Journal of Advances in Science and Technology
Vol.20, Issue No. 1 March-2023, ISSN 2230-9659

Impact of pesticides on earthworms: Assessing the ecological cost of crop protection

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Abstract

Earthworms are an important sign of healthy soil because of the important roles they play in breaking down organic materials, forming soil structure, and cycling nutrients. Using earthworms as a model, this study looks at the ecotoxicological effects of several pesticides on species including *Eisenia fetida* and *Lumbricus terrestris*. Many farmers rely on pesticides to safeguard their crops, yet there are serious ecological worries about the pesticides' unexpected effects on soil species that aren't intended targets. Chemical variety and environmental persistence of chemicals like synthetic pyrethroids and organophosphates are highlighted in the paper, which covers the categorisation and use of pesticides in India. Topics included in the review include alterations to enzymatic activity, reproduction, and death rates in earthworm populations as well as the physiological and molecular impacts of pesticide exposure. More importantly, research highlights the critical need for immediate legislative action and new approaches to pest management in order to save soil biodiversity. Future research on safer agricultural techniques may benefit from this synthesis, which seeks to connect agricultural sustainability with soil ecotoxicology.

Keywords: Earthworms, Reproduction, Soil, Nutrients, Biodiversity.

INTRODUCTION

Pesticides in agricultural contexts disproportionately impact earthworms, the most visible and vulnerable non-target soil organisms. They are particularly vulnerable to the pesticides used in agricultural production because they make up a significant portion of the soil's invertebrate biomass—up to 92%. Numerous studies have shown the crucial role of earthworms in nutrient cycling, litter decomposition, and soil formation. In this research, earthworms were used as a model organism to examine the ecotoxicological effects of several pesticides on soil organisms. [1]

PESTICIDE

You may kill pests using a chemical or combination of compounds called a pesticide. Any material or agent used to combat pests, whether chemical, biological (such as a virus or bacterium), antimicrobial, disinfectant, or gadget, is considered a pesticide. Insects, weeds, molluscs, birds, mammals, nematodes, and microorganisms are all considered pests if they prey on people, damage property, transmit illness, provide an annoyance, or are pathogens in plants. There are pros and cons to using pesticides; for example, they may be harmful to people and other animals.

To eradicate pests in homes and farms, businesses produce synthetic chemicals called pesticides. Both solid and liquid versions of these are commercially accessible. The pest will die from its poisonous effects. Species that are well-suited to laboratory breeding and maintenance, as well as those for which molecular tools are readily accessible, are often used as model organisms in soil ecotoxicological studies. They may not be naturally occurring on soils that are contaminated. The majority of toxicological research using oligochaete annelids have used model species from the genus Eisenia, namely Eisenia andrei, however there has been a recent uptick in the number of studies including species from the genus Lumbricus. Specifically, worldwide toxicity assessments use Eisenia foetida as their reference earthworm.

Molecular biology tools have recently emerged, which have been a huge boon to ecotoxicological research. These methods have improved our knowledge of the molecular mechanisms of action of contaminants. Ironically, few molecular studies have examined the impact of legal pesticides on earthworms, despite the widespread use of these methods to learn about metal impacts. [2]

CLASSIFICATION OF PESTICIDES

In general, pesticides are categorised differently based on the organisms they target. Pesticides, herbicides, nematocide, molluskicide, and so on are some of their classifications. There are pesticides that kill insects, fungicides that kill fungus, herbicides that kill weeds and plants, molluscicides that kill molluscs, and nematocide that kills nematodes.

The following are the categories into which the pesticides were placed according to their chemical composition: Chemicals that do not have an organic bond include mercurial, arsenical, borates, fluorides borates, and an assortment of others. Organic substances found in

nature: examples of such substances include nicotine, rotetone, pytoethrum, and many more. Organochlorine, pyrethroid, and organophosphate carbamates are examples of synthetic organic chemicals.

To protect crops from a wide variety of pests and illnesses, pesticides are often employed in agriculture. Pesticides are effective in controlling pests, but when farmers use them on a big scale in their fields, the residues in the soil mix with water and disrupt the earthworms' enzymatic activity. Pesticides are used extensively over the globe to manage pests that pose a threat to agricultural crops. “The insecticides have several potential uses and may be employed against a wide range of creatures. Because of this, pesticides are crucial in many respects.[3]

PESTICIDE POLLUTION OF SOIL

Limited data on pesticide residue in air, soil, water, and living creatures makes it impossible to assess the degree of pesticidal pollution, and there is no deliberately designed nation-wide monitoring system. There are two potential pathways for pesticides to enter the soil; i.e.

1. Soil pesticides, including weed killers, insecticides, and pesticides, are sprayed directly onto soil in order to manage a variety of pests. Direct application of pesticides for soil treatment or control of soil dwelling pests, nematodes, and pathogens causes pesticide residue to seep into soil and contaminate soil.

2. Heavy rains, industrial effluents, fumes released during pest control treatments, and other indirect pathways all contribute to pesticides reaching the soil. At the same time as pesticides are discharged into the atmosphere as vapours, dust particles absorb them.

Acute Toxicity LD_{50}:

In order to determine the concentration range for confirmation examination, the specialists were brought in. After accounting for natural reaction using Abbott's method, the animal death rate was observed after 24, 48, 72, and 96 hours after exposure to various pesticides.. The LD50 value was calculated by analysing the adjusted mortality data. dosage that is 50% fatal The log concentration and accompanying mortalities (probit kill) were used to determine the LD50 value using a probit regression line.

PESTICIDE IMPORTANCE

Since the degree and mode of action of these compounds' toxicity vary, any discussion of pesticides as pollutants must address the environment, even if these substances may be harmful to both desirable and unwanted organisms. In agriculture, earthworms play an important ecological role by, among other things, improving soil aggregation and porosity, creating a pathway for root development, and encouraging microbial activity in their intestines as they consume organic waste. Although sprayed on crops, pesticides have severe effects on earthworms that live in the soil underneath the plants. In sprayed crops, worms barely reach half their usual weight and reproduce at half the rate of untreated areas.[4]

PESTICIDES IN INDIA

It wasn't until 1896 that inorganic compounds were first utilised as herbicides. The first documented use of herbicides for weed management in India dates back to 1937. Due of its cost-effectiveness versus manual farming, herbicides gained favour among farmers during the green revolution. According to a study conducted herbicides make up over 70% of all pesticides sold in industrialised nations. On the other hand, there has been a progressive increase in herbicide usage in India. But compared to the rest of the globe, India's pesticide usage pattern is unique. In terms of pesticide consumption, India is now ranked tenth globally. Surprisingly, whereas pesticides account for thirty percent of the world's demand, local demand for herbicides accounts for only ten percent.

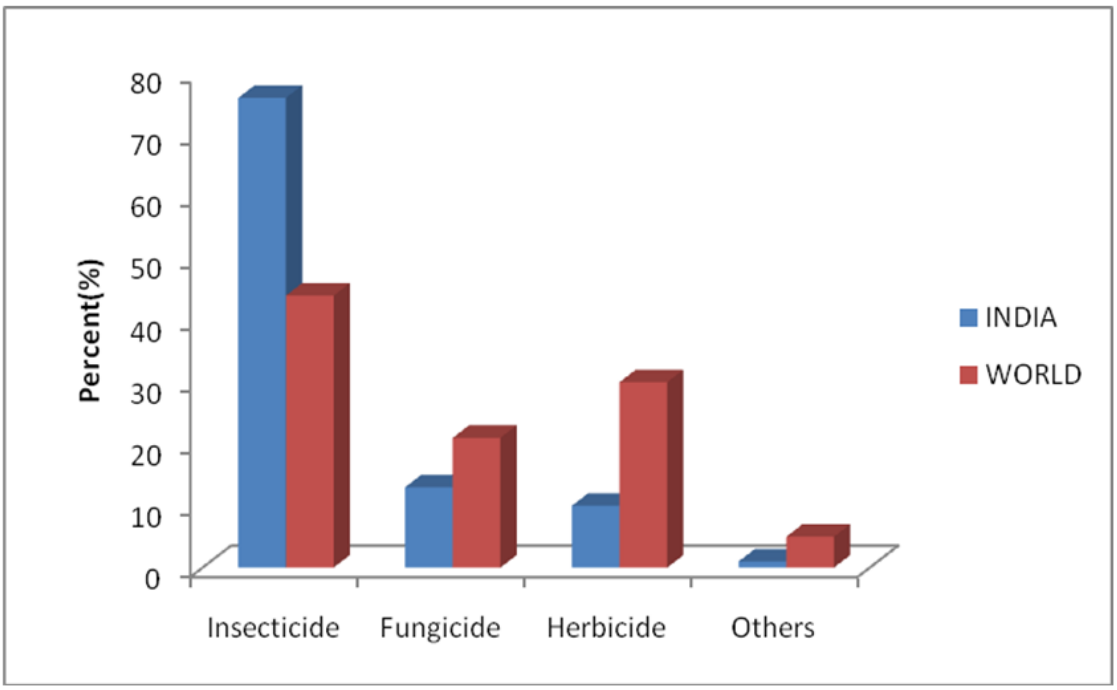

Figure 1. Exploring the variety of pesticides used in India and their global impact

The majority of herbicides are used to plantations in India that are responsible for the production of rubber, oil palm, tea, coffee, rice, and wheat. When it comes to herbicides, the whole country does not utilise them in the same manner. When it comes to the top 10 users, the states of Haryana, Punjab, Karnataka, Andhra Pradesh, Kerala, Gujarat, and Maharashtra are among the most prominent.

Herbicides that are allowed to stay in the soil for a long length of time are responsible for the degradation of soil quality, which is caused by a number of different types of variables. Among them are alterations in the dynamics of soil communities, a shortening of the length of the food chain, and the eradication of fauna that lives in the soil. Little study has been done up to this point on the long-term impacts of herbicides on soil ecosystems, especially those herbicides that are harmful to soil organisms that are not the intended targets. Assessing the toxicity of herbicides to the creatures that live in the soil offers a useful understanding of the potential threat that these chemicals provide to the ecosystems that are found in the soil; nevertheless, the process of risk assessment is very sophisticated and expense-intensive. [5]

Organophosphate (OP) molecules are the building blocks of a wide variety of common industrial compounds and insecticides. There are around 200,000 individuals who pass away every year as a result of organophosphate (OP) pesticide poisoning. The majority of these

deaths occur in rural parts of developing countries, with India having a disproportionately high number of fatalities. As a result of their high rate of biodegradability, rganophosphates have emerged as a significant alternative to chlorinated hydrocarbons. It has been shown that organophophates leave behind residues in water, sediments, and soil, despite the fact that they decompose naturally in the environment. “This is due to the fact that their usage has been uncontrolled. The presence of organophosphate residues has been discovered in a number of agricultural products originating from India. These products include sugar, tea, vegetables, and citrus fruits. The presence of their residues in human and animal tissues, as well as in blood, milk, and honey, demonstrated their bioaccumulative capabilities and excessive consumption. Human and animal tissues were also found to have residues of these substances. [6]

Synthetic pyrethroids are regarded to be safer for wildlife and biodegrade more quickly than organochlorine because of their synthetic nature. The World Wildlife Fund (WWF) advises against using pyrethroids as a replacement for DDT owing to the fact that the pests have the potential to develop resistance to the chemicals and that they have a detrimental effect on creatures that are not the intended targets of the treatment. "Instead, they call for further study to be conducted into the "possible hazards" that pyrethroids may have for human health. Unlike natural pyrethrins, synthetic pyrethroids are not only less toxic to animals but also often more effective than their natural counterparts.

A great number of contemporary pyrethroids have been synthesised as a consequence of structural modifications that have been applied to synthetic pyrethroids in recent years. When the bulk of these pyrethroids interact with the γ-aminobutyric acid (GABA) receptor-ionophore complex, they are responsible for causing neurotoxicity, as stated by the International Physiological and Chemical Society. Permethrin is an example of a modern pyrethroid that is now out there. Cypermethrin is predominantly directed towards the sodium channel that is present in the membranes of neurones. It has been shown by He (1989) that cypermethrin has the capacity to maintain sodium channels open for much longer periods of time, maybe even for many seconds.” Pyrethroids are used extensively in the fields of animal husbandry and public health due to the fact that they are only moderately harmful to humans. When sprayed to soil, pyrethroids have the ability to decrease the number of predatory mites, and when applied in sufficient amounts, they also have the ability to drastically reduce the quantity of earthworms.[7]

THE SIGNIFICANCE OF EARTHWORMS TO THE ENVIRONMENT

Aristotle first noted the function of earthworms as "The Intestines of the Earth" because of their work in aerating soil. But earthworms were thought regarded be pests until Charles Darwin published his book "The Formation of Vegetable Mould through the Action of Worms" in 1881. Darwin provided compelling evidence in this work of the relevance of earthworms to decomposition of organic materials and the establishment and preservation of soil structure. Subsequently, a mountain of literature attests to earthworms' function in enhancing soil structure and fertility. [8] The literatures mention that earthworms play an important role in soil ecosystems, and their contributions include**:**

i) Active engagement via feeding, leaf litter fragmentation, aeration rotation, and dispersion.

ii) The breakdown of organic matter, which results in chemical precipitation and the enrichment of soil nutrients by means of decaying matter and metabolic waste.

iii) Changing the microflora composition of soil and grazing over microflora.

The importance of earthworms beyond their underground function has been emphasised in recent years. They also have an impact on the above-ground subsystem, particularly on plant performance, which includes growth, development, and community composition. [9]

In forest environments, earthworms, particularly litter feeders like Lumbricus terrestris, may eat up all the litter that has been produced on the soil surface in a matter of weeks or months.

Soil quality and productivity have been improved in grassland areas of New Zealand, drained polders of the Netherlands, heathland of Ireland, and mining spoils of the United States when earthworms were introduced to these previously uninhabited regions. Casts made by lumbricids in pasture soil retained 73% of the nitrogen in the litter that the worms had eaten, showing that earthworms are important for both the soil's nitrogen incorporation and the worms' inefficiency in nitrogen digestion. Soil nitrogen is increased by earthworms because more organic matter is mineralised. When earthworms are present, the ratio of nitrate-N to ammonium-N tends to rise because nitrification is increased in their castings. In addition to the soil, earthworm guts and casts contain nitrogen-fixing bacteria; however, castings have higher nitrogenase activity, indicating larger rates of N-fixation, compared to soil.

Because they devour other decomposers and lower the substrate accessible to other decomposers, earthworms raise the level of soil metabolic activity but decrease nematode abundance and microbial biomass. Rapid nutrition cycling is likely to result from this procedure. [10]

MORPHO-ECOLOGICAL CLASSIFICATIONS OF WORMS

Aneics, endogeics, and epigeics are the three main categories into which earthworm species fall. The surface-dwelling epigeic species, the subterranean endogeic species, and the anecics all construct permanent, vertical burrows that go deep into the earth to search for food.

In their role as ecosystem engineers, earthworms significantly impact soil structure, as well as its biotic and abiotic qualities, via decomposing organic matter and combining it with minerals." Epigeic earthworms are easily recognisable by their little size, abundant colouring, and extensive distribution over the planet's major landmasses. Due to their high population density and inability to burrow well, epigeic earthworms are restricted to the uppermost layers of soil in each particular environment. Epigeic earthworms consume, grind, and partly digest trash found on the surface of the earth. Soil nutrient leaching is increased in natural systems due to epigeic earthworms' litter digestion. [11]

CONCLUSION

The analysis makes it quite evident that the widespread use of pesticides in contemporary farming poses serious risks to earthworms, which are vital soil creatures. Organophosphates, pyrethroids, and herbicides are toxic compounds that reduce biomass, hinder reproduction, and disrupt enzyme activity, despite the fact that they perform essential ecological activities such as nutrient cycling and soil structure maintenance. Because whole soil ecosystems are at risk when earthworm populations decline, the effect is both biological and systemic. The persistence of pesticides in soil and food chains is a major cause for worry, even if certain types of pesticides exhibit relative biodegradability. If we want to know the sub-lethal and long-term consequences of these substances, we need ecotoxicological studies that last a long time and use molecular techniques. The negative impact on soil fauna that aren't intended targets may be reduced by the promotion of ecologically friendly alternatives and the implementation of more stringent monitoring of pesticide residues. In order to achieve

sustainable agriculture and environmental protection, it is important to integrate soil biology with pesticide management. [12]

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