Chapter

Nano Pesticides Application in Agriculture and Their Impact on Environment

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Abstract

Environmental contamination and the tolerance developed by the pests, pathogens are some of the environmental issues related to the aimless utilization of chemical pesticides. It has became matter of serious concern for environment, food quality and soil health. Nanotechnology, envisaged as a swiftly emerging field has capability to reform food systems in agriculture. Nanotechnology provides an imperishable solution to these problems by the establishment of nano-pesticides. The functional components or the conveyor molecules used are of nano size. The performance of these nano sized particles is much better the traditional pesticides, as the smaller size aids in proper spreading on the pest surface. Amelioration in solubility of operational components, betterment in stability of formulation, gradual liberation of operational components and enhancement in mobility are some of the paramount advantages of nano particles attributed to the minute size of particles and greater surface area. Thus, nano particles have strengthened activity against target pests in comparison to bulk materials. Furthermore, nano-formulations sustain productive use in agriculture by offering systemic properties, uniform leaf coverage and enhanced soil properties. Despite all the positive aspects, it might have certain negative effects as well, like exposure of humans through distinct routes Viz, exposure to nano pesticides either directly or indirectly like adsorption through skin, or inhalation while breathing air or transfer from one energy level to another by taking contaminated food and water.

Keywords: nanopesticide, formulations, environmental risk, agriculture, future aspect

1. Introduction

Pest management is still greatly dependent on the utilization of pesticides, through the application of organic chemical originated components on crops, products and urban habitat, regardless of divergent alternative methods available. Most of the registered pesticides intrude with the nervous system of insects through their prime method of action, that is they are neurotoxic, and are considered to enhance the threat of expansion of various neurodegenerative diseases, such as

Parkinson's disease [1]. In order to lessen the utilization of neurotoxic compounds, various novel products have been launched during recent times in the market, which include insect killing agents like, destroying agents of adenosine triphosphate (ATP) or controlling agents of insect growth, in spite of this environmental affect is a matter of great concern. In this connection, the matter has been correlated to the lethality caused to mammals, environmental pollution, and biomagnifications in the food chain. Along with amplified tolerance rate developed by insects species to currently used products, the aforesaid concerns have became fundamental challenges in agriculture, and may significantly restrict the beneficial active compounds. To tackle this trouble, there is need of novel pest control strategies for pest management through the initiation of novel ideas related to pest tolerance and advancement in technologies. Nanotechnology has come up with as considerably alluring field of research to achieve these aims, by furnishing advanced methodologies for designing novel operational components with microscopic measurements, formation procedures and dissemination, which are collectively referred to as "nanopesticides." Nanopesticide research, is the introduction of nanotechnology to protect crops. This field encompasses extensive research aspects viz.,

- Learning the basic interrelation notion of nano-scale materials.
- Preparation of nanoemulsions from active components and their dispersal using pesticides.
- Utilizing nanomaterials as active agents to develop novel nanopesticide formulations.
- Using these nanomaterials as nanocarriers for pesticide delivery [2–4].

This nanopesticide research is comprehensive and is believed to address the major drawbacks of the existing pest management strategies and comes up with new advanced nano-based formulations that stay stable and active, that is not influenced by sun, heat, and rain in the target environment, enter the target organism (insect), resist defense of the pest, remain amiable to plants and mammals, formulation and manufacture is lucrative, and ideally possess a new-fangled approach of action [2, 5, 6]. NPs in diverse fashion and chemical make-up including metal, metal oxides, semiconductor quantum dots (QDs), carbon, ceramics, silicates, lipids, polymers, proteins, dendrimers, and emulsions were made by utilizing a wide range of materials synthesized or used from natural materials [7, 8]. Some familiar advantages of NP-based pesticide formulations include:

- Solubility of water-insoluble operative constituents is enhanced.
- Stability of the formulation is elevated.
- Eradicates dangerous organic solvents.
- Ability to liberate operative constituents slowly.
- Early deterioration is averted by improvement in stability.
- High mobility and insecticidal activity is attributed to nano size
- Endurance is believed to get increased due to large surface area [9].

The ideas related to advancement in the manufacturing of nano based formulations are

1. The advancement in traditional pesticide formulations.

2. The establishment of delivery systems.

3. Utility of NPs as nano carriers, and use of solid NPs as operative agents.

2. Nano pesticide formulations

Utilization of technologies such as encapsulation and restrained liberation methods for the use of pesticides is of remarkable concern. Various researchers have laid emphasis on the importance of Nanocapsules and nanoparticles for agricultural purposes [10]. A number of companies have prepared different formulas that comprise of NPs with the dimensions ranging from 100 to 250 nm. A few make use of Nanoemulsions, which are prepared by dissolving nanoparticles pesticides evenly either in water or oil with dimensions ranging from 200 to 400. The manifold applications can be achieved like protective measures, treatment, or preventing reaped product by easily integrating these emulsions into gels, creams, liquids. One of the modern desired restricted liberation of agricultural chemicals is the utilization of materials incorporated with silica. Porous hollow silica NPs (PHSN) was used as pesticide carrier to record the restricted discharge pattern of pesticide namely avermectin [11]. It was revealed that PHSNs can be utilized to restricting pesticide dissemination applications, as these carriers noticeably deferred the release of the pesticide. NPs can imbibe and bind with other compounds effortlessly because of large surface areas, flow without difficulty in lepidopteran systems and certainly be utilized for pesticide development [12]. It has been reported that most terpene compounds have antifeedant action and are extremely volatile. Insecticidal activity and life span of the formulations significantly enhanced by integrating certain plant extracts with nano-silica [13]. Formulations made by integrating a-pinene and linalool with nano-silica improved biological activity of the plant pure chemicals, stability of the formation with superior zeta potential, restricted liberation of the plant derived components compound, and prolonged life span of the plant isolates [13]. These formulations exhibit great antifeedant action against *Spodoptera litura* and *Achaea Janata* (L. These nanoformulations smoothly disseminate, which was made clear by the dissemination dispersion studies. It was concluded that life span analysis of nano formulations with terpenes have no impact on dissemination, dimensions, zeta potential, or biological activity of the nanoformulations up to period of 6 months after harvesting [3, 13].

3. Solid nanoparticles as nanopesticides

A number of nanoparticles have been recommended as potential candidates both as nano carriers as well as operational pesticide agencies or biological pesticides, because of intrinsic antibacterial/pesticidal properties.

3.1 Inert dusts as insecticides

The mechanism of activity of stable dusts such as silica, alumina, and clay is due to the destruction of the waxy coating on the insect's epidermis by surface assimilation and scraping. This destruction trigger insects to dehydrate, dry out and die. Because the mechanism of action is physical, it is difficult to acquire insect resistance [14].

3.1.1 Silica

The utility of silica based nanoparticles (SNPs) for controlling pests in agricultural is reasonably recommended because silicon has the capacity to escalate the resistance of plants to abiotic and biological stresses [12]. The deadly effects of unstructured water loving, and oil loving SNPs to the rice weevil *Sitophilus oryzae* were studied by [15] and found that they were much more helpful and efficient than bulk silica. No new infections were detected after depositing for period of 60 days. Silica particles are physically absorbed by lenticular lipids that destroy the protective cuticle and destroy insects purely by physical means with a similar mode of action observed on diatoms particles used for protection of stored grain [12, 16]. In addition, modified hydrophobic surface-charged silica (3-5 nm) have been fruitfully used in veterinary medicine to control a wide range of essential agricultural and animal ectoparasites [17]. The fungal growth was decreased and germination of seeds was promoted by effective application of surface charged silica as a thin film of seeds [18]. The metabolic process of certain agricultural crop groups and horticultural plants does not get affected by the superficial application of NPs to the leaves and stem. They do not encourage any modification in gene expression in insect organs, so they deserve approval as nano pesticides. Additionally, World Health Organization (WHO) declared the utilization of unstructured silica as a nanopesticide risk free for human consumption. In traditional pesticides these SNPs also serve as carriers. Comparison to small amounts of chlorfenapyr, the biological effectiveness was enhanced by loading the insecticide chlorfenapyr into dispersed SNPs [19]. This is assigned to the nanoscale size and intrinsic insecticidal activity of SNPs. In addition, it has been reported that porous hollow SNPs can safeguard the fleeting insecticide avermectin from UV degradation and liberate it for a long time. SNP carriers have been observed to promote the sustained release of avermectin for approximately 30 days [20].

3.1.2 Diatomaceous earth (DE)

DE is comprised predominantly of unstructured silica originated by decomposing small sized plants under high temperature and pressure. These are employed to safeguard stored grain from pest insects. It has deleterious effects on grain properties especially on bulk density because it is required in high doses. Researchers are engaged to integrate DEs with other insecticides to attain high efficiency, so as to make it effective in low doses. For example, combination of DE and plant decoction bitterbarkomycin was used to control grain pest *Rhyzopertha dominica*, and was recorded to be efficient at low dose concentration of 150 ppm [21].

3.2 Alumina

Nanostructured alumina (NSA) was recognized as a successful insecticide in case of grain pests, *S. oryzae* (L) and *R. dominica* (F) by [22]. They also collated NSA formulations against a foremost traditional DE commodity and declared their formulation to be efficient. NSA dusts manufactured using a modified glycine-nitrate combustion process were reported to be more effective against, *S. oryzae* (L) and *R. dominica* (F) in the recent research. The results revealed that, key factors determining insecticidal efficacy are dimension of particle, surface area, and external features. However, these are not believed to be only factors responsible, and to attain superior outcomes for specific species, there is need to improve preparation pathways [23].

3.3 Clays

Nanoclays are fine layers of silicate minerals with following dimensions (thickness 1 nm and width 70–150 nm). Source of nanoclays is montmorillonite clays, which are mostly found in volcanic ash, formed by size reduction and surface modification and are biocompatible and have less hazardous associated. Among these living materials anionic clays are found to be most promising. They have fruitfully served as conveyor for the α-naphthalene acetate, which is regulator for growth in plants and for the restrained liberation of the 2,4-dichlorophenoxy-acetate. Natural antibiotic cinnamate, which is utilized for pest management, is susceptible to quick deterioration in soil and is required in significant concentration. It was declared that by loading it on double layered hydroxide low pace liberation of the antibiotic and prolonged longevity in the soil is achieved [24]. This indicates the outstanding potential of nano-clays to be used for low pace/target specific dissemination of pesticides and fungicides.

4. Preparation of nano pesticides by encapsulating pesticide nano particles

Encapsulation is a process of encompassing or enveloping one substance inside another fabric on a very little scale or may be characterized as the method by which a material is encompassed and safe guarded from external conditions that would break it down, yielding capsules extending from less than one micrometer to several hundred micrometers in size [25]. Encapsulation can be obtained by few strategies with distinctive purposes in mind. Encapsulation of materials may take place deliberately that the central material be restricted inside capsule walls for a particular period of time. On the other hand, central substances can be incorporated so that the core material will be released either progressively through the capsule walls, known as controlled release or diffusion, or when outside conditions activate the capsule walls to break, melt, or dissolve [26]. The different areas in which encapsulated materials have numerous applications include agriculture, pharmaceuticals, foods, cosmetics and fragrances, textiles, paper, paints, coatings and adhesives, printing applications, and many other industries. Encapsulation permits the farmers to apply pesticides less frequently instead of requiring profound concentration and toxic initial applications to be released over time, allowing farmers to apply the pesticides less often rather than requiring very highly concentrated and perhaps toxic initial applications followed by repeated applications to fight the losses due to leaching, evaporation, and degradation [27]. Protection of pesticides from full contact with the components reduces the risk to the environment and those that might be exposed to the chemicals and provides a more efficient technique for pest control [28].

5. Toxicity and environmental impacts

The vulnerability and environmental consequences of nanoscale-based formulations is of great concern, which needs to be addressed. The amount of nanoformulations in soil, surface water, and groundwater, and effects impacts on non-target organisms have not been predicted much. The fate of nano formulations depends on number of chemical parameters, like pH, ionic strength, and dissolved molecules in the media [29]. Emphasis is laid on certain fundamental concerns mentioned under following sections.

5.1 Direct toxicity on humans and environment

The harmfulness of numerous pesticides utilized in a nano-scale formulation has been determined by specialists, the probable negative impact and the probable impacts of nano dimensions must be taken in to consideration during nano-scale formulations. More inquiry is needed to affirm the harmfulness of nano-scale formulations and the factors contributing to harmfulness of nano-particles like size, charge, shape, and chemistry.

5.2 Durability and persistence

The fundamental criteria for analyzing dangers associated with the application of nano pesticides is their longevity in the environment. The non target organisms get exposed when there is suspended liberation or release for a prolonged period of time [30].

5.3 Bioavailability

The nanocarriers promote transfer of some of the immobilized operational components, which is considered one of the likely detrimental effects. Thus increase the availability to organisms [31]. Enhancement in absorption by target organisms have been reported by certain nanoformulations. It must be ensured that no damage caused to non-target organisms.

5.4 Release profile/degradation

The two important factors which govern the liberation of operational components involve class of nanocarrier and the dissemination of active components in matrix. Research suggested that environmental affect and virulence of operational ingredients is contributed by set of factors viz., surface desorption, dissemination via the polymer matrix, and deterioration of the polymer [31].

5.5 Fate of the carrier

The centre of attention of research now are carriers established using natural biologically degradable polymers like, polysaccharides, or lipids, which deteriorate into by-products of least concern [13].

6. Nanopesticides interaction with other environmental contaminants

The evaluation of pesticides is done on a product-by-product basis, in a similar fashion to other contaminants. In the real environment, mixed interactions are possible as they co-occur with other substances. A nanopesticide may have collaborative interaction with other contaminants through the Trojan-horse effect, so hazard analysis of environmental mixtures is generally not needed for product hazard estimation [24]. In this effect the substance are carried to a tissue of organism or to an organism by interaction of substance with ENP, due to which the interior exposure to contaminants is enhanced, and might not get accumulated. The need of hour is to integrate these interrelations into authoritative hazard analyzing schemes.

7. Nano-pesticides for greener agriculture

Nano-pesticides are defined as preparations that deliberately introduce elements in the nm size range and the characteristics related with this small size range are new, these nanopesticides have earlier been launched in the market. Nanopesticides cannot be treated as a single category but have been blended in a numerous products. The various classifications of Nanopesticides include organic components viz., A.I., polymers and inorganic components like oxides of metals in diverse configurations like particles and micelles [32]. One of the most economical and multifaceted method of containing insect pests is the residues remaining on the surface after application. Microencapsulation; a nanotechnological approach can be employed to modify the insecticidal value by protecting the operational components from environmental conditions and by promoting persistence. The usage of engineered nanoparticles (ENPs) is gaining considerable attention in the pesticide sector due to the establishment of a wide varieties of plant protection products termed as "nanopesticides". Nanopesticides "involve either very small particles of a pesticide active ingredient (A.I) or other small engineered structures with useful pesticidal properties". The advantages offered by this emerging technology involves amplified efficacy, durability, and a cutting down the amount of active ingredient required. Nanoemulsions, nanocapsules like polymer and commodities containing pristine engineered nanoparticles, such as metals and their oxides, and nano-clays have been recommended. These products can be exploited to intensify the efficiency of prevailing pesticide operational components or results in improvement of environmental safety profiles or both [30].

8. Nano pesticide: future possibilities

Recent investigations have shown that nano-pesticides can reduce the deleterious effects of chemical based pesticides and furnish target-specific control of pests, and help develop intelligent nano-systems for minimizing problems like environmental imbalance, and negative effects on food security, and crop productivity [33]. They are effective for long term utility and provide solution to environmental related problems like nutrient richness in water bodies and accumulation of non-biodegradable components in the food chain due to restricted liberation of operational ingredients. Furthermore, nano-pesticides show efficient pest control property due to amplified solubility and stabilities of operational components [34]. Still, there is necessity to modify the techniques in order to have remarkable benefits to agriculture. A few aspects for nano-scale pesticide delivery platforms discussed by [33] in their review include:

- The effectiveness of nanopesticide development is enhanced by use of green chemistry and environmentally viable principles [35].

- Upgrading traditional utilization of nanopesticide.

- Realistic utilization should be estimated at field level by comparing it with traditionally used products.

- The vulnerability of nanopesticides is estimated by Environmental impact assessment.
- Modification in the policy for application of nano material in agriculture.
- Agrochemical industries will come up with many solutions by the launching of smart nanopesticide, that is solubility of the operational components, stability, restricted liberation, and dissemination of active components on specific organisms, but lot of research need to be done to get acquainted with the fate of nanopesticide in the environment.

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