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Vermiremediation to Remediate Organically Contaminated Soils

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ABSTRACT: Vermiremediation is an expanding technology that uses earthworms to remediate organically contaminated soils and has been attracting attention from researchers gradually. This review outlines general aspects of vermiremediation, including its concepts, processing of organics-polluted soils, its advantages and limitations, the methods for enhancing vermiremediation, and other peripheral issues. Processes involved in vermiremediation of soils contaminated by organic chemicals mainly include vermiaccumulation and vermiremediation, vermitransformation, and drilodegradation. Vermiremediation plays an important role in vermiremediation and should be highlighted. Vermiremediation technology can be characterised as environmentally friendly, effective, sustainable. Strategies for enhancing vermiremediation might include the use of surfactants, nutrient amendments, management strategies, or combinations with other remediation technologies. Unlike previous reviews, peripheral issues such as the inoculation and colonising of earthworms in contaminated field and methods for harvest and disposal of earthworms used in vermiremediation are also discussed. However, there are many issues need to be clarified, including

- i) The capacity, contribution, and mechanisms of different vermiremediation processes;
- ii) The behaviour of organic pollutants in the drilosphere,
- iii) Enhancement measures for vermiremediation and their side effects, and
- iv) Earthworm collection methods in polluted soil and their post-harvest disposal. This review gives a general outline of vermiremediation, which is expected to promote further studies and practical application of vermiremediation in organically contaminated soils.

KEYWORDS : Vermiremediation , Earthworms , chemical , detoxifying , bio-accumulate, biodegrade ,bio-transform , chemicals

I. INTRODUCTION

Empirical and theoretical information from the literature showed evidence of the significant contributions of earthworms to the removal of soil organic contaminants and metals. Earthworms indirectly facilitate the conversion of organic contaminants by promoting microbial and enzyme activities. Some organic contaminants are directly taken up through dermal and intestinal absorption and accumulated by preferential sequestration in sub-organismic and tissue fractions of earthworms. Metals are directly removed and accumulated by the mechanism of detoxification and sequestration, via metallothioneins induction. [1]The terms ‘contaminants’ and ‘pollutants’ have different meanings and should not be used interchangeably. Although vermiremediation presents an ideal clean-up technique, it is limited in application to only mildly contaminated soil environments. Ethical concerns should not pose a serious issue because vermiremediation simply takes advantage of earthworms’ natural soil-conditioning abilities. Many vermiremediation processes, especially of organic wastes, are harmless to earthworms, improving the soil for their growth and survival.[2] Vermiremediation presents a good long-term biological option to clean up mildly contaminated soil. It may be deployed as a secondary measure to rid the soil of residual contaminants after applying physicochemical remediation techniques to an overtly polluted soil environment.[3]

II. OBSERVATION

Earthworms in general are tolerant to many chemical contaminants including heavy metals and organic pollutants in soil and can bio-accumulate them in their tissues. Earthworms species like *Eisenia fetida*, *Eisenia tetraedra*, *Lumbricus terrestris*, *Lumbricus rubellus* and *Allobophora chlorotica* have been found to remove heavy metals (Cd, Pb, Cu, Hg, etc.) pesticides and lipophilic organic micropollutants like the polycyclic aromatic hydrocarbons (PAH) from the soil. They ‘absorb’ the dissolved chemicals through the moist ‘body wall’ in the interstitial water and also ‘ingest’ by mouth while the soil passes through the gut. [4]

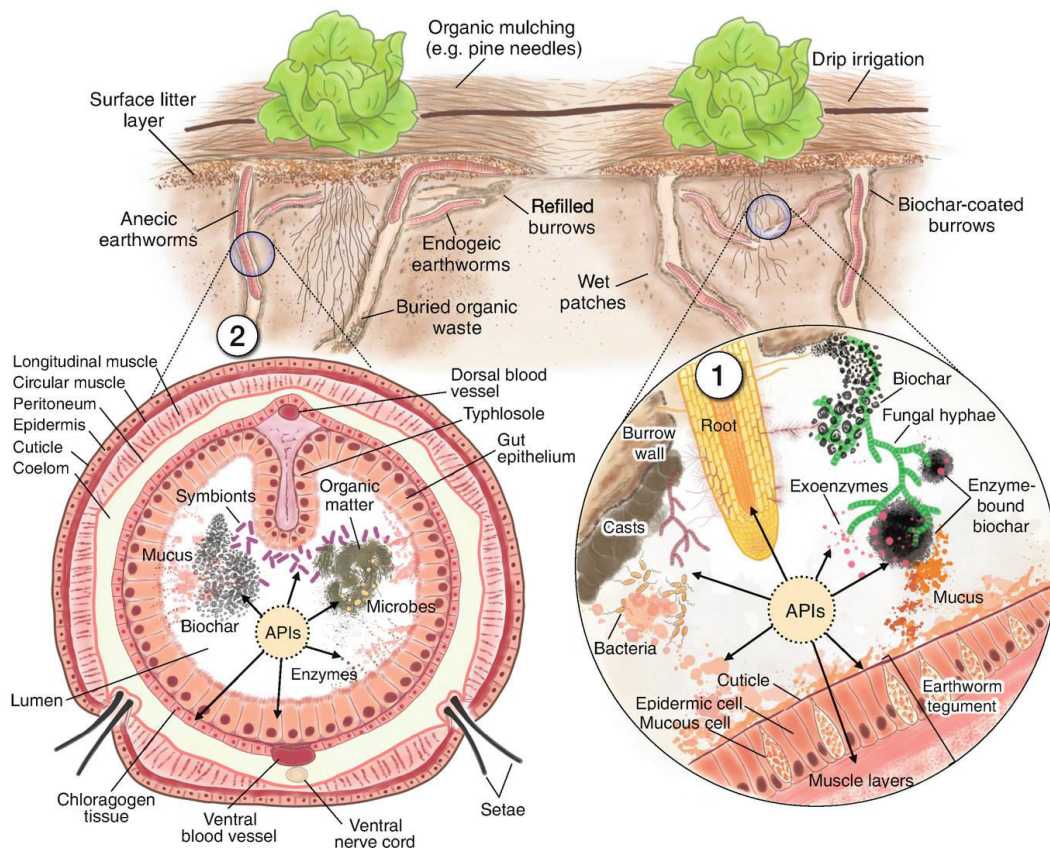


Fig.1: Vermiremediation technology

They either ‘bio-transform’ or ‘biodegrade’ the chemical contaminants rendering them harmless in their bodies. Meanwhile the quality of the soil is improved significantly in terms of physical, chemical and biological properties as the worms thoroughly upturn and disperse the soil, ingest large volumes of soil and excrete nutritive materials (NKP and micronutrients) in the form of ‘vermicasts’ along with millions of beneficial soil microbes including nitrogen fixers.[5]

Earthworms uptake chemicals from soil pore water through passive ‘absorption’ of the dissolved fraction through their integument. Intestinal uptake can also occur as soil is ingested and passed through the gastro-intestinal tract. Earthworms consume relatively large quantities of soil, soil-dwelling microbes and organic matter during their lifetime. Earthworms apparently possess a number of mechanisms for uptake, immobilization and excretion of heavy metals and other chemicals. They either ‘bio-transform’ or ‘biodegrade’ the chemical contaminants rendering them harmless in their bodies. [6] Most biotransformations and biodegradation are done in the gut before the contaminants enter the worm tissues. Not all contaminants enter the worm via the GIT. Some simply pass through the gut and are excreted in the casts. Those that enter the gut can be metabolized, complexed and excreted, or sequestered in tissues or vacuoles. While most contaminants are rendered harmless, some might be activated to other toxic forms. [7]

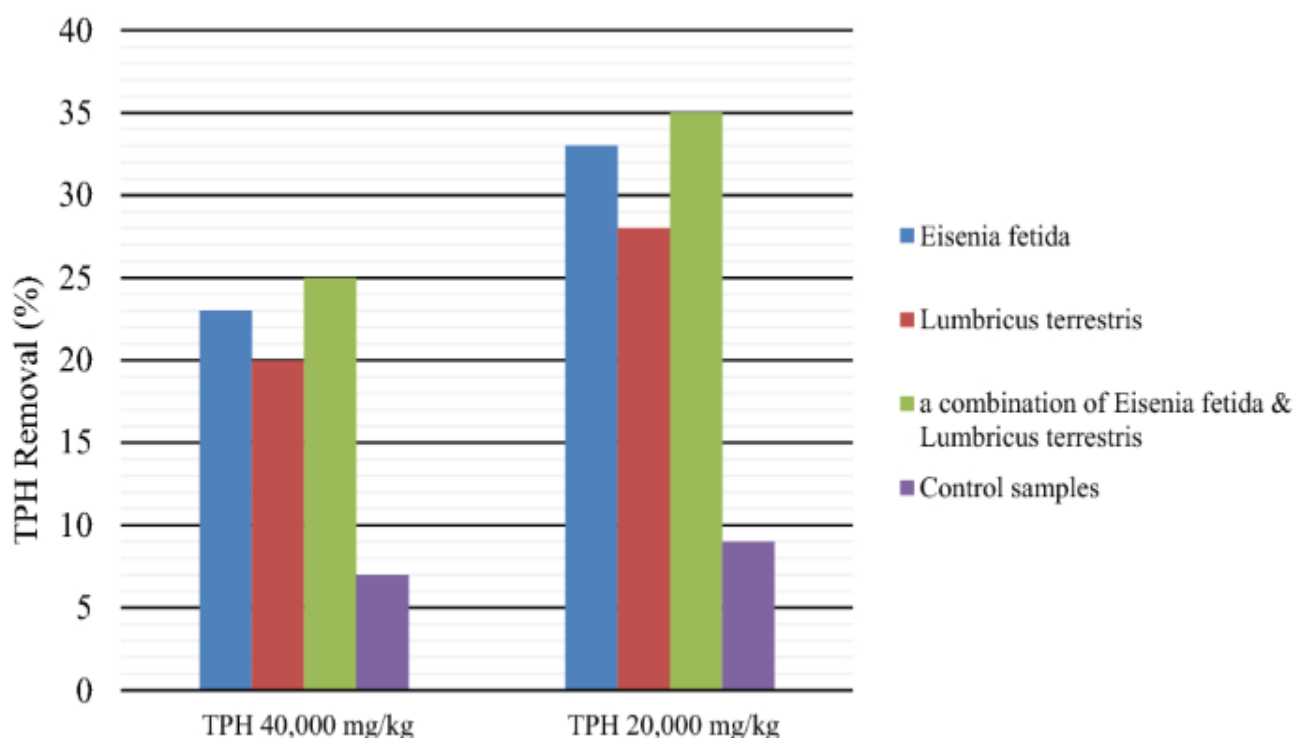


Fig.2. Comparative vermiremediation process

III. DISCUSSION

Some metals are taken up by earthworms and bound by a protein called 'metallothioneins' which have the capacity to bind metals. Ireland (1979) found that cadmium (Cd) and lead (Pb) are particularly concentrated in chloragogen cells in *L. terrestris* and *D. rubidus*, where it is bound in the form of Cd-metallothioneins and Pb-metallothioneins, respectively. Small amounts can be deposited in waste nodules (vacuoles). The chloragogen cells in earthworms appear to accumulate heavy metals absorbed by the gut and immobilize the metals in small spheroidal chloragosomes and vesicles found in these cells.[8]

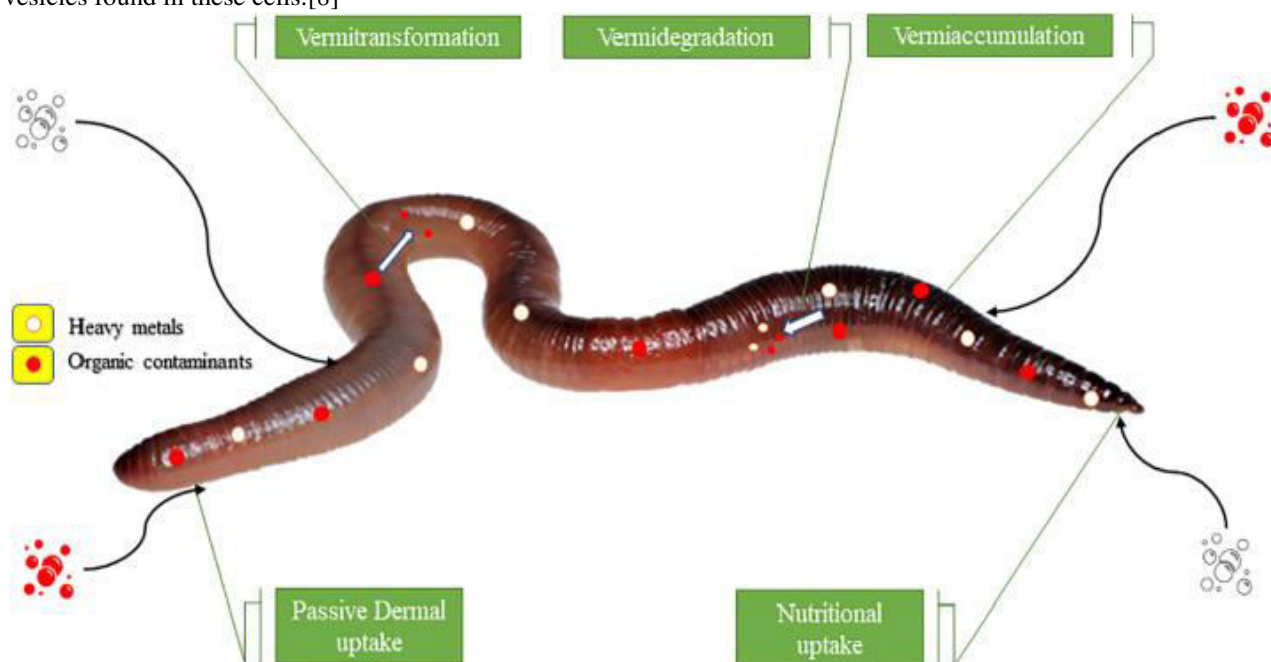


Fig.3. Vermiremediation process

Hydrophobic organic contaminants are taken up by the earthworms in two ways: 1. Dermal absorption—passive diffusion from the soil solution through the worms outer membrane; 2. Intestinal absorption—of the compounds from the soil while it passes through the gut (by digestion) The process of passive diffusion is driven by the concentration gradient between the soil pore water and the earthworm's tissues . The accumulation increases when the concentration of PAHs in their surrounding soil water or in their food increases . It was reported that the earthworms may absorb PAHs dermally and via the gut selectively feeding on organic matter to which the PAHs are adsorbed. [9]



Fig.4. Vermiremediation of contaminated soil

Degradation of PAHs occurs when microorganisms break the aromatic rings and produce aliphatic compounds that readily enter the tricarboxylic acid cycle (metabolic activity) operating in living cells. *Cunniughamella elegans* and *Candida tropicalis* have been reported to degrade PAHs . The bacterial flora associated with the intestine and vermicasts of the earthworms and found species like *Pseudomonas*, *Paenibacillus*, *Azoarcus*, *Burkholderia*, *Spiroplasma*, *Acaligenes* and *Acidobacterium*. Some of them, such as *Pseudomonas*, *Acaligenes* and *Acidobacterium*, are known to degrade hydrocarbons. Some fungi such as *Penicillium*, *Mucor* and *Aspergillus* have also been found in the intestine of earthworms and they degrade hydrocarbons. *Acaligenes* can even degrade PCBs and *Mucor dieldrin*. [10]

IV. CONCLUSION

Vermiremediation technology by earthworms is a self-promoted, self-regulated, self-improved, self-driven, self-powered and self-enhanced, low or no energy requiring zero-waste technology, easy to construct, operate and maintain. Any vermiculture technology involves about 100–1000 times higher 'value addition' than other biological technologies . Obtaining earthworms from vermiculture farms would be one-time cost in any vermiremediation technology as the earthworms multiply rapidly creating huge army of worms which further promote and enhance the process . Vermiremediation of chemically polluted/contaminated soils/lands would cost about \$500–1000 per hectare as compared to \$10,000–15,000 per hectare by mechanical excavation of contaminated soil and its landfill disposal. [8] Of considerable economic and environmental significance is that the worm feed used in vermiremediation process is necessarily an 'organic waste' product. This means that it would also lead to reuse and recycling of vast amount of organic wastes which otherwise end up in landfills for disposal at high cost. And what is of still greater economic and environmental significance is that the polluted land is not only 'cleaned-up' but also 'improved in quality'. [6]

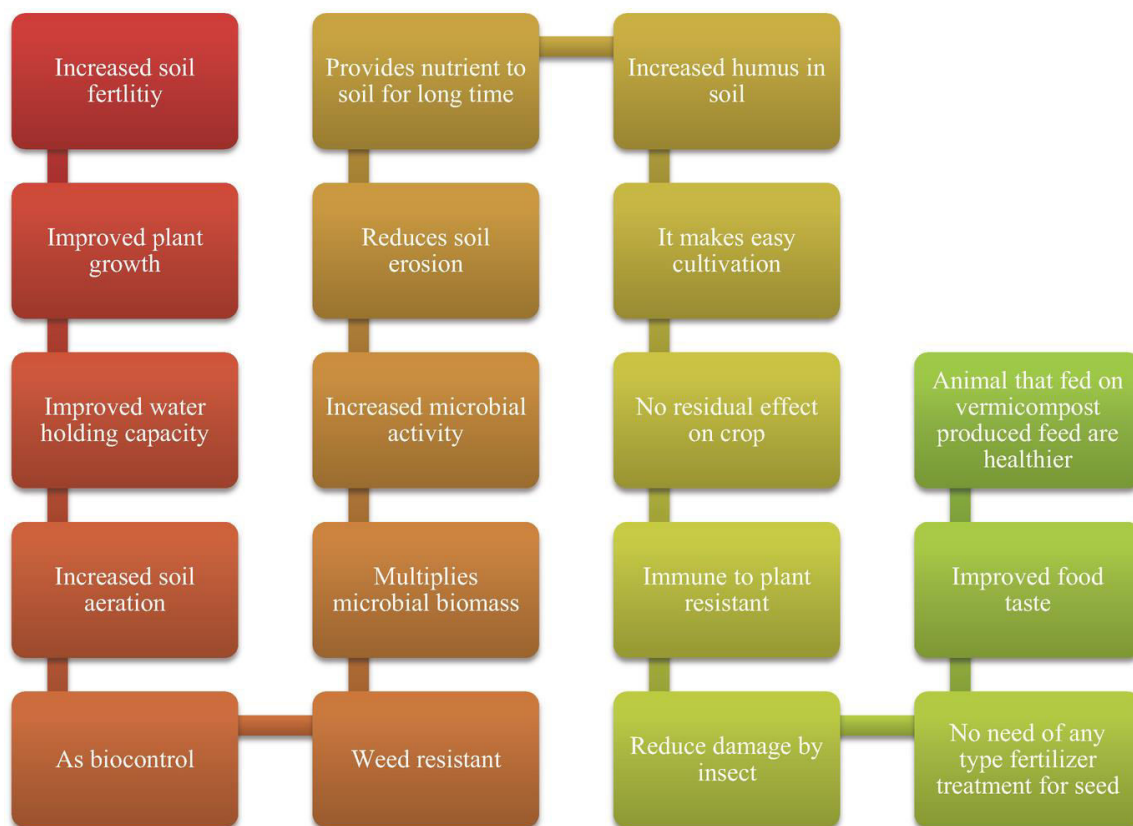


Fig.5. Earthworms as ecofriendly resource

V. FUTURE SCOPE

Vermiremediation may prove a very cost-effective and environmentally sustainable way to treat polluted soils and sites contaminated with hydrocarbons in just few weeks to months. With the passage of time, the remedial action is greatly intensified. As worms reproduce relatively rapidly, they can quickly achieve levels of enhanced degradation of PAHs. In comparison to the cost of mechanical treatment by excavation of contaminated soils, this technology is economical. Significantly, vermiremediation leads to significant improvement in the quality of soil and land where they inhabit. During the vermiremediation process of soil, the population of earthworms increases significantly benefiting the soil in several ways. A 'wasteland' is truly transformed into 'wonderland'. [3,10]

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