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MINI REVIEW

Use of Nanotechnology for the Removal of Agrochemicals from Soil and Water

Ochoa LG[1] and Balderrama Carmona AP[2]*

[1]Department of Water and Environment Sciences, Technological Institute of Sonora, 818 South, Colonia Centro C.P. 85000, Obregon City, Sonora, Mexico
[2]Department of Chemical-Biological and Agricultural Sciences, University of Sonora, Southern Regional Unit. Blvd. Lázaro Cárdenas 100, Colonia Francisco Villa C.P. 85880, Navojoa, Sonora, Mexico

ABSTRACT

Agrochemical contamination is a severe problem that damages the ecosystem and reduces the quality of life of the people exposed; to remedy this problem, nanotechnology is an attractive bioremediation alternative for these types of chemicals. This study emphasizes bioremediation actions such as investing in alternatives, for example, the method of photocatalysis using Titanium Dioxide (TiO2) and Zinc Oxide (ZnO), and alternatives that aid in the degradation of most chemicals such as sonolyisis or ozonolysis to improve their effectiveness are of great interest. In this paper, the uses of nano remediation to reduce the effects of chemicals in agricultural soil were reviewed and its use is highly recommended.

*Corresponding author(s)

Balderrama Carmona AP, Department of Chemical-Biological and Agricultural Sciences, University of Sonora, Southern Regional Unit. Blvd. Lázaro Cárdenas 100, Colonia Francisco Villa C.P. 85880, Navojoa, Sonora, Mexico

E-mail: paola.balderrama@unison.mx

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Introduction

Chemical substances from agricultural soil and water are a known problem for several years ago in the entire world. The excessive and inappropriate use of synthetic agrochemicals to increase the yield of crops leads to the deterioration of soil health, the degradation of agroecosystems, causes problems related to environmental insects, and phytopathogenic microorganisms [1]. Nanotechnology opens a wide range of opportunities in agriculture to produce agricultural products, which will increase food yields in an environmentally sustainable manner [2]. Implementing the use of nanotechnology in the agricultural field is considered important because it offers benefits in improving the quality and safety of food throughout the stages of its production, perfecting the use of production optimizing the use of agro-food contact with pathogens and toxins, and accelerating their detection in the food [3]. The acceleration of progress in agriculture has made the use of nanotechnology in the form of smart food packaging, breeding of varieties using gene nanocarriers, as well as in the synthesis of nanomaterials a routine procedure.

Environmental technology makes use of nanotechnology handled under the name of nanoremediation, this is used to protect the environment for the cleanup of hazardous waste sites [4,5]. The principal contaminants present in agricultural soil and water matrixes are pesticides, heavy metals coming from erosion, mineralization degradation of organics from agrochemicals, and proximity to mining sectors [6], inclusive of another contaminant present in irrigation water such as dyes [7]. Health needs to remove these materials as these can cause food poisoning and other diseases such as developing cancer, kidney damage, and among many other health problems [8].

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According to the United Nations Environment Programme (UNEP), the contamination by chemicals like persistent organic pollutants (POPs) [9] and heavy metals (Pb, Cd, Hg, Cu, Co, Zn, Cr, Ni, As) mainly derived from the mining [10], energy sector, transportation sector, wastewater and the application of agrochemicals as pesticides which to this day the exact amount of damage to the environment and human health cannot be quantified are a threat to the environment [11]. Therefore, nanoremediation as an alternative to soil treatment is necessary to avoid further damage to the environment.

Nano remediation *in situ* has different advantages as reduces overall cost, reduces the cleanup time for contaminated sites, can be used on a large scale, discard the need to treat the contaminated soil, and reduces chemical concentrations until reaching almost complete elimination [12]. This paper briefly reviewed the use of nanotechnology for the removal of chemical substances from agricultural soil and water.

Nanoremediation

Nanomaterials (NM) have properties that favor chemical reduction and catalysis to mitigate pollutants, these properties of NM allow them to be used *in situ* in water and soil matrixes (Figure 1). For example, Nanoparticles (NPs) can fit into small spaces and spread more rapidly than larger particles, although, they cannot move far from the point of injection [13]. For nanoremediation to be effective, adequate characterization of the sites is needed: location, geological conditions (composition of the soil matrix, porosity, and depth of surface), proprietary red potted (porosity and depth of the water table), crop, the concentration of nitrates, nitrites, and sulfates), as well as the concentration and type of pollutants. These variables will determine if the NPs will be able to infiltrate the area to be remediated and if the conditions are favorable for the transformation of contaminants. Various materials have been tested for remediation, for example, zeolites, metal oxides, noble metals (silver, palladium, copper), titanium dioxide, carbon nanotubes, fibers, and enzymes. However, the most widely used is zero-valence iron [14].

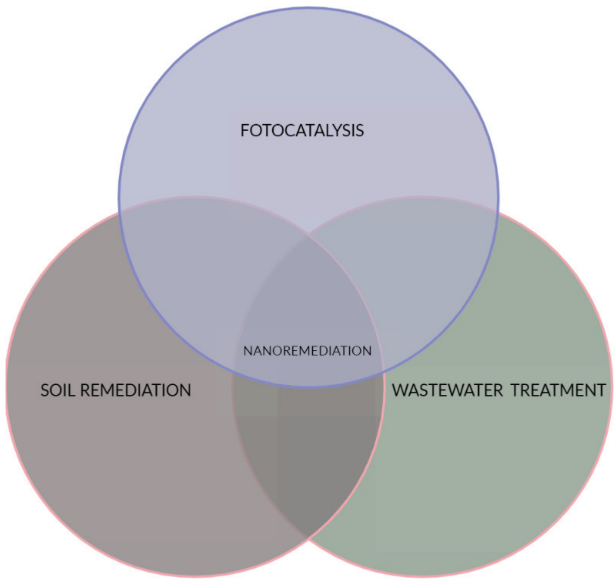

Figure 1 Nanoremediation may involve the use of photocatalysis for soil and water remediation.c

Photocatalytic Nanoparticles for Removal of Chemical Contaminants

NPs that are activated by light are cheap and can be produced in massive quantities, as well as being slightly toxic; NPs such as Titanium Dioxide (TiO_2) and Zinc Oxide (ZnO), which are semiconductors with a wide bandgap, are highly studied for removing contaminants in polluted sites [15,16]. For example, ZnO nanoparticles are capable of sensing on the one hand, and photocatalysis the destruction of dangerous polychlorinated phenols on the other. There is a great interest in manipulating the surface of these particles with organic and inorganic pigments or dyes to have not only response in the UV but also in the visible spectrum and in this way, making photocatalysis more efficient for the transformation of pollutants in the environment [17]. Keep in mind that only 5% of the solar radiation that reaches the earth's surface is in the UV range. Several types of NPs designed to reduce pesticide application and degradation and supply micronutrients, control pathogens and increase crop yields are currently being considered in NM sciences [17]. Veerakumar, et al. [18] used palladium and silver nanoparticles embedded in ZnO nanostars for photocatalytic degradation of pendimethalin and trifluralin, on the other hand, Sangami and Manu [19] showed the efficacy of amethrin removal by using Fe nanoparticles used as a Fenton-type catalyst. Rani, et al. [20] concluded that degradation by sonolysis at 20 kHz, ozonation, photolysis at 254 nm, and photocatalysis using TiO_2 and zero-valent Fe nanoparticles as adsorbents can remove most organochlorine herbicides (Table 1).

Removal of Agrochemicals from Soil

For a long time, biotechnology has been applied to soil remediation and the use of bacteria and fungi for the degradation of pesticides has been successfully explored [28]. The nano-encapsulation of enzymes of bacterial origin were proposed to improve this technology; the nanocapsules stabilize, protect, and immobilize the enzymes, promoting enzymatic activity [29]. It has also proved that the nanocapsules are then easily degraded by soil microorganisms [30]. NPs have also been proven effective for soil remediation; such is the case of nano-iron NPs that have been shown to remove organic pesticides from the soil with an efficiency of 25-100% [31]. On the other hand, of

Table 1: Photocatalytic nanoparticles for removal of various compounds from soil and water.

NPs	Pollutants removed	Matrix	References
TiO_2	Heavy metals, pesticides	Soil	[21]
TiO2/fly ash	Heavy metals, pesticides	Water	[22]
ZnO	Heavy metals, insecticides	Water	[23]
CdS	Dyes	Water	[24]
CdS/ ZnS	Heavy metals	Water	[25]
CdS/ZnS-mBet	Heavy metals	Water	[26]
MgO/WO_3	Heavy metals	Water	[27]

even greater efficacy are the metal-organic NPs that have also been used for water remediation [32].

Removal of Agrochemicals from Water

Pesticides in water are a public health risk, that's why their removal is necessary, however, conventional physicochemical methods are expensive and difficult to apply and some leave polluting residues that must also be cleaned [33]. An original solution is the use of bioadsorbent nanomaterials for the removal of organic contaminants [34], NPs have also been implemented, such as the case of ZnO NPs, synthesized by green chemistry, which can remove up to 99% of water herbicides [35].

Conclusion

The use of nanoparticles is a practical possibility for the removal of agrochemicals, however, the suggested methodologies for degradation are not yet used commercially, in addition, studies on the toxicity of nanomaterials in the environment and their degradation are still lacking, and it expected that the creation of innovative technologies and the boom in these findings will allow that soon the degradation of pollutants of any origin will be using nanomaterials.

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