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Consequences of Nanoparticle-Insecticides on Aquatic and Terrestrial Non-Target Organisms: A Review

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Abstract

Insects create great nuisance in different manners and spread various diseases. Mosquitoes are arthropods of medical and veterinary importance as they are the vectors of deadly diseases like malaria, dengue and Zika virus. Many different methods are adopted at various parts of the world to control mosquitoes ae well as other insect pest. But challenges are faced with the adoption of such measures, which leads to resistance of target organism and harmful effects to non-target organisms. Bio-pesticides as well as nanotechnology is considered a potential eco-friendly approach in mosquito control research. Plant-mediated nanotechnology is current most and effective method to control the population of mosquitoes. Furthermore, it is analyzed from the various evidences of ill-effects of nanocomposites to the non-targets organisms including mammals, humans, and aquatic insects.

Keywords: Nanotechnology; Nanoparticles; Non-target organisms; Pest-control; Nanocomposites

Introduction

Arthropods are dangerous and destructive organisms as they can kill the entire race of target organism, as many are vectors of extremely dangerous diseases [1-3]. Apart from the open ocean, insects can be found in all habitats; swamps, jungles, deserts, even in highly harsh environments such as pools of crude petroleum. Many agricultural insect pests also create nuisance to the farmers and billions of dollars are spend to control the crop pest and these pest control strategies currently diverted to nanotechnology. Plant-mediated or synthetic nanoparticles have been introduced into the market as fewer doses can effectively control the population of the pest.

Among them, mosquitoes (Diptera: Culicidae) are also the great threat for billions of people in the whole world; they spread diseases like malaria, dengue, yellow fever, filariasis, Japanese encephalitis and Zika virus [3-6]. Moreover, Culicidae transmit key pathogens and parasites very susceptible to dogs and horses like dog heartworm, West Nile virus, and Eastern equine encephalitis [7]. After the research of many years still vaccines are not available for many diseases like dengue is the one at the prime list. Also, even for other mosquito borne diseases, such as malaria, the vaccines available are still not appropriate to treat the disease [3,8].

Nanotechnology now a day has been used in research and other areas each and everywhere like imaging, sensing, targeted drug delivery, gene delivery systems and artificial implants [9]. Many different types of inorganic and organic nanosized formulations have been introduced with the help of nanotechnology in various areas [10]. Due to the usage of such different formulation in medical, drug-delivery, controlling systems they are released intentionally or unintentionally into the environment [11]. Such concerns have introduced many new research disciplines in the field of nanotoxicology. Firstly, it is important to evaluate the control measures and how nanotechnology has overcome such measures and harmful to non-target organisms.

Role of Nanoparticles against Non-Target Organism

The potential of any control measure varies against organisms on which it is going to be used. It depends on the lethal dose as well as the chemicals used. The insecticide which is used against any insect pest is considered as a target organism whereas any other organism is whether bird, mammals, reptiles, aquatic organisms are non-target organisms. The nano-particles which are used these made from plant-based emulsions are harmful as per upto the particular amount of dose used to control the pest and accidently introduced into the environment.

Aquatic Organisms

Aquatic organisms are quite old as compare to other animal taxa in the evolutionary sense so these organisms have inefficient primitive system in the body and their detoxification system is not effective enough to detoxify the particles used to control the insect pests. The neurological and respiratory system are same as that of the insects, nanoparticles effect aquatic organism same and it effects their population [12]. Whereas in comparison to terrestrial organisms whose system are much developed and able to degrade such toxic compounds from the body, in case of aquatic organisms the degradation is much slower. Due to their high sensitivity to most insecticides, testing of cladocerans is internationally recognized as representative of the hazards that toxic chemicals pose to zooplankton organisms [13]. However, other plank-tonic crustaceans can differ in susceptibility to some insecticide classes. Many nanoparticles are significantly more toxic to copepods and ostracods than to cladocerans, whereas copepods and brine shrimps are more susceptible to organo-metallic compounds than cladocerans and ostracods [14]. In this regard, epibenthic crustaceans such as freshwater ostracods found to be more susceptible to imidacloprid which is also used for the preparation of nano-emulsions and quite toxic, with LC50s two orders of magnitude lower (range 300-700 μg/L) than those for cladocerans [15]. The excretion of nanoparticles inside the body of the aquatic organisms is very weak as the system is not much developed and this leads to the concerns against the matter.

Nanoparticles and Fishes

Due to the various environmental changes and destructions in the spawning grounds of the fishes, scientists introduced many artificial spawning sites [16,17]. A researcher has elaborated the effects of nanoparticles in fishes and basically zinc oxide was tested on the fish model by Khan MS, et al. [18] as ZnO-NPs have potentially deteriorated the environment. Basically, in the control methods the application of such nanoparticles should be released directly into the environment to get the desired results but the consequences on the non-target organism has raised many concerns [19]. There is a need to study the effect of nanoparticles on the behavior, physiology or the bioactivity of organisms especially in the aquatic organisms as very meager reports are available which supported the ill-effects against living organism in the aquatic environment. One researcher has reported the adverse effect of nanoparticles in the liver and heart of African catfish [20]. Scientist has observed an increase in intracellular reactive oxygen species (ROS) was observed in zebra fish embryos exposed to ZnO-NPs and implemented some toxic effects [21]. There are reports which are showing that ZnO-NPs can cross the chorion layer reach to the embryo or the juvenile are more toxic to such stages as compared to adults than that of the equivalent metal salt [22]. Researchers confirmed the absorption of fine ZnO and TiO2 particles across porcine skin if orally consumed. ZnO-NPs also found to be toxic against medaka fish (Oryziaslatipe) and their embryo depends upon the dose [23,24].

Amphibians

In amphibians, the changes have been noticed after coming in contact with that of nanoparticles. The investigation of the detrimental effects of nanoparticles on amphibians, salamanders as well as newts (caudates) done by Spence, et al. [25]. The effect of nanoparticles has been reported on egg, larval, and adult Rough skinned Newts (Taricha granulosa). The researcher has reported the chronic exposure to ZnO nanoparticles caused higher mortality at 10.0 and 100.0 mg L-1. Whereas after the acute exposure (24 hr) to 10.0 mg L−1 nanoparticles at a late developmental stage, larvae hatched 5 days early, at a decreased developmental stage, and smaller size compared to the control. The nanoparticles are harmful for the amphibians as various morphological and physiological changes occurred in an organism when exposed to the nanoparticles. In the field level, as these nano-emulsions are used for the control of different pest accidentally released into the aquatic environment.

Effect of Nanoparticles against Terrestrial organism

Earthworms

Earthworms are the biological indicators of the environment, any changes in the behavior of earthworms raises the eyebrows something's wrong has happened in the environment. Various experiments have been performed on Eiseniafetida using 20 nm Ag-NPs in suspension in water (1 to 100 mg/mL) showed that the exposure of silver nanoparticles increased the number of apoptotic cells. However, it was also reported that the effect of nanoparticles was diminished after 24hours, as the effect is found to be slow in the soil as compared to the water. The increased apoptotic cells were observed in parts of the body which were directly exposed to nanoparticles like cuticle and intestinal epithelium. So, it is concluded that nanoparticles affect the immune system of the organisms as the protection which was offered by chloragogenous tissue as the extended barrier constituted with mucus and antibacterial molecules were affected because of nanoparticles [26]. The exposure of copper nanoparticles was also examined and showed that Eiseniafetida when exposed to nanoparticles only 20% were excreted and rest remains inside the body and found in blood and cocoons and spermatogenic cells.

Bees

Honey bees play an important ecological and economical role as pollinators of crops and produce honey. Apis mellifera, is an essential pollinator for agricultural crops in many countries [27]. Many investigators made to use the bees and its products to monitor the purity of the environment [28-30]. Among the most important pollinators and direct contact with that of the crops leads to face many threats by nanotechnology as it is used abundantly in the pest control strategies. Therefore, there is a big need for examine the toxic effects of nanoparticles on honey bees [31]. A report has confirmed the neurotoxicity of ingested zinc oxide nanomaterials ZnO nanoparticles on honey bees. A variety of biomarkers, including the neurotoxicity biomarker acetyl cholinesterase (AChE), metabolic impairment, feeding rate, and survival, as well as the activities of a stress-related enzyme glutathione S-transferase have been evaluated. It was observed that the activity of AChE was increased in bee workers exposed to nanoparticles. The feeding rate was also found to be effected in honey bees. It is concluded that nanoparticles have a potential to make adverse effects in the honeybee colonies and destruct the population. Another scientist has reported the toxicity of boron particles on Apis mellifera [32]. The worker bees observed to be highly influenced after the exposure to 96h nanoparticles which were reported to be highly toxic to bees. The exposure period of the nanoparticles depicts the toxicity so it is important to use the dose of any compound in a suggested limit as well as consider its half-life.

Mammals

Nanoparticles effect against mammals and humans has been observed and reported by many scientists all over the world [33]. It penetrated inside the body through transcutaneous manner. In various cases, the size of nanoparticles permits endocytosis to penetrate a cell and transcytosis to penetrate several cells, one after the other. When mammals inhale these substances, they reach to the nervous system at the end of the neurons through epithelium. In another way, they also reach to the lungs, then blood and attempted the blood-brain barrier. Many different organs like bone marrow, lymph nodes, spleen, or heart are also arrested by the effect of nanoparticles. It has been shown that it also provokes inflammation and both pro oxidant and antioxidant activities, oxidative stress, and modification of mitochondrial distribution. These effects were dose-dependent and exerted according to the type of nanoparticles.

Many experiments have been performed on rats to test the ill-effects of nanoparticles. In the rat, an exposition to Cu-NPs (40 and 60 nm diameter) initiates the proliferation of endothelial cells of brain capillaries after exposure to low concentrations (i.e. 1.5 μg/ml). Whereas with the exposure to higher concentrations (i.e. 50 μg/ml) induced an increase of prostaglandin E2 in the rats [34]. Another Scientist tested the effect of Ag-NPs @25, 40, or 80 nm after exposure of 24-hour on rats to affected the blood-brain barrier, inducing a pro inflammatory reaction which could develop a brain inflammation accompanied with neurotoxin effects [35]. However, many reports are available which shows the cytotoxic effects of nanoparticles @ 25 and 40 nm which are smaller in size as compared to bigger ones about 80 nm. It was also observed that the nanoparticles affect the locomotory activity in rats [36].

Studies also revealed that cerebral edema has occurred after the treatment of nanoparticles to rats and mouse which arrest the permeability of blood-brain barrier, thus affecting brain blood fluxes at the stronger level. The Copper and silver nanoparticles about the size of 50 to 60 nm were found to have more devastating effects as compared to aluminum nanoparticles of the same sizes as many morphological changes has reported like neurons injuries, changes in the activity of some glial cells, and the loss of myelin fiber [37]. Rats are more prone to the nanoparticles as compared to mice. Silver nanoparticles also observed to have destructive effects on pigs [38]. Even in rats it was found to have induction of the hyperactivity of the tracheal smooth muscle by the action of acetylcholine with a production of NO (nitric oxide) @25nm [39]. After the investigation of the various organs post-exposure to silver nanoparticles, there traces were observed in spleen red pulp, lungs, and kidneys in mouse [40]. A degradation of the heavy chain of clathrin, a cytoskeleton protein was recorded after the injection of nanoparticles to the cultured mouses and smaller nanoparticles showed toxic effects on the shape of cells which became narrow and contracted, disrupting the cytoskeleton actin [41].

Conclusion

Nanoparticles are used worldwide for the different purposes but their persistence ability is too high as it causes an alarming effect to the environment. It is concluded that nanoparticles have adverse effects on the animal kingdom whether they are aquatic or terrestrial. The population of different non-target organisms has reduced drastically which disrupts the ecological balance in the ecosystem. Not only animals which are an important part of ecosystem, insects too are an integral part of it but they are considered as pests. So, any method adopted to control this pest population should be wisely adopted. The nanoparticles can be used at a certain limit but not at the cost of imbalance in the nature.

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