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Fabrication of light-responsively controlled-release herbicide using a nanocomposite

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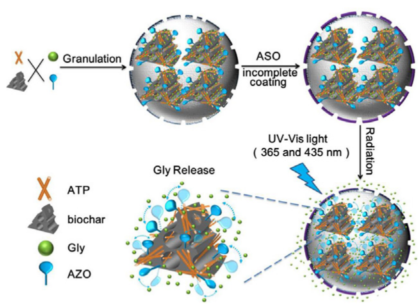
HIGHLIGHTS

- A light-responsively controlled-release herbicide particle (LCHP) was fabricated.
- LCHP consisted biochar, attapulgite, glyphosate, azobenzene, and amino silicon oil.
- Azobenzene acted as a light-motivated stirrer to promote glyphosate release.
- LCHP showed a higher adhesion ability and control efficacy on weeds than glyphosate.
- LCHP was stable against coexisting ions and pH.

GRAPHICAL ABSTRACT

A novel light-controlled release herbicide was fabricated using azobenzene as light-motivated "stirrers", which might have a huge application prospect in agriculture field.



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ABSTRACT

In this work, a light-responsively controlled-release herbicide particle (LCHP) with core–shell structure was developed using a nanocomposite composed of biochar, attapulgite (ATP), glyphosate (Gly), azobenzene (AZO), and amino silicon oil (ASO). Therein, nanonetwork-structured ATP distributed evenly in the pores of biochar to form porous biochar-ATP compound which acts as a carrier to efficiently load plenty of Gly and AZO molecules, obtaining porous biochar-ATP-Gly-AZO granule. Subsequently, the resulting biochar-ATP-Gly-AZO granule was incompletely coated by ASO, forming LCHP with abundant micro pores in the ASO coating. Under UV–Vis light radiation, trans-cis and cis-trans isomer transformation of AZO molecules will occur, acting as light-motivated "stirrers" to promote the release of Gly from LCHP through those nano pores. Thus LCHP displayed an excellent light-responsively controlled release performance, which could be also demonstrated by pot experiments. Importantly, LCHP possessed a good adhesion performance on surface of weeds leaves, which was greatly favorable for improving the control efficacy on weeds. Besides, coexisting ions (CO_3^{2-}, SO_4^{2-}, and Cl^-) and pH posed little impact on LCHP release in water, proving the high stability of this technology. Therefore, this work

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provides a promising approach to control the release and enhance utilization efficiency of herbicide, which has a potential application prospect.

1. Introduction

Pesticides have been applied in controlling weeds, pests, and diseases of crops worldwide, greatly contributing to maintaining agricultural productivity [1,2]. However, traditional pesticides tend to discharge into environment through leaching, volatilizing, and rainwater washing, resulting in a low utilization efficiency [3,4]. Importantly, pesticide loss posed severely adverse impacts on ecosystem and hazard to health of human beings [5–7]. As a result, developing novel technologies to control pesticide loss, enhance utilization efficiency (UE), and relieve the corresponding pollution is of great significance.

In recent years, a variety of slow release pesticides have been developed based on microcapsule [8], organosilicone [9], nanoadditive [10], polymers [11,12], tablets [13,14] etc. Those technologies could decrease the loss and increase UE of pesticide to a certain extent, nevertheless it was difficult to control their release to precisely fulfill the demand of crops and dramatically enhance the UE, which greatly restricted their large-scale application [15,16]. Therefore, development of controlled-release pesticides (CRP) has become one of the hot spots in agriculture and environment fields [17].

Until now, several kinds of CRPs have been fabricated using pH and temperature responsive materials [18,19]. The release could be efficiently adjusted by pH and temperature to match the demand of crops, resulting in a rather high UE [16–18]. However, they displayed some disadvantages: pH-responsive CRP might bring about negative effect on growth of plant attributed to the use of acid or alkaline solution, and temperature-responsive CRP exhibited high energy-consumption and complex operation [17]. Those disadvantages became the dominant limitation factors for their wide application. Hence, it is urgent to develop an environmentally-friendly and facile CRP.

Over the past several decades, light-controlled systems have been applied in various aspects such as drug delivery [20], materials fabrication [21], photo-catalytic reaction [22,23] and so on, owing to the advantages of simple operation and eco-friendly property. Herein, a novel light-controlled-release pesticide was prepared using light responsive material, which could be conveniently used in field and especially greenhouse with UV light facilities, displaying a higher application potential compared with pH and temperature responsive CRPs.

In this work, a light-responsively controlled-release herbicide particle (LCHP) was fabricated through incorporation of biochar, attapulgite (ATP), glyphosate (Gly), azobenzene (AZO), and amino silicon oil (ASO), and the fabrication procedure and mechanism were shown in Fig. 1. Therein, biochar and ATP, two natural and abundant micro/nano materials with environmentally-friendly performance and high adsorption abilities, were combined to form a porous biochar-ATP compound [24–27]. The biochar-ATP acted as the adsorbent for Gly which was a kind of widely used herbicide with high migration and toxicity for human beings [17,28]. Besides, AZO acted as a light-motivated stirrer to promote Gly release [20,29], and ASO acted as a coating with abundant micro pores for delivery of Gly and kept the shape of LCHP in water [17]. The release behavior and kinetics of Gly from LCHP in water under UV–Vis light with characteristic peaks at 365 and 435 nm was studied. Meanwhile, the influence of pH and co-existing ions including CO_3^{2-}, SO_4^{2-}, and Cl^- on the release was investigated to obtain the optimal condition of this technology. In addition, the adhesion performance of LCHP on weeds leaves was determined. Pot experiment was performed to evaluate the control efficacy (CE) of LCHP on weeds. In order to elucidate the mechanism, the interaction in LCHP system was analyzed. This work provides a novel approach with simple operation and environmentally-friendly properties to reduce loss and enhance UE of pesticide, which might have a high industrialization prospect.

2. Materials and methods

2.1. Materials

Rice husk-based biochar powder (black color, 100–200 mesh, bulk

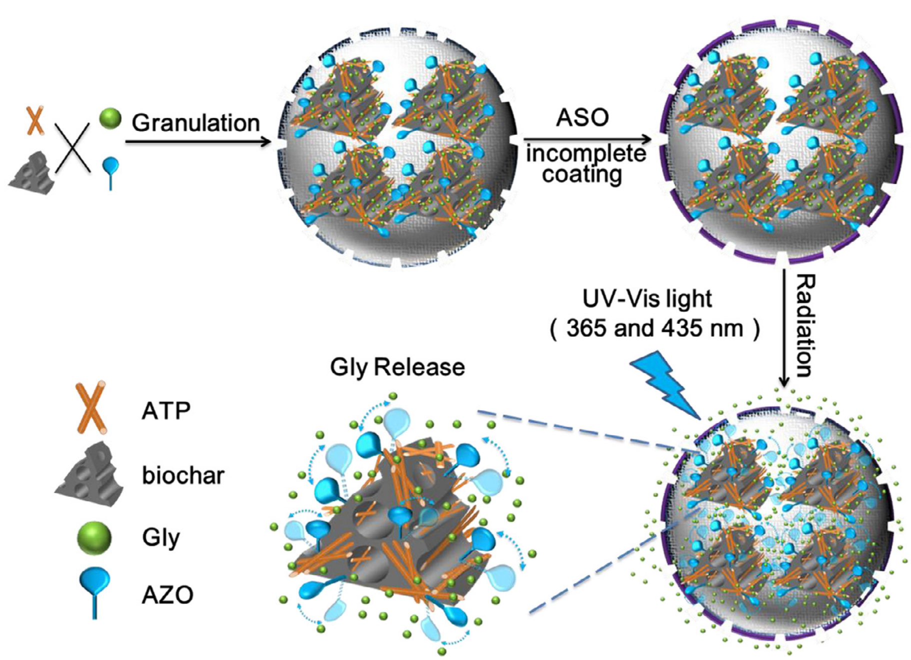

Fig. 1. Schematic illustration of fabrication and mechanism of LCHP.