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Review

Nanotechnology-based recent approaches for sensing and remediation of pesticides

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ABSTRACT

Pesticides are meant to control and destroy the pests and weeds. They are classified into different categories on the basis their origin and type of pest they target. Chemical pesticides such as insecticides, herbicides and fungicides are commonly used in agricultural fields. However, the excessive use of these agrochemicals have adverse effects on environment such as reduced population of insect pollinators, threat to endangered species and habitat of birds. Upon consumption; chemical pesticides also cause various health issues such as skin, eye and nervous system related problems and cancer upon prolonged exposure. Various techniques in the past have been developed on the basis of surface adsorption, membrane filtration and biological degradation to reduce the content of pesticides. However, slow response, less specificity and sensitivity are some of the drawbacks of such techniques. In recent times, Nanotechnology has emerged as a helping tool for the sensing and remediation of pesticides. This review focuses on the use of this technology for the detection, degradation and removal of pesticides. Nanomaterials have been classified into nanoparticles, nanotubes and nanocomposites that are commonly used for detection, degradation and removal of pesticides. The review also focuses on the chemistry behind the sensing and remediation of pesticides using nanomaterials. Different types of nanoparticles, viz. metal nanoparticles, bimetallic nanoparticles and metal oxide nanoparticles; nanotubes such as carbon nanotubes and halloysite nanotubes have been used for the detection, degradation and removal of pesticides. Further, various enzyme-based biosensors for detection of pesticides have also been summarized.

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1. Introduction

Pesticides are the materials intended to eliminate as well as control the pests and weeds. They are widely used in agricultural fields to protect the crops from various diseases and pest damages. Pesticides can be categorized on the basis of: (a) origin; and (b) type of pest; as shown in Fig. 1. Among the different types of pesticides, chemical pesticides find huge applications in the agricultural fields. However, more than 90% of the sprayed pesticides reach the destinations other than their targets because they are sprayed over the entire agricultural field. These chemicals persist in the soil and reach the water bodies via agricultural run-offs (Damalas and Eleftherohorinos, 2011; Khatri and Tyagi, 2015). The quality of water significantly decreases due to the presence of pesticides (Khatri et al., 2016a).

The excessive use of pesticides comes with various environmental apprehensions. The most injurious type of pesticides for humans and environment are the chemical pesticides such as dichlorodiphenyltrichloroethane (DDT), dichlorodiphenyldichloroethylene (DDE), parathion, malathion, chlordane and atrazine to name a few. Some of the adverse effects of these agrochemicals on the environment include declining biodiversity, reduced population of insect pollinators (Wells, 2007), threat to endangered species (Miller, 2004) and destruction of the habitat for birds (Palmer et al., 2007). Higher doses worsen the pollution levels of these pesticides in soil and water. Most of the chemical pesticides are fat-soluble, which are retained inside the body of organisms. This is a major cause behind the biological magnification of these agrochemicals with increasing levels of food chain. The people having regular exposure to pesticides are likely to develop skin and eye-related problems. These pesticides affect the nervous system, cause cancer, mimic the hormones and lead to death in severe cases (US EPA, 2014). Every year, more than a million workers from agriculture fields develop symptoms of pesticide poisoning (Miller, 2004).

In past years, a number of methods based on surface adsorption, membrane filtration and biological degradation have been developed to reduce the levels of these pesticides in the environment, especially in soil and water. However, such methods target a diverse population of contaminants in the environment, which significantly affects the pesticide removal efficiency of these approaches. Analytical techniques like High Performance Liquid Chromatography (HPLC) and Gas Chromatography-Mass Spectroscopy (GC-MS) have been used for the detection of pesticides. These techniques are powerful and exhibit very low detection limits. Though, some of drawbacks associated include the requirement of intensive sample purification, experienced operator and expensive equipment (Stan, 2005; Alder et al., 2006). With the advent of newer technologies in the recent years, the limits of these pesticides to pose a health risk have reached the molecular level, which means that just a few molecules of such agrochemicals would be enough to adversely affect the health of people. Hence, a technology working at molecular and atomic levels to detect and degrade these pesticides is the need of the hour.

Nanotechnology is the field, which can serve this purpose. It involves the manipulation of atoms and molecules for manufacturing materials having dimensions in the range of nanometers (Khatri et al., 2017; Tharmavaram et al., 2017). Nanotechnology-based approaches have attracted global attention in recent times for the detection, degradation and removal of hazardous pesticides. These approaches are known to be highly specific during detection and degradation of pesticides. Different types of nanomaterials, viz. nanoparticles, nanotubes and nanocomposites have led to the enormous research in this area though myriad methodologies (Liu et al., 2008; Zhang and Fang, 2010). The small nanoscale size, high surface-to-volume ratio, physicochemical properties and high target specificity of these materials help in highly specific sensing of the pesticides. Myriad nanomaterials have found applications in the fabrication of biosensors to identify pesticides in different sample matrices (Liu and Lin, 2007; Zhang et al., 2009; Aragay et al., 2011; Perez-Lopez and Merkoci, 2011). In addition to sensing of pesticides, these nanomaterials have been employed for their degradation as well. The explicit surface activity and specific surface area possessed by the nanomaterials have an

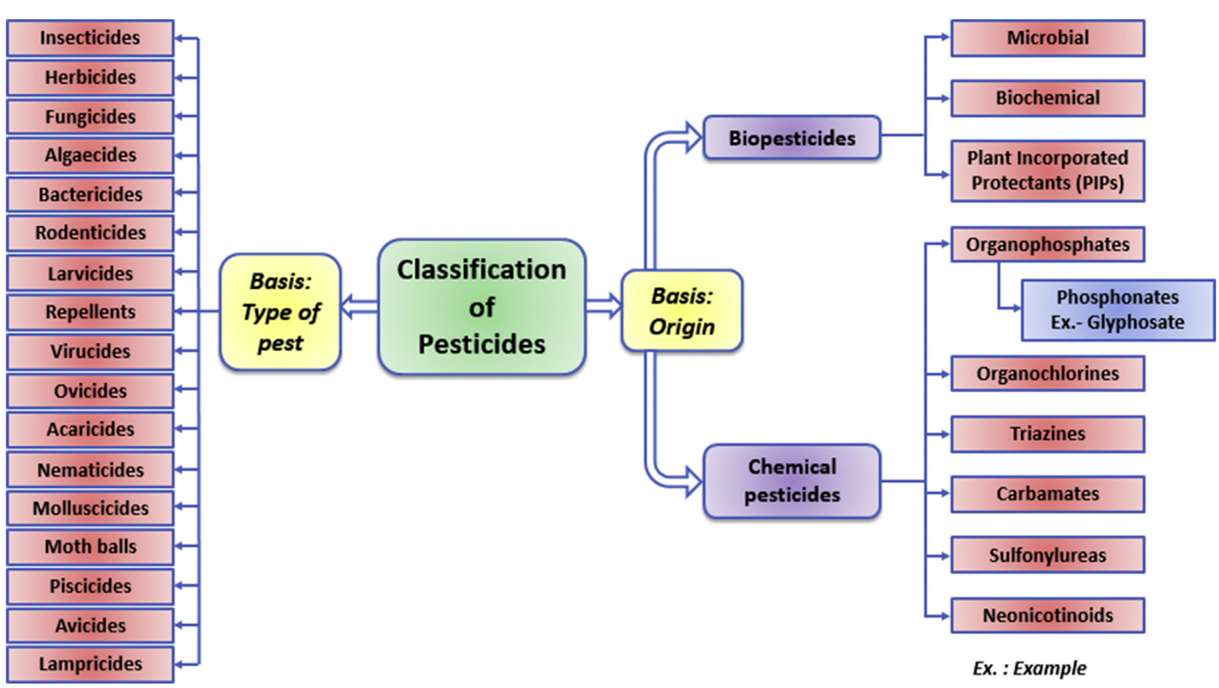

Fig. 1. Classification of pesticides.