Journal of Advances and Scholarly Researches in Allied Education
Vol. 19, Issue No. 5, October-2022, ISSN 2230-7540

Earthworm and its role in the Detoxification of soil Pollutants

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Abstract - Pollution of the soil is a serious issue for the planet. Soil pollution from organic contaminants and heavy metals, among others, has increased dramatically as industrialisation has progressed rapidly. A variety of pollutants released into the environment are absorbed by the soil. Sources of heavy metals in soil range from industrial emissions and wastes to fertilizers and coal combustion residues to sewage and pesticides to mine tailings. Heavy metals have a greater possibility for direct and accidental exposure due to traits such as fast production rates through human activities and their inability to be kept in a localized location. The vast majority of metals are very stable and resistant to breakdown by microbes and chemicals. Heavy metal contamination poses a risk to human health because it reduces soil microbial activity and agricultural yield.

Keywords - Pollution, soil, microbes and chemicals, heavy metal.

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INTRODUCTION

With a history stretching back 600 million years, earthworms have established themselves as one of Earth's most vital animal populations. Soil qualities, agricultural/industrial operations, and environmental pollution are only a few of the elements that may drastically alter the population dynamics or biomasses of these invertebrates. Soil quality & fertility may be improved thanks to earthworms, according to previous research. Particularly in recent times, scientists have been interested in one defining characteristic of earthworms. Earthworms have been demonstrated in several studies to translocate and accumulate harmful metals in their tissues, potentially altering the availability, absorption, or accumulation of heavy metals. The purpose of this chapter is to provide an overview of earthworms and their function in soil heavy metal detoxification.[1]

GROUPING EARTHWORMS BY THEIR ECOLOGICAL ROLES

Earthworms' eating, casting, and burrowing considerably improve the soil's physical, chemical, and biological qualities. The fundamental physi- cal characteristics of soil are affected differently by earthworms of the epigeic, endogeic, and anecic lifestyles. Epigeic plants like Lumbricusrubellus, Eisenia fetida, or Dendrodrilusrubidus thrive in the humus zone of soil. They derive most of their sustenance from the organic stuff that grows on top of the mineral soil, although they will ingest the occasional particle of soil. Epigeic species are those that live in the soil, rather than in the air. They dig their burrows into the organic material layer, or between 0 and 2.5 centimeters deep into mineral soil, where they feast mostly on elements rich in bacteria. Epigeics tend to be little, reddish-brown worms that are shorter than 7.5 cm. The largest and longest Anecic species, which are all reddish brown in color and range in length from 12.5 to 20.0 cm, are Lumbricusterrestris, Aporrectodea longa, and Dendrobaenaplatyura. They live in burrows, consume decaying plant matter from the soil's surface, then defecate and urinate via an entrance. The top 50 cm of soil is ideal for the Endogeic Species, which live off the organic stuff there. Differentiating them from epigeic and anecic species are their intensely pink heads and gray bodies. Adults of endogeic species could be anywhere from 3 centimeters to 12.5 centimeters in length.[2]

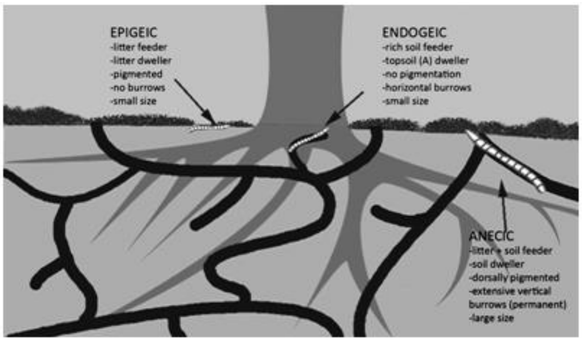

Figure 1: Soil worms are categorized ecologically.

THE ROLE OF EARTHWORMS IN THE TOPSOIL

There are probably over 6,000 distinct species of earthworms. Earthworms are very versatile, capable of thriving in a wide variety of soil environments, from mild to extreme (such as those found in agricultural, forest, and pasture ecosystems, as well as desert and glacier soils). Earthworms have lengths of up to two meters as adults and range in weight from 10 milligrams to one kilogram. The tropics of South and Central America, Africa, Southeast Asia, Australia, and New Zealand are common places to find giant earthworms. In other parts of the world, smaller earthworms predominate. While the other families are more common in tropical and subtropical regions, the Lumbricidae are mostly a temperate zone family. Depending on the kind of soil, as many as ten different species of earthworms may cohabit. Similar earthworm species tend to coexist in areas with similar climates and soils. There may be anything from 10 to 1,000 earthworms per sq meter of soil, and 1 to 200 g earthworm biomass, depending on the time of year and the soil's surrounding environment.

The kind of plants that do well in a given area and the prevailing weather patterns are highly associated with the soil's biodiversity and the number of earthworms living in it. Earthworm abundance and diversity may also be affected by the proportion of deciduous to coniferous trees in a forest. The soils of the temperate zones were found to be dominated by 12 different species of Lumbricidae, whereas the soils of Africa were only home to 7. Evidence suggests that tropical agroecosystems are home to a greater diversity of earthworm species (at least 20). The typical earthworm lives between 10 to 12 years, however many species only live for 1 or 2 before being eaten by a larger bug, a mole, or a bird. [3]

ENVIRONMENT-RELATED INFLUENCES ON EARTHWORM ABUNDANCE AND ACTIVITY

Environmental variables and biological connections are two broad categories under which earthworm populations and soil activities may be examined.

Climate

Earthworms' biology & life cycle are directly affected by changes in their habitats and diets, which are in turn influenced by climate. Temperature, for instance, affects the metabolism and dispersal of earthworms. High temperatures encourage the quick decomposition of organic waste by epigeic and anecic species, lowering the quantity of debris on the surface. Compared to soils in more temperate climes, this process moves significantly more swiftly in tropical soils. Drier soil and higher temperatures are bad for earthworms. At field capacity (10 kPa tension), earthworm growth is at its peak; at 100 kPa moisture tension, it rapidly declines; when it reaches the permanent wilting threshold, it halts entirely (1,500 kPa). Earthworm activity is very seasonal in temperate regions. [4]

Due to the depth at which they are digging, the seasons of spring and autumn see the greatest excavation rates, while winter sees the lowest. They may survive the driest summers by burrowing deeper into the soil and waiting out the dry conditions in immovable coils. However, although cocoons are only created at particular times of the year, manufacturing may take place all year round. In temperate zones, the optimal times for making the first cocoon are spring and early summer, whereas the secondary cocoon is created in the autumn. The typical number of cocoons created by earthworms is anything from one to twenty. The frequency and intensity of earthworm activity are both significantly affected by the degree of moisture and the accompanying temperature in the soil. Conditions that are too dry or too damp are equally harmful to earthworms. Temperatures below 1 degrees Celsius and over 35 degrees Celsius are lethal to most animals. When circumstances on Earth are too harsh for the earthworms to continue living, they enter a state of dormancy known as a cocoon.[5]

Soil Properties

Several elements, such as the soil's texture, thickness, pH, & organic content, determine the earthworm population & activity level in a given area. The effects of climate on these traits are significant. Some causes of soil salinity include the leaching out of Na^+, Mg^{2+}, & Ca^{2+} in high-rainfall areas, and the subsequent reduction in soil pH. Earthworm activity decreases down significantly below a pH of 4.5, and most species become extinct below a pH of 3.5. In general, earthworms in temperate regions like pH levels between 5.0 to 7.4. On the other hand, earthworm populations & activity levels tend to decrease in very acidic soils. This is because limited precipitation in dry or semi-arid locations causes soils there to be deficient in organic matter. Earthworm numbers and activity may be affected by the physical characteristics of the soil. Worms will rather live in loamy soil than one that is sandier or clayier. Earthworm activity may be diminished after a precipitation because thick clay soils can become anoxic for extended periods of time or sandy soils can have a lower water holding capacity. Soil depth may also have a role in the distribution of earthworms in both temperate and tropical climates. It has been noted that earthworm species living in deeper soil layers are often less active than those surviving in shallower soil.[6]

There is a one-to-one relationship between the amount and quality of SOM, which is consumed by earthworms, and the plant life that flourishes on the soil's surface. Litter layers composed of grass, herbaceous plants, and deciduous trees have a C:N ratio that is less than 20:1, which is optimal for plant growth. Earthworms or other soil creatures may benefit from organic matter supplements. Animal faeces, however, may have the opposite effect on earthworms and hinder their activity when added to soil owing to the high salt and ammonia concentrations in animal waste. Plant biomass rises after liming and chemical fertilisation of acidic soils, leading to an increase in earthworm biomass.[7]

EARTHWORM CASTINGS

In general, earthworms may digest 60% of their body mass in soil or organic matter, and they excrete their feces in the form of pellets known as earthworm castings, which they deposit in the soil near their burrows. The majority of worm poop falls into four distinct categories. The first is spherical and is often made by larger earthworm species like anecics and endogeics. Endogeics and anecics may also create the second kind, however this one lacks structure. Finally, these organisms also drop round pellets on the ground. Smaller species of earthworms, such as epigeics, tiny endogeics, and diverse anecics, create the fourth kind, which looks granular or pellet-like. When it comes to the impact of their excrement on soil structure, earthworm species may be rather picky. [8]

Granular castings are on the other side of the spectrum from the preceding three categories, which are all bigger, denser, and more compact. There are some chemical and biological similarities between earthworm faeces and the organic matter that these worms eat. Both the earthworm's digestive microbes and the worm's own mechanical grinding mechanism help to create this quality. When compared to the organic material that earthworms consume, the cast of earthworms has a higher concentration of nutrients, a lower C:N ratio, more stable microbial characteristics, and higher extracellular enzyme activity. Earthworm castings are thus commonly utilized as a natural fertilizer.[9]

Earthworm Effects on Soil Characteristics

Earthworms largely alter soil properties via their eating, casting, and burrowing habits. As a result of the mineral soil OR organic material they consume, earthworms may alter the features of the soil in their castings, which they collect close to the soil's surface. Due to the high levels of carbon, nitrogen, & water, the organic components in worm castings are rapidly mineralized. Soil aggregates build more steadily as a consequence. Stronger contact between soil particles is promoted by the presence of fungal hyphae as well as other microbial compounds in faeces, which is a major contributor to the creation of stable soil aggregates. Earthworms' gallery-building activities, which increase macropores in soil, are species- and environment-specific. These galleries may be as little as 1 mm or as large as 10 mm in diameter, depending on the earthworm's ecological classification. Species that are epigeic tend to be tiny and occupy the top few centimeters of soil. They tunnel vertically or horizontally for a short distance through the first few centimeters of soil. [10]

Endogeics are organisms that tunnel underground constantly, creating a system of interconnected passages. These animals have a habit of defecating within their galleries, which might prevent water from reaching the ground below. Vertical galleries dug by anecic earthworms may extend as far as 2 meters underground. These galleries have a more stable water flow and greater bulk soil density around them. When earthworms poop, the readily decomposable organic matter is mixed with the mineral soil below, creating aeration. How much organic matter and nutrients are decomposed and converted by earthworms depends on their population density and nutrition. Epigeal earthworms typically dine on the decomposing organic debris that collects in the soil's uppermost O and uppermost A layers. By facilitating the incorporation of organic matter into topsoil, they promote the mineralization of compounds by making more of these compounds available to microorganisms. Anecic species deposit their faeces on the surface of the soil as they move organic materials from the top to the bottom layers of the soil. Both epigeic and anecic earthworms are responsible for creating an active A horizon as well as the "mull" soil horizon. [11]

They trigger the production of organo-mineral compounds derived from worm poop in the Ah zone (vermimul). The casts and tunnel walls of endogeic species are highly mineralized & contain more nutrients than that of the surrounding environment because they exclusively consume other endogeic species. The soil sub-compartment inhabited by earthworms and the gallery zone excavated by epigeic species are together referred to as the "drilosphere." More bacteria and much more active enzymes may be found in the feces or burrow walls of endogeic and anecic species alike. Feces from earthworms have unique microbiological qualities due to the organic matter they consume. In particular, the microbiological features of the feces of earthworms that ingest organic materials with narrow C:N ratios are enhanced, with more abundant microbial biomass and greater enzyme activity. Earthworms may also alter the soil's pH. Due to a higher proportion of basic cations ($Ca2+$, $Mg2+$, and $K+$) than their surroundings, earthworm castings are beneficial. Earthworm activity also improves the availability of soil nutrients. [12]

Soil pollution is an international problem. Soil pollution from organic contaminants and heavy metals, among others, has increased dramatically as industrialisation has progressed rapidly. A variety of pollutants released into the environment are absorbed by the soil. Industrial emissions & wastes, fertilizer, coal combustion leftovers, sewage, pesticides, or mine tailings are all possible sources of heavy metals in the soil. Because of characteristics such as high production rates via human activities or the difficulty to keep heavy metals in a contained area, they pose a larger risk of direct and unintentional exposure. Almost all metals are very stable and challenging for microorganisms and chemicals to degrade. The decrease in soil microbial activity or crop productivity that results from heavy metal pollution is a reason for worry for human health because of the food chain.

Cd, Cu, or Zn are typical metal pollutants found in soil (Zn). The other three most poisonous heavy metals are lead, mercury, and cadmium; however, cadmium serves no recognized biological function. Cadmium is known to have an effect on a wide variety of enzymes in the body. Cd is considered to cause renal damage resulting to proteinuria by interfering with the activity of enzymes involved in protein reabsorption in the kidney tubules. Cd may induce demineralization of bones either directly via bone damage or indirectly via renal failure. Reduced lung function as well as an increased risk of lung cancer have both been related to long-term exposure to airborne Cd in the workplace.[13]

If you look at the usage of metals throughout the world, copper is in third place. Cu pipes or copper-based pesticides used to prevent algal growth may both contribute to the possibility of copper contamination in municipal water supplies. Particles from suspended soils, combustion sources, the manufacture or processing of cerium commodities, and mine tailings have been linked to copper in the atmosphere. The three most significant sources of emissions are agricultural practices, municipal waste treatment plant sludge, and municipal and industrial solid waste. Copper may cause anemia, kidney and liver damage, gastrointestinal distress, and even death at high enough concentrations. Long-term exposure to copper has the potential to cause nasal, oral, and ocular irritation as well as abdominal pain, lightheadedness, nausea, vomiting, and diarrhea. Copper poisoning leads to Wilson's disease, characterized by hepatic cirrhosis, cognitive decline, renal failure, and copper deposits in the cornea.

Zinc is an essential trace element for human health, along with a number of others. Zinc ions are relatively harmless compared to other heavy metal ions. Zinc fingers in DNA complexes need it, and it serves as a structural component in enzymes. Long-term exposure to copper is associated with copper absorption, although zinc acts as an absorption blocker. The brain is an extremely apparent organ for cell death & cytotoxic activities requiring zinc. Zinc is very toxic to all forms of life when present as a free ion in solution.[14]

Ingestion, skin contact, the food system, drinking contaminated ground water, and reduced crop yields owing to phytotoxicity are just a few of the ways in which heavy metal pollution may negatively impact human and environmental health. Scarcity of farmable land leads to food insecurity. In light of this, it follows that heavy metal resistance is an absolute need for the continued existence of all forms of life. Bioremediation refers to the practice of using a wide range of living organisms to clean up polluted areas, and it has been made feasible by advances in science and technology.

Subterranean worms, or earthworms, play a significant role in terrestrial food webs. As the "intestines of earth," soil microorganisms play an important role in fostering plant growth and increasing soil fertility. A broad range of environmental toxins, such as pesticides, metals, DDT, and PCBs, may harm earthworms. Evidence suggests that earthworms may be used as a reliable gauge of environmental pollution. It is possible for them to bio-accumulate and even flourish in environments contaminated with chemical toxins such as heavy metals and organic pollutants in the soil. Earthworms are known to absorb heavy metals, which they then either retain in nodules produced inside the worm's body cavity or expel via calciferous glands. Even though heavy metals are known to be fatal to most creatures, research has revealed that certain populations of invertebrates can tolerate exposure to levels much higher than the deadly threshold.[15]

Thanks to grubs, who consume massive quantities of dirt, microorganisms are dispersed across a wider region. Complex and diverse relationships exist between earthworms and microorganisms. The earthworm's digestive system is home to millions of microorganisms. Microbes are required for several activities, including the breakdown of organic materials and the fixation of nitrogen. We don't know whether or when these germs

Whether or whether the earthworms' home plays a significant role in the cleansing process is unknown. Bioremediation benefits from microorganisms because certain of these organisms, with the aid of enzymes they create, may utilize environmental contaminants as food. Because heavy metals provide a selective pressure throughout growth, microorganisms have evolved a wide variety of strategies to cope with the stress they cause. Bacteria and algae have evolved mechanisms for coping with and clearing off toxic metals. Heavy metals in contaminated fluids may be bioaccumulated, precipitated, and bio-absorbed by microbes. Through a process known as bioaccumulation, the microbes store and concentrate the metals. In order to accumulate within the microbe, heavy metal ions must first cross the membrane that separates the inside from the outside. The bio adsorption process involves adsorption of metal cations to the negatively charged ionic groups on cell surfaces, and this is how heavy metal ions, especially positive charged ions, are stored.

It is widely known that the vast majority of microorganisms possess genes that provide resistance to the toxic effects of heavy metal ions. Genomic islands or plasmids usually house resistance genes. It was discovered that metal resistance determining genes might be activated. Bacteria can control the amount of metal ions within their cells and even learn to tolerate toxic metals by using a wide variety of genetic pathways. Active refluxing of the metals to the outside of the cell or enzyme chelation are two mechanisms by which bacteria gain this metal resistance.

The detoxification process, in which dangerous substances are converted into less hazardous ones chemically, allows for their elimination from the body. Thus, the importance of microorganisms' tolerance/detoxification of metals for the ecosystem and human health cannot be overstated.[16]

CONCLUSION

As the most common soil pollutants, heavy metals are well-documented to be tolerated and accumulated by earthworms over time. In this study, we analysed the effects of copper and zinc on endogeic earthworms (Pontoscolexcorethrurus). Copper's prominence stems from its status as one of the three most dangerous heavy metals. To form strong connections, copper rapidly interacts with free oxygen radicals, making it a reactive metal. Copper is very harmful due to its oxidising and reducing properties, and it may have a wide range of consequences on various organisms. The production of hydroperoxide radicals is the mechanism through which copper interacts with cell membranes to cause toxicity. Copper's effects on earthworm development were not immediate or fatal at lower doses, but were more pronounced as the concentration grew. Size and mass steadily decreased. Earthworms may be especially vulnerable to copper because of the ineffectiveness of current detoxifying procedures.

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