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Impact of Nanomaterials on Earthwoms : A New Threat to Megadrili Resources

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ABSTRACT

Nanoscience is a very exciting and useful branch of science, in which, nanoparticles are designed for various purposes. World market for nanomaterials is increasing rapidly and advanced countries are earning a substantial amount from marketing of nanoparticles. But other side of the coin is related to the ill-effects of nanomaterials. Now-a-days nanomaterials are widely and indiscriminately used without realizing their short- and long-term consequences. Applications of nanomaterials may lead to several adverse effects on fauna and flora of the Earth. The disposed nanomaterials contaminate soil system which is the home of various invertebrates including earthworms. They effect metabolism, reproductive potential and life cycle and sometimes lead to death of organisms living beneath our feet. It declines soil sustainability and hampers productivity leading to economic losses. Therefore, no nanomaterial should be used without its impact assessment otherwise we will not be in a position to revert irreparable losses caused by use of nanomaterials.

Keywords: Nanoparticle, earthworm, nanotoxicology, metabolism, stress, life-cycle

Nanoscience has revolutionized the world. It is the science of particles at nanoscale. Manipulation, manufacturing and application of nanoparticles (1-100nm size) created nanotechnology subject. Nanoparticles may be natural or artificial. Generally engineered particles of nanoscale are referred to as nanoparticles. They are purposefully designed with a very precise shape, size and property. Commonly used engineered nanomaerials are metal and metal oxide nanomaterials, carbon nanomaterials, quantum dots and so on. Nanomaterials may be used for biosensing, imaging, catalysis, photodegradation, photoprotection, , cosmetics, drug delivery, gene therapy, biomedical products, water treatment, pollution control, bioremediation etc. Applications of engineered nanoparticles have been increasing since 1990s but it has grown rapidly from 2000 onwards. Due to dynamic potentials of nanoprticles the production of nanomaterials is anticipated to be worth US dollar few trillions in the days to come. Here I would like to point out that benefits from new technologies also bring disadvantages (non-desirable effects). Use of nanoparticles ends up with their release in environment leading to many adverse effects in biosphere. They may pollute air, soil and water systems and hamper the health of biota living there in. Recently, a new branch i.e. nanotoxicology came into existence, which deals with the study of harmful effects of nanoparticles and nanomaterials. One may ask the question why nanoparticles are to organisms? The toxicity may be because of many reasons such as : 1. Extremely small size of nanoparticles enhances the surface area to volume ratio which facilitates their interactions with living organisms, 2. Surface charge of nanoparticles contribute to toxicity, and 3. Chemical properties of nanoparticles attribute to high reactivity leading to toxicity. Further it has been found that non-coated nanoparticles are more toxic than coated particles. In fact intrinsic (physicochemical) and extrinsic (functional) characteristics determine the toxicological properties of nanomaterials. Human society is largely unaware about hazards of nanomaterials. Presently Identification, categorization, coding and information generation about interaction of nanoparticles with biological system are the major challenges to scientists (Pourmand and Abdollahi, 2012). If one could connect the nanomaterial features with the degree of toxicity then the prediction of potential hazards will be easy (Fadeel, 2013). It will certainly support a safe manufacturing approach to produce nanoparticles with minimal or no toxicity.

Nanoparticles easily enter into environment and organisms due to their extremely small size and high reactivity. They undergo various transformations in their physiochemical properties ones reach to the environment . Mainly nanomaterials enter aquatic and terrestrial ecosystems by industrial effluents, sewage sludge and domestic waste water. They enter into terrestrial and soil fauna through skin, respiratory tract and digestive system and ultimately reach to different tissues and organs. Nanoparticles may also reach to brain and affect neurons. Some nanomaterials cause irreversible damages to cells due to oxidative stress and organelle injury. Virtually the toxicity of nanoparticles depends on particle size, shape, coating, chemical properties and concentration so also encountering organisms. The hazardous effects of nanomaterials has raised a great issue as to how one can manage, reduce or counter the ill-effects of these materials. Since megadrili resources play a key role in maintaining the structure and function of soil system, they are employed as a potential candidate for nanotoxicological studies. Most of the laboratories consider earthworms for ecotoxicological investigations. The Organization for Economic Cooperation and Development (OECD) and International Organization for Standardization (ISO) have given some guidelines for ecotoxicological risk assessment in soil organisms particularly for earthworms. They documented the effects of unwanted chemicals on survival and reproduction of earthworms. In laboratories the toxicological assessments on earthworms have been performed by using *Eisenia fetida* and *Eisenia andrei* in artificial soil.

Diversified uses of nanoparticles at industrial, commercial and domestic level ultimately release the nanoparticles into the environment where they are dispersed in air, water and soil (Nowack and Bucheli, 2007; Holden *et al*., 2014). This transforms the surface properties of nanoparticles altering the particle charge etc. (Handy *et al*., 2008 ; Lombi *et al*., 2013 ; Ma *et al*.,2013). Aggregation or agglomeration occurs among nanoparticles only when energy of attraction exceeds the energy of repulsion (Farre *et al*., 2009). These phenomena have been described in water and soil ecosystems (Quik *et al*., 2010 ; Kiser *et al*., 2010). The nanotoxicological assessment in below-ground fauna is very limited due to complexity of soil and lack of suitable techniques for characterization of nanoparticles in soil system. Nanomaterials find their way into agroecosystem by applications of sewage sludge, nanoherbicides , nanopestcides , nanofertilizers and so on. Ingestion of soil produces toxicity in soil fauna including earthworms. Release of nanoparticles in terrestrial ecosystem generates potential risk to microorganisms and animals (Boxall *et al*., 2007; Unrine *et al*., 2010). Nanoparticles have been reported to contaminate food chain. Evidence is available for transfer of nanoparticles at trophic level and biomagnifications in terrestrial food chain (Judy *et al*., 2011).

The class Oligochaeta contains a few-bristle worms which constitutes an important taxonomic group of aquatic and terrestrial ecosystems. This class was traditionally separated into microdriles and megadriles. Microdriles are small oligochaetes which may live in fresh water, sea water and wet soil. However, megadriles are often large oligochaetes which mostly live in terrestrial soil. Few megadriles are aquatic or semi –aquatic in nature. Earthworms belong to megadrile group. They were one of the first animal group colonizing human soils from the end of Palaeozoic era. Charles Darwin was first to realize the importance of earthworms in formation of vegetable mould and indicated them as a friend of farmers. A matter of serious concern is that the hazardous effects of nanomaterials are gradually increasing in pedoecosystem. It is attracting many scientists to study behavior and biological effects of nanoparticles in environment. Scott-Fordsmand *et al*. (2008) reported the impacts of double walled carbon nanotube and C60 fullerenes on reproduction of the earthworm, *E. veneta*. It has been found that titanium oxide and zinc oxide nanoparcles induce enzymatic changes and cellular dysfunctions causing DNA damage in *E. fetida* (Hu *et al*., 2010). Adverse impacts of silver nanoparticles on survival, structure and behavior of *Allolobophora chlorotica* have been documented (Brami *et al*., 2017). Silver nanowires have been demonstrated to cause cytotoxicity in *E. Andrei* (Kwak *et al*.,2017). Majority of works on earthworm nanotoxicology are concerned with silver and carbon nanomaterials. Zinc oxide nanoparticles is one of the most commonly used particles of nano scale. It has a broad range of applications from chemical sensors to personal care products. Few workers investigated the toxic effects of zinc oxide nanoparticles on *E. fetida* (Unrine *et al*., 2008; Hu *et al*., 2010; Li *et al*., 2011). Survival of megadrili soil bioresources is greatly affected by presence of nanoparticles in pedoecosystems.

Treatment of zinc oxide and titanium oxide nanoparticles to the earthworm, *E. fetida* in artificial soil for about one month exhibited adverse effect on reproduction (Canas *et al*., 2011). The toxicity of zinc oxide nanoparticles was higher as compared to titanium oxide nanoparticles. Similarly, exposure of *E. veneta* to zinc oxide nanopartcles reduced reproductive capability by 50 percent (Hooper *et al*., 2011). Tourinho *et al*. (2012) also reported decline in reproduction of earthworm in response to exposure of zinc oxide nanoparticles. Hu *et al*. (2010) demonstrated increase in toxicity and accumulation of zinc oxide and titanium oxide nanoparticles in *E. fetida* as a function of their increasing concentrations. They suggested that higher concentration of zinc oxide nanopaticles is toxic to DNA and antioxidant system. Higher concentration of zinc oxide nanoparticles greatly affects survival and causes mortality in *E. fetida* (Yausheva *et al*., 2016). The degree of toxicity depends on the type of nanoparticle. For an instance the different levels of oxidative stress were observed in response to treatment of same concentration of copper, copper oxide and zinc oxide nanoparticles to *E. fetida* (Mwaanga *et al*., 2017). Treatment of fullerene (C60) induced the lethality and inhibited growth and reproduction of the earthworm, *Lumbricus rubellus* (Van der Ploeg *et al*., 2011). They found juveniles more sensitive to C60 than the adult earthworm.

Earthworm is an excellent bioindicator and sentinel fauna for testing of toxicants in soils. Chouhan and Tripathi (2018a) reported a gradual decrease in LC50 values with exposure period of *E. fetida* to zinc oxide nanoparticles. The bedding temperature and pH affected the median lethal concentration of nanoparticles. They also found increased mucus secretion and changes in body colour after exposure to zinc oxide nanoparticles. Exposure of juveniles of *E. fetida* to zinc oxide nanoparticles declined body mass and length gain more in artificial soil as compared to natural substrate (Chohan and Tripathi, 2018). Treatment of zinc oxide nanoparticles to *E. fetida* significantly decreased profiles of various biochemical constituents including metabolic enzymes. The reductions in biochemical contents were concentration-dependent (Chohan and Tripathi, 2019). Exposure of *E. fetida* to zinc oxide nanoparticles decined cocoon production, hatching and rate of reproduction (Chouhan and Tripathi, 2020). There is an urgent need to understand potential risk of nanoparticles and mitigate their toxic effects. The drawback, side effects or danger of using nanomaterials should be realized soon and necessary measures should be taken well in time to save environment and biological world.

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