Removal of Water Contaminants Using Nanotechnology

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ABSTRACT

Contamination of California ground and surface water by pesticides, including herbicides and fungicides, due to agricultural application is an important environmental issue that affects California welfare. Consumption of water contaminated by the pesticides can cause adverse effect on human health in both direct and indirect ways. It is necessary to develop new techniques and approaches for the treatment of contaminated water. We are developing a technique that combines nanotechnology and visible light radiations for the removal of pesticides from water. Propanil has been chosen for investigation in the present research project. Our preliminary data indicate that photocatalysis of Propanil containing water sample initiates the degradation of Propanil molecules in water. It is also found that the photocatalysis of the Propanil molecule in water follows the first order chemical kinetics, and the photocatalysis of Propanil was faster under the sunlight radiation than the light bulb radiation.

Keywords: nanotechnology, photocatalysis, water

1 INTRODUCTION

Removal of agricultural application related organic contaminants from water plays a pivotal role in recycle and reuse of water in agriculture and industry. It has been reported that a total of 195 million pounds and 189 million pounds of pesticides were used for agricultural practice in California in 2013 and 2014, respectively [1], among them Propanil is in the top 100 pesticides used list [1]. Because pesticides are relatively mobile and persistent in soil they can penetrate into ground water following their soil application by farmers. As a result, pesticides have been detected in surface and ground water in many areas of California with various concentrations [2-10]. Crops including vegetables and fruit could be contaminated if the water containing these pesticides were reused for irrigation. Research shows that consumption of well water contaminated with pesticides may play a role in the etiology of Parkinson's Disease in Rural California [11-12]. It is therefore imperative to remove the pesticides from the contaminated water prior to reuse of the water.

There are several techniques currently used for water organic contaminants removal, including Activated Carbon Adsorption [13], Chlorination [14-17], UV Photolysis [18-20], Ozonation [17, 21-23], Ferrate Oxidation [24-25], and UV radiation in the presence of nano-materials [26]. Although these techniques are useful in treating contaminated water, they have limitations in terms of removal completion, efficiency, rates, and operational costs. So it is desirable to develop new techniques and approaches aiming at pesticides degradation and removal for the treatment of contaminated water. We are developing a photocatalysis technique using visible light radiation in the presence of nanomaterials for removing agricultural organic pollutants from water to improve the water quality in a cost-effective way. This technique utilizes the large surface areas of the nanoparticles that help adsorb the pesticide molecules onto the nanoparticles, and incorporates transition metals into the nanomaterials that, when irradiated by visible lights, provide electrons for redox reaction to occur, which initiates the degradation of the pesticide molecules [26]. In this report we present our preliminary results of photocatalysis of Propanil using visible light radiation in the presence of nanomaterials.

2 EXPERIMENTAL

Figure 1 shows the schematics for the photocatalysis of Propanil in water. As show in the Figure 1, the water sample containing Propanil is placed in a reactor (either a beaker or Erlenmeyer Flask). A Pyrex tube coated with nanomaterials on the outer surface is also placed in the reactor. A visible light source is placed outside the reactor to generate the visible radiation for the photocatalysis process. We did experiments with two different light sources: a 15 W light bulb and the sunlight. The nanoparticles was synthesized in our laboratory based on the synthesis procedure of Lü et al. [26] with some significant modifications. The size of the particles are mostly on nanoscales. We analyzed the water sample using liquid chromatography coupled with mass spectrometry (LC-MS), Fourier Transform Infrared spectroscopy-Attenuated Total Reflectance (FTIR-ATR), and Ultraviolet-Visible (UV-Vis) spectroscopy.

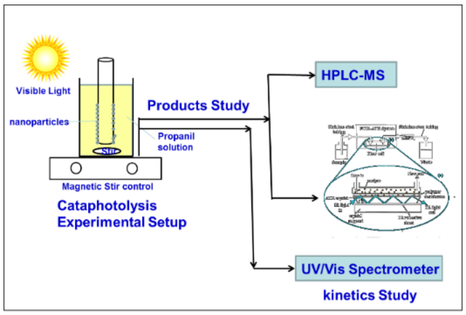

Figure 1: Schematics of experimental arrangement for the nanoparticle and visible light based photocatalysis experiments.

3 RESULTS

Figures 2-3 show our typical preliminary results of photocatalysis of 100 mL of 10 ppm Propanil water sample, with Figure 2a-b showing the UV-Vis spectrum and the kinetics data collected with the light bulb radiation, and Figure 3 showing UV-Vis spectrum collected with the sunlight radiation. The sunlight experiment started from 8:45 am and stopped at 5:00 pm. It can be seen from Figures 2a and 3 that upon exposure to visible light radiation in the presence of the nanomaterials the Propanil in water undergoes photocatalysis since its characteristic absorption peaks at λ = 207 nm and λ = 246 nm decrease as irradiation time increases, which results in a decrease of Propanil in the water sample.

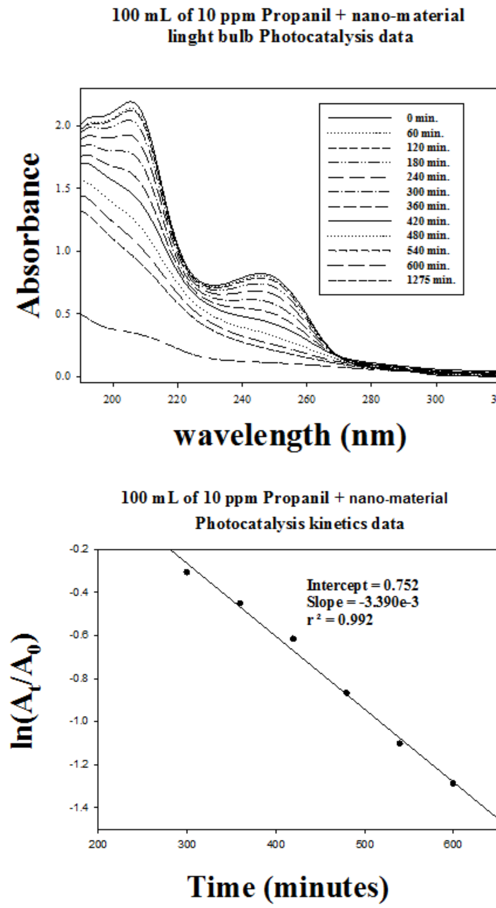

Figure 2: Typical spectral (a) and kinetics (b) data of visible light photocatalysis of 100 mL 10 ppm Propanil solution with light bulb.

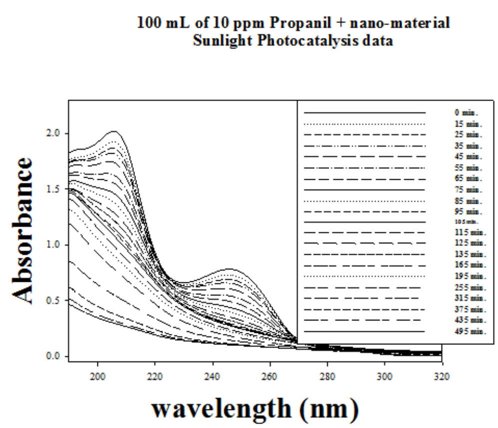

Figure 3: Typical spectral data of visible light photocatalysis of 100 mL 10 ppm Propanil solution with sunlight.

4 DISCUSSION

Our preliminary results indicate that the technique of nanoparticle and visible light radiation based photocatalysis can be applied to removal of Propanil from water, and the photocatalysis of Propanil follows the first order chemical kinetics under light bulb radiation. It is also found that the photocatalysis takes place faster under the sunlight radiation than under the light bulb radiation. Therefore this technique has a potential for the removal of pesticide compounds from water.

5 CONCLUSION

We developed a photocatalysis method, with use of both visible radiation and nanomaterials, for removing Propanil from water. The use of visible light as the radiation source allows efficient, low cost removal of Propanil from water, with the removal process following first order chemical kinetics. Our future work will focus on characterization of the photocatalysis products and extension the application of this technique to remove other pesticides from water.

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