



Degradation Or Elimination Of Hazardous Impacts Of Pesticides Containing Organochlorines With The Use Of Novel Nanomaterials Approach

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Abstract

At present, unmanaged application of pesticides is having an impact on the environment, agriculture, and livelihoods all over the world. Excessive consumption of pesticides to improve agricultural yields and ensure adequate food supply is causing a number of serious issues with the environment.

Managing the use of pesticides effectively and cleaning them up is one of the most difficult challenges to overcome. The effectiveness of the existing pesticide biodegradation approaches, involving various microorganisms and enzymes, is restricted. Therefore, a new approach is required to protect the ecosystem from the severe environmental threat.

Due to their distinctive characteristics of being small and having a large surface area, nanomaterials have gained interest in a variety of fields in recent years. In a variety of bioremediation procedures, nanotechnology has been considered to be a promising and successful technology. It also offers several important advantages for enhancing environmental technologies through the application of nanomaterials with effective performance.

The aims of this review article to demonstrate the significance, impact, and important applications of nanomaterials in the bioremediation process for the efficient removal of harmful pollutants like pesticides.

Key points: pesticides, environmental issues, biodegradation, Nanotechnology, nanomaterials.

Introduction

India at present produces the most pesticides in Asia and ranks twelfth in the world for pesticide consumption. A large proportion of people in India are working in agriculture, exposing them to pesticides employed for pest control (Singh *et al.*, 2022). The green revolution in Indian agriculture from 1967 to 1972 prompted an explosion in the usage of pesticides. Additionally, certain pesticides that are prohibited in Western countries such as DDT, HCH, endosulfan, etc are extensively utilised in India and still pose a threat to public health and the environment (Priyanka *et al.*, 2022; Zinovyev *et al.*, 2005). Government of India, till date, has banned the use of more than 30 different types of pesticides belonging to different classes including DDT, and at the same time, has also restricted the use of many other pesticides (Correa-Torres *et al.*, 2016).

Chemicals referred to as pesticides are employed to prevent, eliminate, repel, or lessen the effects of many pests, including weeds, rodents, bacteria, fungi, and insects (Rasool *et al.*, 2022). The Organochlorines pesticides (OCPs) comprise the largest class of organic pollutants, including aldrin and dichlorodiphenyltrichloroethane (DDT), followed by organophosphorus (OPs) pesticides, then by flame retardants and polyaromatic hydrocarbons (PAHs) and other chemicals (polychlorinated biphenyls PCBs); the by-products of the above-mentioned compounds also constitute for the same (Abhilash and Singh, 2009). Pesticides are now an essential resource for protecting crops, increasing food production, and managing a wide range of vector-borne diseases (Agbeve *et al.*, 2014).

Hazardous impacts of pesticides

Although pesticide use was crucial in expanding crop yields, it has also brought up a number of serious concerns about the health of people and animals. Although pesticides have been used to keep pests away, only 1% of them are effective in killing the pests; the rest contaminate the soil, water, and air (Sun *et al.*, 2018). When pesticide residues enter the food chain, they impact a number of organs,

including the thyroid gland and the endocrine system (Huang *et al.*, 2017), cause neurological disorders (Schmidt *et al.*, 2017), have direct cytotoxic effects, and may even accelerate human mutations (Teodoro *et al.*, 2019).

As pesticides target the endocrine system, several reproductive and fertility problems have been encountered in farm animals (Marlatt *et al.*, 2022). In addition to their negative effects on the female reproductive system (Ramakrishna *et al.*, 2022), pesticides negatively impact the male reproductive system by poisoning the plasma membrane of sperm (Torres-Badia *et al.*, 2022). In the past few decades, pesticides have been shown to negatively impact the biodiversity of invertebrates, mostly insects, in numerous nations (Vogel, 2017). Bird populations are drastically declining as a result of the careless application of pesticides, which reduces the amount of agricultural area utilised by winter-migrating birds.

Organochlorine pesticides (OCPs) are carbon-containing compounds that prefer to concentrate in fatty tissues due to their increased solubility in lipids. In human body tissues such as blood, placenta, and amniotic fluid, as well as secretions like breast milk and semen, a variety of OCPs have been identified in detectable amounts. The physicochemical properties of OCPs contribute to their dispersion and distribution in the environment; their low water solubility and hydrophobicity result in high adsorption and low degradation (Lu *et al.*, 2011). Endosulfan, DDT, and HCH have been shown to produce a large number of free radicals, which raise oxidative stress both in vitro and in vivo. Free radicals attack all of the body's macromolecules, including DNA, lipids, and proteins. Several changed bases are produced when free radicals, especially the hydroxyl radical, assault a DNA molecule (Dehn *et al.*, 2005).

The wide range of OCPs that are extremely hazardous are unable to be effectively eliminated by the current treatment techniques, such as oxidation, activated carbon, activated sludge, and reverse osmosis. Moreover, the by-product generated during the process of degradation may turn out to be more dangerous than the parent chemical. Methods include filtration, disinfection, discoloration, sedimentation, coagulation and flocculation, steam distillation, ion exchange, deionization, reverse osmosis, and biological treatment using microorganisms are also employed for water purification.

The elimination of pesticides from soil and the environment requires essential actions that should be conducted with these dangerous features in account. In order to effectively remediate harmful pollutants like pesticides, this review paper aims to emphasise the significance, impact, and important uses of nanomaterials in the bioremediation process.

Nanotechnology- Approach in elimination of pesticides

The innovative field of nanotechnology is advancing new developments in all facets of life and, to the greatest extent feasible, is transforming social progress. In terms of cost and performance, a highly efficient, eco-friendly, sustainable, and sustainable process made feasible by nanotechnology may be a competitive alternative to conventional technologies (Khan *et al.*, 2019). Therefore, there should be efficient treatment technology for OCPs if secondary or tertiary therapy is not needed. This area of research is rapidly evolving and changing because to the diverse applications of nanomaterials, nanoparticles, and nanocomposites in several scientific and technological endeavours (Rajput *et al.*, 2022).

Green chemistry-based approaches are now widely employed to synthesise nanomaterials for environmental applications, offering a zero-waste, sustainable substitute for chemical-free procedures. Because of their minuscule size, nanoparticles possess a very large surface area, which amplifies their surface chemical phenomena and permits chemical reactions across their surface. When compared to other traditional technologies, nano-based procedures are more cost-effective, multifunctional, and highly efficient. They also need less reaction time. The most popular methods for organic pollutant cleanup using nanotechnology are organic pollutant oxidations and adsorption followed by degradation (Karakartal *et al.*, 2005).

Various researchers work and evaluate significant biodegradation percentage by using nanoparticles which were synthesised by using different metals and also with plants extracts, these experimental innovations are summarised and described following according to chronology.

Jara *et al.* (2024) employed the natural reducing and capping agent found in *Vernonia amygdalina* plant leaf extract to create iron nanoparticles (FeNPs) using an environmentally friendly process. The

catalytic degradation investigation shows that, under the right circumstances, both crystal violet (CV) and methylene blue (MB) into non-toxic products, with maximum degradation efficiencies of 97.47% and 94.22%, respectively.

According to Herrera *et al.* (2024), TiO₂, ZnO nanoparticles, and nanocomposites of TiO₂ and ZnO supported on SPIONs (SPION@SiO₂@TiO₂ and SPION@SiO₂@ZnO) were used in the photocatalytic degradation of chlorpyrifos (CP). At pH 7, the CP photodegradation levels of the nanocomposites of SPION@SiO₂@TiO₂ and SPION@SiO₂@ZnO were greater than those of free nanoparticles, reaching 95.6% and 82.3%, respectively.

Nnaji and colleagues (2023) gathered wastewater samples from thirteen enterprises located in five states in Nigeria to eliminate the detected pollutants, biomagnetite nanoparticles (BioMag), magnetite nanoparticles (MagNPs), biomagnetite-CMC nanocomposite (BioMag-CMC), and magnetite-CMC nanocomposite (MagNPs-CMC) were synthesised and examined.

Chauhan *et al.*, (2022) developed ruthenium and gold metal nanoparticles-incorporated zirconium dioxide (ZrO₂@Ru and ZrO₂@Au) nanostructures promising photocatalysts for wastewater remediation.

Goel and Arora (2020) effectively employed spherically shaped gold nanoparticles (GNPs) with a size of around 9 nm for the photocatalytic destruction of the dangerous insecticide endosulfan (ES).

Iron oxide nanoparticles were created by Chaudhary *et al.* (2020) using the co-precipitation technique and they were then used to degrade organochlorine insecticides through sophisticated oxidation processes. The degradation investigation revealed that organochlorine insecticides might degrade up to 98.38%.

For the photocatalytic degradation of dimethoate, Zhu *et al.* (2020) created zinc oxide (ZnO)/reduced graphene oxide (rGO) nanocomposites using a hydrothermal synthesis approach. The ZnO/rGO nanocomposite exhibited a photo-degradation efficiency and rate of dimethoate that were 1.5 and 4 times greater, respectively, than the naked ZnO.

Cobalt-doped magnetite nanoparticles were employed by Carvalho *et al.* (2020) to remediate the examined chemicals. They used a liquid-liquid microextraction procedure that was validated for the extraction, pre-concentration, and determination and degradation of 10 OCPs in water samples: α -BHC, p,p'-DDE, δ -BHC, dieldrin, p,p'-DDT, endosulfan I, endosulfan sulphate, heptachlor, heptachlor epoxide (isomer B), and methoxychlor.

According to Li *et al.* (2020), nanoparticles can increase the long-term toxicity of organochlorine pesticides, indicating a significant danger of co-occurrence for the environment. They used an *in vivo* *Caenorhabditis elegans* system to expose the animals to nanoparticles (NPs) and/or two kinds of OCPs, namely hexachlorocyclohexane (HCH) and chlordane. Compared to the single exposure group, the mean lifetime of the chlordane- and HCH-joint groups was substantially reduced by 16.2% and 11.8%, respectively.

Ulucan-Altuntas and Debik (2020) synthesised the bimetallic Fe/Pd nanoparticle employing palladium as the catalytic ingredient. One of the most common persistent organic pollutant pesticides in the world, dichlorodiphenyltrichloroethane (DDT), was examined in relation to its breakdown by Fe/Pd nanoparticles.

Metallic gold nanoparticles (AuNPs) were prepared and stabilised by Abd El-Aziz *et al.* (2018) using henna (*Lawsonia inermis*) extract. They used Gas chromatography-mass spectrometry (GC/MS), FTIR, and UV-Vis spectrophotometry to assess the breakdown of DDT. Dichlorodiphenyldichloroethene (DDE), Dichlorodiphenyldichloroethane (DDD), Dichlorodiphenylmethane (DDM), and Dichlorophenylethane (DCE) are the five peaks in the GC/MS spectra that correspond to the DDT breakdown products.

Conclusion

According to the numerous information on pesticide contamination of soil that are now accessible, the amount of pesticides in the environment continues to increase frequently, which has an impact on both human and environmental health. Therefore, it is important to apply pesticides ethically,

particularly in emerging and undeveloped nations where there is a lack of an effective monitoring mechanism. The use of pesticides, which have a short half-life and high biodegradability, should be prioritised when there is an actual requirement. Even though there are many different methods for cleaning up pesticide contamination, the most of them have drawbacks. Although the numerous trials involving the incorporation of nanoparticles into the bioremediation process have demonstrated encouraging promise, further investigation and testing are necessary in this field.

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