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Review Article

IMPACT OF RADIATIONS ON EARTHWORMS

Shyamasree Ghosh*

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ABSTRACT: Radiations include electromagnetic radiation, including light and radio waves and high-energy ionizing radiation released by the decay of radioactive isotopes including X-rays, gamma, alpha and beta rays that can damage human and animal health by ionizing atoms and breaking chemical bonds, damaging DNA and also lead to cancer. Animal models of mice has been extensively studied in this context. However very few studies exist on effects of radiation on invertebrates. One such organism, of importance to human life are the earthworms that resides in the soil and are called as the natural tillers of the soil, contributing to the soil fertility, enhancing soil nutrient cycling, mixing of soil, production of mucus and organic matter and their excreta increases the soil nutrients. In the soil they are constantly exposed to harmful pollutants, radiations, radioactive chemicals and pathogens. Therefore, it is important to understand and study the effects of radiation on earthworms. However very few studies have been conducted in these lines and very few reports exist on the effect of radiation on earthworm health. In this article we discuss in depth recent findings across the globe on the effect of radioactive chemicals and radiations on diverse species of earthworm health and the applications of radioactive tracers in detecting effect of harmful pollutants on the earthworm health and bioaccumulation.

Key words: Radioactivity, Earthworm, Bioaccumulation.

INTRODUCTION

Earthworms, belonging to the invertebrate true coelomates, Phylum Annelida are soil inhabitants, contributing immensely towards maintenance of soil fertility and is of profound importance for the farmers and is of great economic importance in man.

The earthworm ecology includes four different ecotypes including the (i) Compost earthworm including *Eisenia fetida* and *Dendrobaena veneta* that exist predominantly on areas rich in rotten vegetation and compost, thriving in warm and moist environments, identified by bright red colour and stripy. Their rapid consumption enables disposal of waste and contaminants from soil. (ii) Epigeic earthworms or surface dwellers including *Dendrobaena octaedra*, *Dendrobaena attemsi*, *Dendrodrilus rubidus*, *Eiseniella tetraedra*, *Heliodrilus oculatus*, *Lumbricus rubellus*, *Lumbricus castaneus*, *Lumbricus festivus*, *Lumbricus friend*, *Satchellius mammalis* do not burrow but live on soil surface niche and feed on leaf litter and organic matter, exhibiting dark colour skin pigmentation with bright red or reddish-brown, protecting them from UV rays and are with non-striped body form. (iii) Endogeic earthworms or top soil dwellers including *Allolobophora chlorotica*, *Apporectodea caliginosa*, *Apporectodea icterica*, *Apporectodea rosea*, *Murchieona muldali*, *Octolasion cyaneum* and *Octolasion lacteum* live in soil, at a depth of about 20 cm from top soil surface making horizontal burrows and they feed on the soil and is identified by predominant body forms of pale colours, blue, grey, green or pink. (iv) Anecic ecotypes or the sub soil dwellers residing about 3 m from the soil surface including *Aporrectodea longa*, A*porrectodea nocturna*, *Lumbricus friendi* and *Lumbricus terrestris* are soil dwellers that live by making permanent vertical burrows in soil and feed on leaves, depositing their casts at the entrance to their burrows, with predominant dark coloured red or brown head with pale tails.

As the anecic species makes permanent burrows into the deeper layers of soil, endogeic species makes non-permanent burrows in the upper mineral layer of soil, thus enabling soil mixing and epigeic species surviving on soil surface, and feeding on decaying organic matter, enable mixing of organic and inorganic matter (Bhadauria

School of Biological Sciences, National Institute of Science Education and Research (NISER), Bhubaneswar, Odisha 752050, India. Homi Bhabha National Institute, Training School Complex, Anushakti Nagar, Mumbai 400094, India.
Corresponding author. e-mail: sree.s@niser.ac.in

and Saxena 2010) (Fig. 2) and their excreta rich in organic matter, nutrients, and water can lead to increased microbial activity (Bhadauria and Saxena 2010). Elements including nitrogen, phosphorous, potassium and calcium in earthworm cast, urine and mucous can be easily taken up by plants (Bhadauria and Ramakrishnan 1989, Barois and Lavelle 1986).

Earthworm cast with increased Carbon (C) and Nitrogen (N) can increase plant growth and stabilization of soil microfauna (Bouche 1977, Villenave *et al.* 1999, Lavelle and Martin 1992, Aleksakhin 2009). Radioactive contaminations in soil by natural and accidental sources, however can affect the agriculture cover and soil biota and its effects on lifeforms is a major concern globally. Earthworm activity could mobilise the radionuclide contaminant in soils leading to easy uptake by plants (Markovic and Stevovic 2019). Earthworms are known to uptake and bioaccumulate metals and radionucleotides. This bioaccumulation in earthworm is not without harmful consequences affecting not only the earthworm health but also health of animals at different trophic levels, affecting the entire ecosystem (Smièiklas and Šljiviæ-Ivanoviæ 2016) (Fig. 1).

Alternatively, radionucleotides have enabled tracing of harmful chemicals and their effects on earthworm.

RADIOACTIVE POLLUTANTS AND EARTHWORMS

Radioactive tracers of pollutants

Radioactive tracers have enabled the detection of the effects of harmful chemicals on the environment. Earthworms are constantly exposed to pollutants in the soil and their effects on pollutant degradation have been studied by the application of radioactive tracers. 14C-tracers have enabled detection of effects of Bisphenol F (BPF) isomers which are phenolic resin dimers, made from phenol and formaldehyde on the environment. When studied in an oxic rice soil in presence of earthworm *Metaphire guillelmi* it decreased the mineralization leading to the increased number of bound residues (BRs) of 4,4'-BPF thus generated in soil, leading to increase in the ecological risk of 4,4'-BPF (Guo *et al.* 2019).

Polynitramine hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX), heterocyclic polynitramine, a soil contaminant, revealed bioaccumulation *Eisenia andrei* and probable transfer across the food chain (Sarrazin *et al.* 2009).

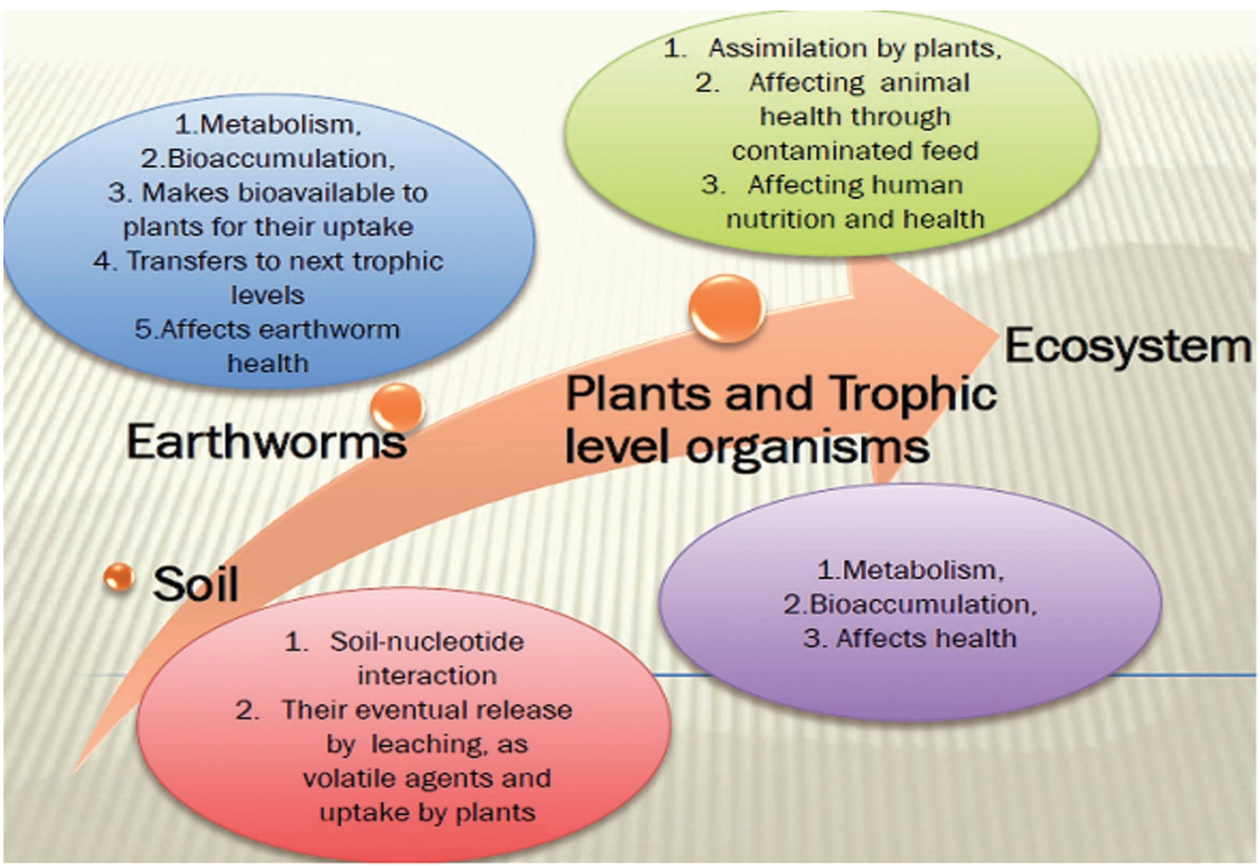

Fig. 1. Effects of radionucleotides on the ecosystem.

Fig. 2. Earthworm collected from Bhubaneswar, India.

Bioaccumulation and impact of radionucleotides on earthworm

Bioaccumulation and release of bound, or non-extractable, residues of 14C labelled racemic cycloxaprid (CYC) were reported from *Metaphire guillelmi* (Liu *et al.* 2015) and bioaccumulation of 14C radiolabelled nonylphenol was also reported from *M guillelmi* (Shan *et al.* 2010).

Increased intestinal concentration of radio-cesium 137Cs generated by anthropogenic activities, a radioactive isotope of Caesium (Cs) was detected by autoradiography methods and reported in Japanese epigeic earthworms of family Megascolecidae, after the Fukushima Dai-ichi Nuclear Power Plant accident (Tanaka *et al.* 2015, Tanaka *et al.* 2018). An autoradiography is a method by which decay emissions like beta particles or gamma rays being generated from a radioactive source is detected by generating an image on an x-ray film or nuclear emulsion called as an autoradiogram.

While accumulation of Caesium from soil was reported from earthworm *Aporrectodea longa*, 134Cs, organic matter with 137Cs and from plant litter was revealed in the gut of earthworm indicating their bio-accumulation (Brown and Bell 1995).

Nanoparticles, although of importance to the human lives (Ghosh 2014, 2015, 2018, 2019), their application and safety is of global concern (Ghosh 2019). They have been known to be environmental pollutants, affecting animals across the trophic levels. Radiolabelled cerium dioxide nanoparticles (CeO2 NPs) and tin dioxide nanoparticles (SnO2 NPs) when exposed to earthworm *Eisenia fetida* revealed that they were up taken and were released in excreta (Carbone *et al.* 2016). 14C-pyrene and 14C-lindane from soils revealed bioaccumulation in *E. fetida* (Smídová *et al.* 2012). *E. fetida* exposed to 14C-TNT (trinitrotoluene) reveals accumulation as non-extractable residues, with longer half-life, and finds importance as biomarker indicative of TNT contamination, (Belden *et al.* 2011). Bioaccumulation of radioactive labelled TNT has been reported from *Chironomus tentans* and *L. variegates* (Belden *et al.* 2005).

Delta-2-14C-diazinon when exposed to earthworm *E. foetida* savigny revealed their uptake and were reported from non-extractable fractions and bound within the earthworm tissue (Leland *et al.* 2003).

Radium 226 bioaccumulation from sediment and water was revealed in *Lumbriculus variegates*, reported from studies conducted in Ontario and Saskatchewan, Canada (Wiramanaden *et al.* 2015).

A bioaccumulation and probable transfer in the food chain of radiolabelled synthetic steroid 17 alpha-ethinylestradiol (14C-EE2) from spiked sediment is reported from endobenthic freshwater oligochaete *Lumbriculus variegates* (Liebig *et al.* 2005).

14C-labeled tetra- and pentabromo diphenylether, in *L. variegatus* revealed bioaccumulation and may be transferred through the trophic level (Leppänen *et al.* 2004). In *L. variegatus*, bioaccumulation of 14C radiolabelled 2,4-dichlorophenol, 2,4,5-trichlorophenol, pentachlorophenol, pyrene, Fenpropidin, and Trifluralin (Verrengia *et al.* 2002) has been reported.

DISCUSSION

Earthworms also known as farmer's friends are natural tillers of soil. However, the earthworm health is highly threatened by the environmental pollutants in the soil from both natural and anthropogenic sources of which nanoparticles, harmful chemicals and radioactive wastes pose the major challenges of bioaccumulation and transfer to different trophic levels, uptake by plants and adversely affect the earthworm health. Studies on the earthworm immune system have revealed a robust immune system to combat the pathogens and pollutants (Ghosh 2018, Ghosh 2019).

Although diverse environmental pollutants have been reported to affect the earthworm immune system and health, very few studies have been done on the effect of the radioactive chemicals on the immune system of earthworms. In this study we have reviewed and summarised the effect of different radioactive chemicals and their bioaccumulation in earthworms and the application of radioactive tracers to detect the bioaccumulation of harmful chemicals in earthworms.

CONCLUSION

It was observed from our study that the immune system of earthworm is almost of robust nature, despite being in a primitive organism with molecules in the coelomic fluid including coelom cytolytic factor (CCF), antimicrobial peptides (AMPs). In the course of this study, it is observed that no study has been conducted so far on the downstream pathway effects of radionucleotides on the earthworm immune system, signalling pathways and biochemical and histological studies indicative of changes in the biochemistry of the earthworms are not conducted.

It was also observed that an information gap from records reported in these lines so far from India. No data of published literature was observed on the effect of radionucleotides on diverse strains of earthworms from India which is known for its rich biodiverse resources. Such studies would find importance from ecotoxicology and monitoring of earthworm health.

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