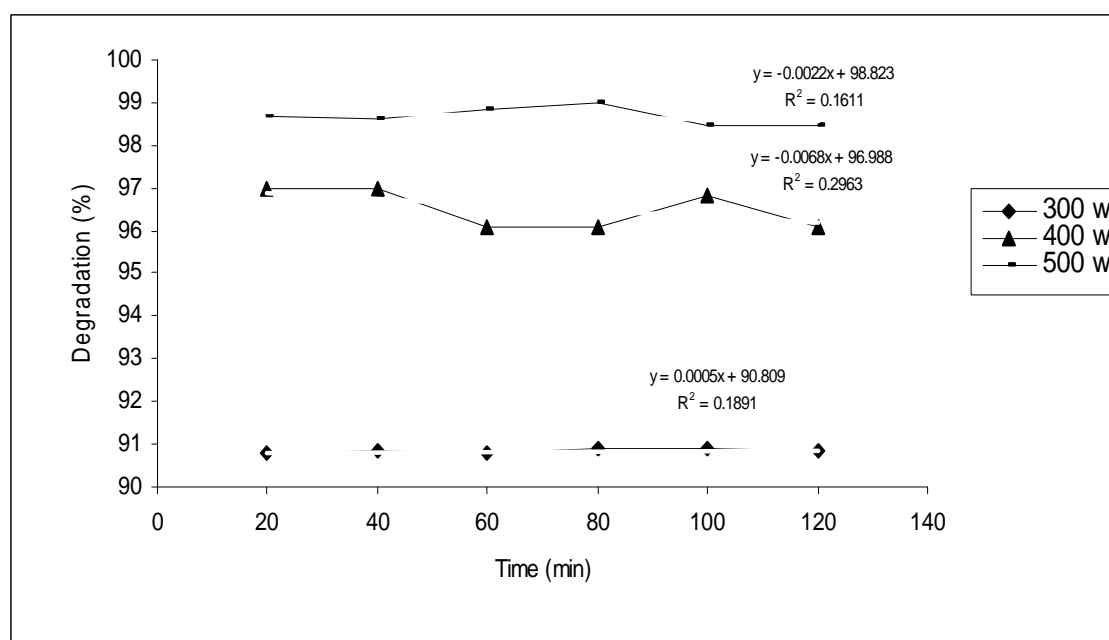
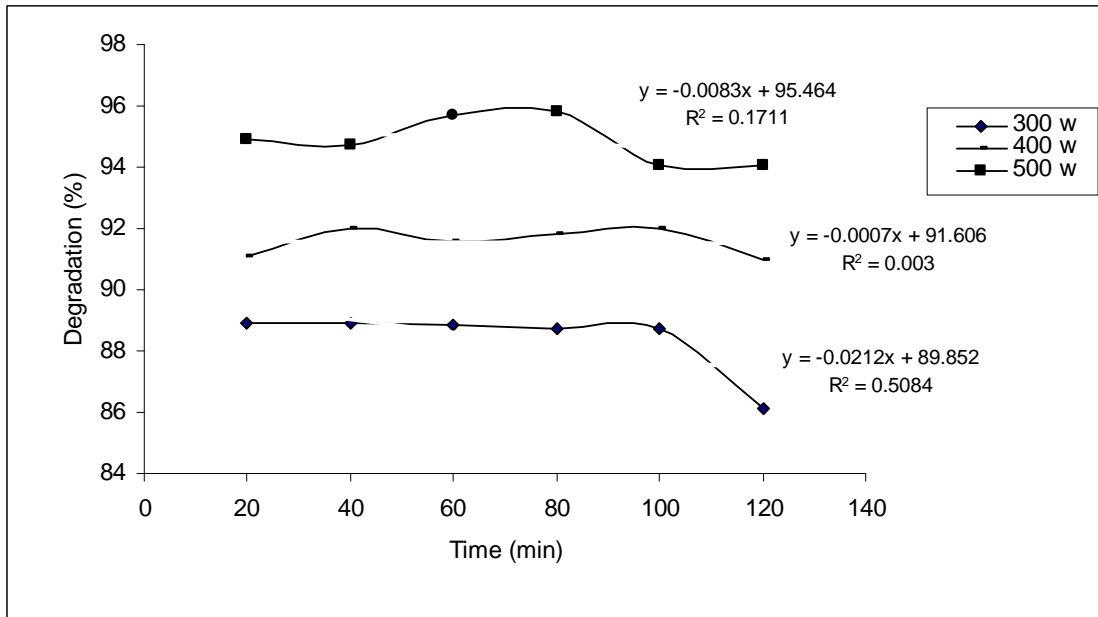**Fig. 1.** Comparison of degradation percentage at different powers for 2 mg/L

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Fig. 2. Comparison of degradation percentage at different powers for 4 mg/L
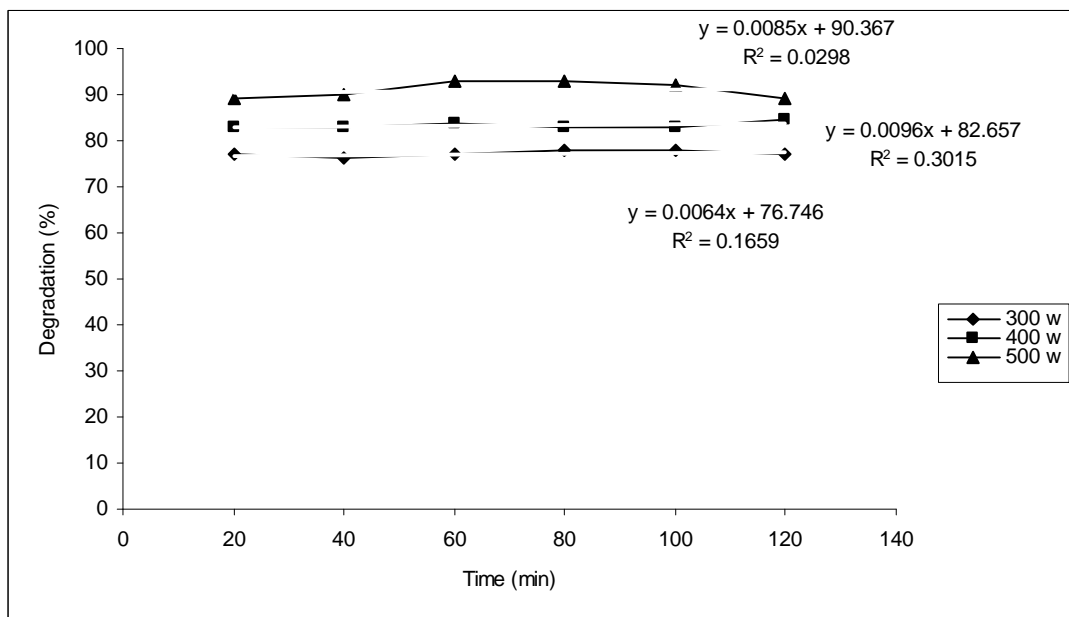

Fig. 3. Comparison of degradation percentage at different powers for 8 mg/L

Discussion

It is possible to degrade efficiently the diazinon pesticide in water by APR. Statistical analysis shows that power and initial concentration are effective parameters for degradation of diazinon.

Matouq et al. (2008) indicated that percentage of degradation rate of diazinon varies with initial concentration after exposing to irradiation which is basically the steady state phase. Matouq et al. (2008) re-

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ported that initial concentration decreases with time. Hua et al. (2001) indicated that a low pH is not required for sonodegradation of pesticide. Hua et al. (2001) reported that faster sonodegradation rates are observed at higher power densities.

Statistical analysis shows that power and initial concentration are effective parameters for degradation of diazinon. The best circumstance for sonodegradation was provided for lower initial concentration and the highest power after 120 min. On the other word, an increase in concentration results in decrease in the degradation efficiency.

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