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Removal of Pesticides from Aqueous Solutions Using Recycled Waste Hydrogel as a Low-Cost Adsorbent

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ABSTRACT

The free radical method was used for the synthesis of hydrogel, relying on environmentally friendly and available monomers such as acrylic acid (AC) and acrylamide (AM) in the presence of (CdS). The application of (AC-co-AM)/CdS hydrogel nanocomposite for the removal of Cypermethrin Pesticides (CYP) shows wide potential; as highly efficient absorbents for treating water contaminated with CYP under ideal conditions. The most important factors affecting the adsorption process, such as equilibrium time and hydrogel dosage, were studied. Optimal conditions for insecticide removal were found to be pH 9.0, equilibration time = 150 min, hydrogel weight = 0.1 g, concentration = 10 mg L −1. Temperature had a strong effect on the biosorption process. Moreover, the hydrogel was characterized by FESEM, TEM and XRD. Increased weight of hydrogel nanocomposite results in increase removal percentages; 0.1 g/L of weight of hydrogel resulted in 81.333 % absorption. The pH solution increased, with removal percentage of pH =2 (41.55 %) to pH=11 (89.78%) increased. (AC-co-AM)/CdS hydrogel nanocomposite surface has a very high efficiency in regeneration and use, so that it is characterized by its stability and high stability compared to (AC-co-AM) hydrogel, so that it is characterized Stability of 5 cycles (81.67% to 70 .22%). Overall, the present study suggests that this environmentally friendly, effective and low-cost hydrogel may be useful for removing insecticide from aqueous solution.

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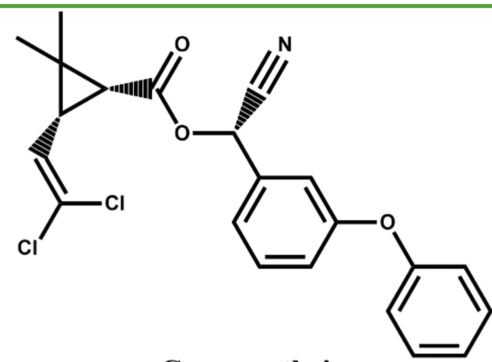
Graphical Abstract



Cypermethrin

Introduction

Agriculture has been revolutionized in recent years with the introduction of pesticides. Reliance on the use of pesticides has increased dramatically, and it has guaranteed a fixed number of annual returns without major fluctuations. Thus, now day's market-oriented agriculture makes heavy use of pesticides to determine the demands of the world's population [1, 2]. Pesticides can be defined as "any mixture or substance of substances intended to prevent or mitigate any pest (weed mites, insects, nematodes, mice, *etc.*) that have a harmful effect on agricultural crops and lead to crop damage [3-5]. Insecticides can be used in various fields such as transportation, forestry, crop protection, vector-borne disease prevention, food processing industry, wood storage and protection [6].

Pesticides can be in different forms, such as herbicides, rodenticides, fungicides, algaecides, and nematicides. They can also be classified depending on their mode of action and efficiency, target organisms, toxicity levels, sources of origin, and formulations. Depending on their chemical structure, pesticides can be classified into several categories: organophosphorus pesticides, organochlorine pesticides, pyrethroids, carbamates, urea derivatives, and organosulfur [7, 8] .

Pesticides are chemical substances used to control pests and include herbicides, insecticides, fungicides, nematicides, and others. The most widely used and common are herbicides, which are used daily to control pests out of the total number of pesticide uses worldwide. Most pesticides are used as plant protection products (also known as crop protection products), which generally protect plants from fungi, weeds, or insects. A pesticide is a biological or chemical agent (such as bacteria, viruses, or fungi) that deters, hinders, kills, or otherwise inhibits pests [3, 4]. Cypermethrin is a synthetic parathyroid that is widely used as an insecticide [4, 6]. As shown in Figure 1.

A large amount of water could be retain by a hydrogel in a swollen state within its network [9, 10]. The functional group of this surface play a major role in adsorption of water, this depend on the chemical; structure of adsorbent and adsorbate [11-14].

The cross linker can be mentioned as materials that can interconnect molecules furthermore enhanced the hydrogel surface properties. The use of cross linker in hydrogels to form the 3D structure increases molecular weight, provides higher mechanical properties, improves stability, and affects physical properties such as polymer elasticity, viscosity, and polymer insolubility [15-17]. Hydrogels are widely used in manufactures [18, 19].

The aim of this study is to develop an environmentally friendly, cost-effective hydrogel nanocomposite using recycled waste materials for the efficient removal of Cypermethrin pesticides (CYP) from aqueous solutions. Given the increasing reliance on pesticides in modern agriculture and their widespread presence in water sources, there is an urgent need for effective water treatment solutions. This work seeks to investigate the adsorption capabilities of an (AC-co-AM)/CdS hydrogel nanocomposite under various conditions, such as pH levels, hydrogel dosage, and equilibrium time, to optimize its performance. Additionally, the study aims to characterize the hydrogel nanocomposite using techniques like FESEM, TEM, and XRD to understand its structural properties and evaluate its regeneration potential for repeated use in water purification processes.

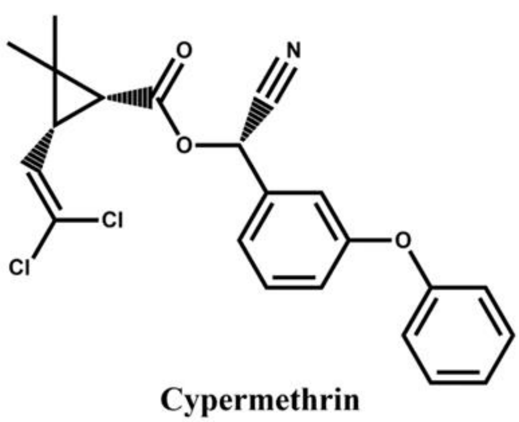
Materials and Methods

Preparation of (AC-co-AM)/CdS hydrogel nanocomposite

Preparation of (AC-co-AM)/CdS hydrogel nanocomposite by dissolve CdS in 0.1 g in 5mL distilled water and acryl amide in 0.5 g/20 mL distilled water, and added 3ml of acrylic acid stirring for 10 min at 20^{0}C and CdS solution is added to solution. Then, KPS added via 0.05g/1 mL distilled water, MBA 0.08 g /1mL distilled water to solution, processes happen in the presence of N_2 to form free radicals, the (AC-co-AM)/CdS hydrogel nanocomposite washed several times to get rid of any uncreative materials. Then hydrogel dried in an oven at 75 ^{o}C for 24 h.

Adsorption isotherm

The impact of adsorption dosage was applied via adding changed amount of (AC-co-AM)/CdS hydrogel nanocomposite of 0.05–0.2 g/100 ml solution. In adsorption equilibrium study, mass of (AC-co-AM)/CdS hydrogel nanocomposite 0.1 g in to 100-mL adsorbate with Pesticides concentrations of 1–10 mg/L at 20 ^{o}C and solution pH 9.2 pH solution adjustments were carried out via adding HCl 0.1 N or NaOH 0.1N. This experiment was conducted in batch adsorption for 2 h



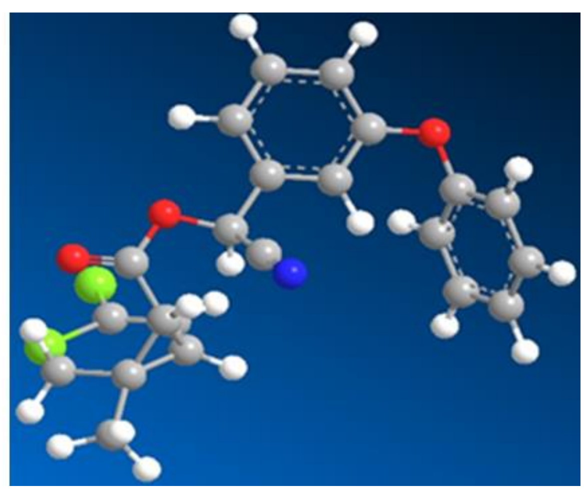


Figure 1. Chemical Structure of Cypermethrin Pesticides (CYP) : left) 2D; right) 3D

After the adsorption constant was reached, the CYP concentration was calculating via UV–visible spectrophotometer at maximum wavelength 290 nm. The adsorption efficiency (Qe mg/g), and removal percentage E % in Equations 1 and 2.

$$E\% = \frac{Co - Ce}{Co} \times 100 \quad (1)$$

$$Qe = \frac{(Co - Ce)Vml}{W\,g} \quad (2)$$

Where Qe (mg/g) adsorption capacity, E% removal percentage, Ce equilibrium concentration (mg/L), Co (mg/L) initial concertation, W(g) weight of hydrogel and V (ml) volume of CYP .

Result and Discussion

Through Field Emission Scanning Electron Microscopy (FE-SEM) method, the features of (CD-co-AM)/CdS nanocomposite hydrogel for before adsorption and after loading pollution] were studied This method gives us information of presents of a particle in the polycristalline or single crystal form, about its shape, if particles aggregate and what is the surface. Besides, it contributes to determining the porosity and surface roughness as well as the incorporation of hydrogel nanocomposite onto a substrate [16, 20].

It clearly infers from FE-SEM pictures, seen in Figure (2a,b) that the surface of hydrogel nanocomposite is smooth. The surface is wrinkled with many randomly aggregated folds. But the above-mentioned Morphological shows of the sample surface changes from the other view after adsorption. An irregular structure the van cause an increase in the surface roughness and porosity [19, 21].

Transmission Electron Microscope (TEM) has a vital role in determining the properties and morphology of surfaces and helps in controlling the surface behavior. Figure 3 show an image of TEM (high resolution) that present a nanocomposite hydrogel (AC-co-AM)/CdS with CdS bulk background color and the thinner and darker parts have size diameter average of 200 nm, The TEM also shows the distribution of particles on the surface, and some aggregation of them into darkish aggregates (aggregates generated by adding CdS NPs) was also observed [22-24].

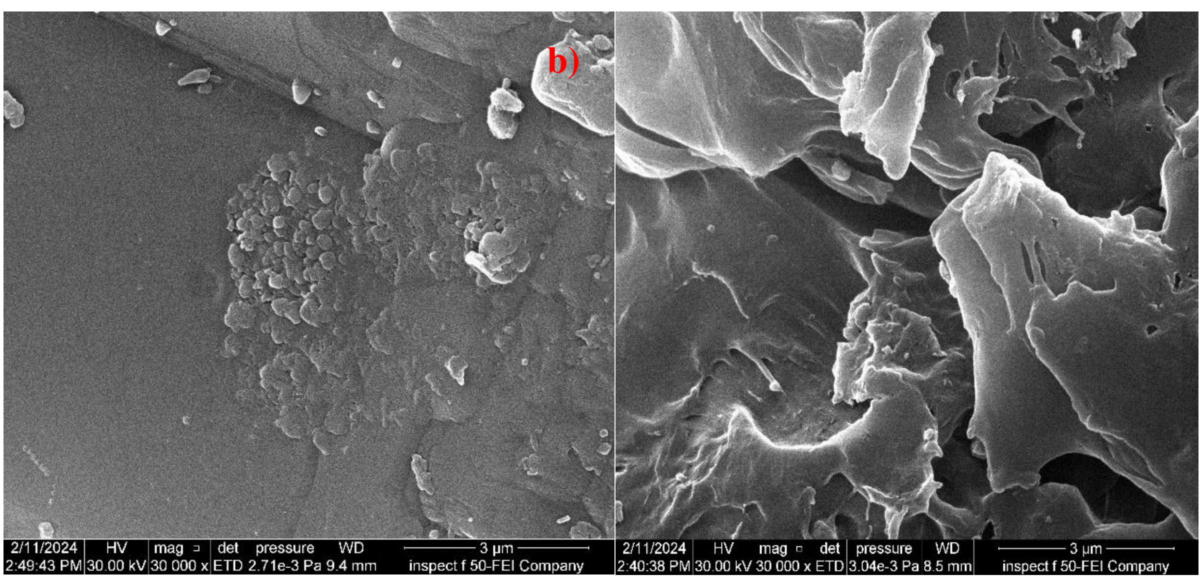


Figure 2. FESEM image of (AC-co-AM)/CdS hydrogel nanocomposite before adsorption, b) hydrogel nanocomposite after adsorption

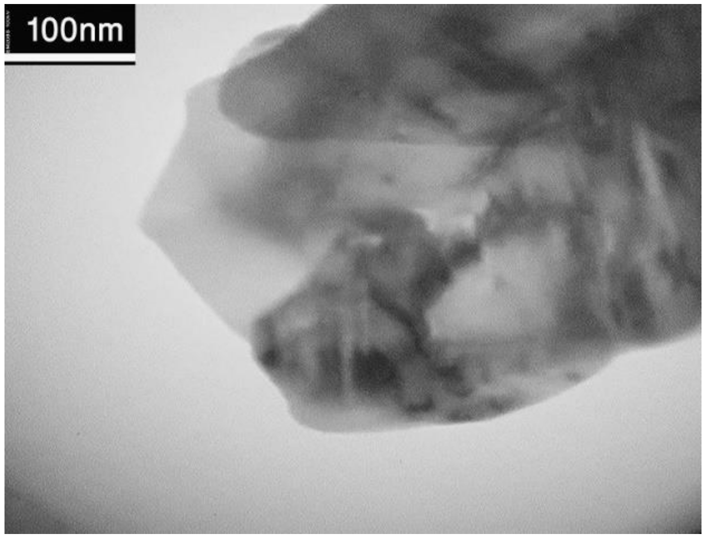


Figure 3. TEM image of (AC-co-AM)/CdS hydrogel nanocomposite

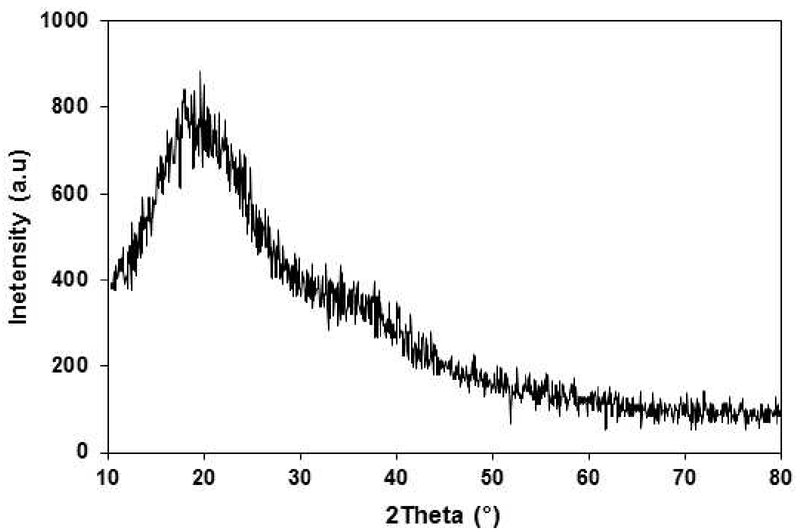


Figure 4. XRD diffraction of (AC-co-AM)/CdS hydrogel nanocomposite

XRD analysis

The synthetic materials' structural characteristics in the (AC-co-AM)/CdS hydrogel nanocomposite were analyzed using the XRD technique. The obtained XRD pattern for the (AC-co-AM)/CdS hydrogel nanocomposite is shown in Figure 4. The peaks appeared at values of 18.3° and 32.2°, which align well with the values of the literature. The broadening of the peaks is due to the amorphous nature of the hydrogel [1, 25].

Effect of weight of hydrogel nanocomposite

The effect of adsorbent dose (AC-co-AM)/CdS hydrogel nanocomposite on to Pesticides adsorption was studied in the series of several doses (0.05-0.2 g) at pH=7 and concentration of Pesticides 10 mg/L (Figure 5).

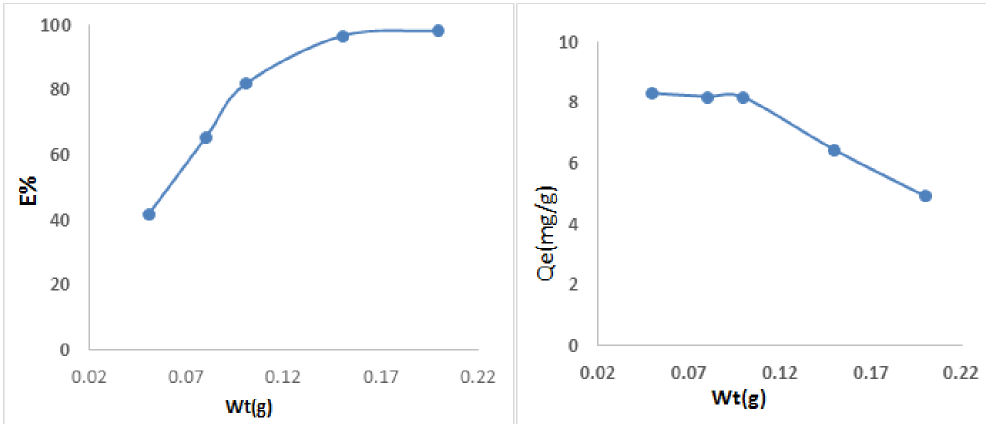


Figure 5. Effect of weight of hydrogel nanocomposite on to removal of CYP

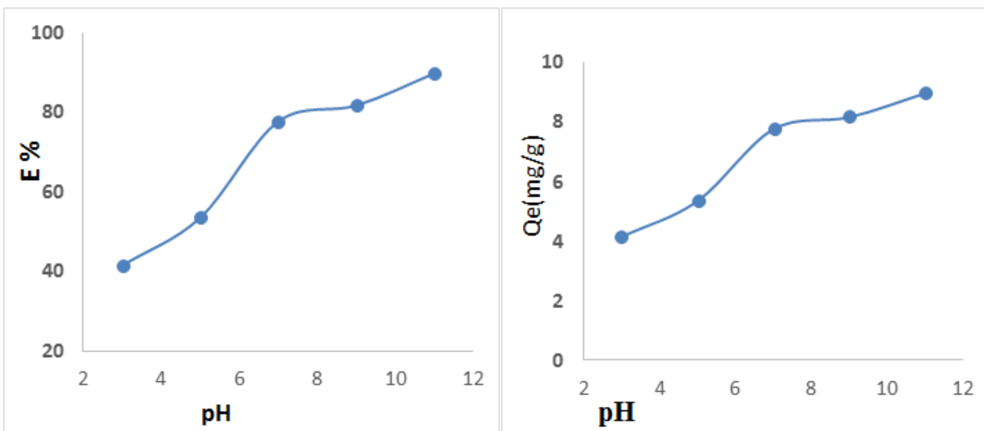


Figure 6. Effect of pH solution onto removal CYP by hydrogel nanocomposite

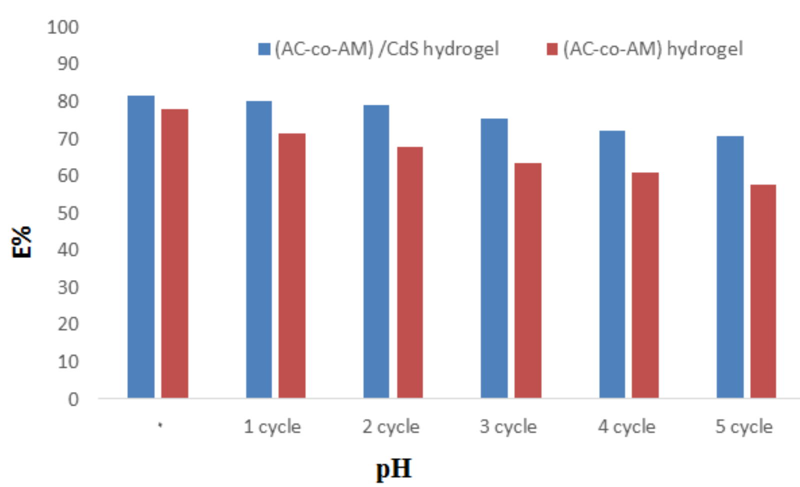


Figure 7. Effect of Reactivation of AC-co-AM) hydrogel and (AC-co-AM)/CdS Hydrogel nanocomposite

Increased weight of hydrogel nanocomposite results in increase removal percentages; 0.1 g/L of weight of hydrogel resulted in 81.333 % absorption [26, 27]. The enhancement in percentage removal with increasing adsorbent weight could be clarified via the presence of extra adsorption active sites on the adsorbent. Because of the strong competition among the adsorbent and active sites on the adsorbent, the percentage removal remains essentially constant at an adsorption mass of 0.1 g [28, 29] .

Effect of pH

Effect of pH solution via adjusting the pH of the CYP solution from 3.0 (hydrochloric acid 0.1 N) to 10.0 (sodium hydroxide) while maintaining constant hydrogel weight (0.1 g), the role of acidic media on the adsorption effectiveness of hydrogel was tested. Figure 6 shows the adsorption capacity that increased with increasing of acidic media. Adsorption capacity rose relatively when the pH of the solution was altered from 2.0 (Qe =4.152 mg/g) to pH 11.0 (Qe =8.976 mg/g). Also, it was found that as the pH solution increased, with removal percentage of pH 2.0 (41.55 %) to pH 11.0 (89.78%) increased [5, 30].

Reactivation of hydrogel nanocomposite

To know the surface efficiency of the prepared (AC-co-AM)/ hydrogel and after loading (CdS) onto hydrogel to increase the surface efficiency and reactivate it to reduce the economic cost and also reduce secondary pollution [31]. After the adsorption process, the (AC-co-AM)/CdS hydrogel nanocomposite and (AC-co-AM) hydrogel surfaces is washed more than once with distilled water to get rid of the contaminant and obtain a clean surface that can be used a second time to remove the contaminants.

It is noted that the (AC-co-AM)/CdS hydrogel nanocomposite surface has a very high efficiency in regeneration and use, so that it is characterized by its stability and high stability compared to (AC-co-AM) hydrogel, so that it is characterized Stability of 5 cycles (81.67% to 70 .22%) [12, 32] as shown in Figure 7.

Conclusion

In this study, an environmentally friendly free radical-based hydrogel was prepared from natural and synthetic monomers to remove CYP from drinking water. (CdS) is loaded onto the hydrogel to increase the surface area and surface efficiency for removing pollutants from the aqueous solution. Adsorption capacity rose relatively when the pH of the solution was altered from 2 (Qe =4.152 mg/g) to pH=11 (Qe =8.976 mg/g). Also, it was found that as the pH solution increased, with removal percentage of pH=2 (41.55 %) to pH=11 (89.78%) increased. increased weight of hydrogel nanocomposite results in increase removal percentages; 0.1 g/L of weight of hydrogel resulted in 81.333 % absorption. hydrogel nanocomposite surface has a very high efficiency in regeneration compared with hydrogel, so that it is characterized Stability of 5 cycles (81.67% to 70 .22%).

Disclosure Statement

No potential conflict of interest was reported by the authors.

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Authors' Contributions

All authors contributed to data analysis, drafting, and revising of the article and agreed to be responsible for all the aspects of this work.

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