Research And Impact of Bioremediation on Soil Cadmium

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Abstract. There are many studies on the interaction between Cd pollution and bioremediation at home and abroad, mainly local and short-term toxicological effects, and there is a lack of systematic reviews. The purpose of this report is to provide a summary of the research on several bioremediation methods through specific experiments and mechanisms. and a summary and report on the principles and mechanisms of phytoremediation technology and animal remediation technology. In the future, bioremediation technology should focus on further exploration in the treatment cycle and final treatment of materials, avoid secondary pollution, strengthen the prevention and control of soil cadmium pollution, master more scientific soil cadmium pollution prevention and control technology, and expand more experiments and research on bioremediation If necessary, researchers can comprehensively apply and match a variety of different control technologies to enhance the control effect of soil cadmium pollution. It is also hoped that more attention will be paid to some potential future research on remediation methods for soil cadmium pollution, and that bioremediation is not only for the further exploration and discovery of cadmium and other heavy metal pollution in soil.

Keywords: Cadmium pollution; bioremediation; phytoremediation technolog.

1. Introduction

Soil contamination with potentially toxic elements (PTM) has become a global issue related to the sustainable development of human society. Among PTMs, cadmium (Cd) is the main poison in soil because of its high mobility and toxicity. According to the latest national soil pollution survey, more than 7% of farmland in China is contaminated by Cd. To make matters worse, soil Cd levels in some areas are higher than 10 mg/kg, which is significantly higher than the allowable threshold level for agricultural land in China (0.3 to 0.6 mg/kg). Public concerns about food security have increased dramatically due to the risk of ingesting cadmium through food consumption, especially following the cadmium rice case. Therefore, the remediation of Cd-contaminated soil is particularly urgent. Cadmium (cd) is one of the most toxic heavy metals and cannot be degraded by organisms. Therefore, when absorbed by plants, it will affect plant growth. Cadmium (cd) will also have toxic effects when accumulated in the human body through the food chain. Cadmium is one of the most toxic heavy metals and cannot be degraded by organisms. Therefore, when absorbed by plants, it will affect plant growth. Cadmium will also have toxic effects when accumulated in the human body through the food chain. In response to the current serious situation of soil cadmium pollution, physical, chemical, biological, and other soil remediation technologies are widely used to reduce the cadmium absorption of plants and reduce its transfer to the biological chain by reducing the cadmium content in the soil or changing its existing form. inflow. However, these methods have some shortcomings, such as high cost, long cycle, low efficiency, and unstable effects. If certain agronomic measures can be taken in cadmium-contaminated soil to directly regulate the physiological metabolic process of crops during their growth, reduce the absorption of cadmium by crops, or inhibit its transport to edible organs, it will ensure the safety of my country's agricultural products and reduce the risk of Cadmium poisons the human body, energy conservation and green sustainable development are of great significance.

2. Current Status of Cadmium Pollution in China

2.1. Current Status of Soil Cadmium Pollution

As shown in Figure 1, looking at the distribution of soil cadmium pollution in my country, metal mining areas, sewage irrigation areas, industrial areas, and township enterprises are the main areas where cadmium pollution is concentrated. The problem of soil cadmium pollution in China has always been a concern. It mainly comes from agricultural activities, industrial wastewater discharge, discarded batteries, coal combustion, and other processes. Long-term use of chemical fertilizers and pesticides in agricultural activities is also one of the causes of soil cadmium accumulation. In addition, there are regional differences: there are regional differences in the distribution of cadmium pollution in China (Figure 1). Some agricultural-intensive areas, industrialized areas, and rice-producing areas may be more susceptible to the effects of soil cadmium pollution. Cadmium accumulates in agricultural soil, especially in rice-growing areas. Due to the high absorption capacity of cadmium in rice, it may lead to the accumulation of cadmium in the food chain. Please note that soil cadmium contamination status may change over time, so it is recommended to consult the latest research and government reports for the latest information on soil cadmium contamination in China. The average cadmium content in farmland soil in my country is shown in Figure 1. The average cadmium content in soil across the country is 0.23 μg·g -1. Hunan soil has the highest cadmium content, reaching 0.73 μg·g -1. The average cadmium content in Guangxi soil is also Around 0.70 μg·g -1 [1].

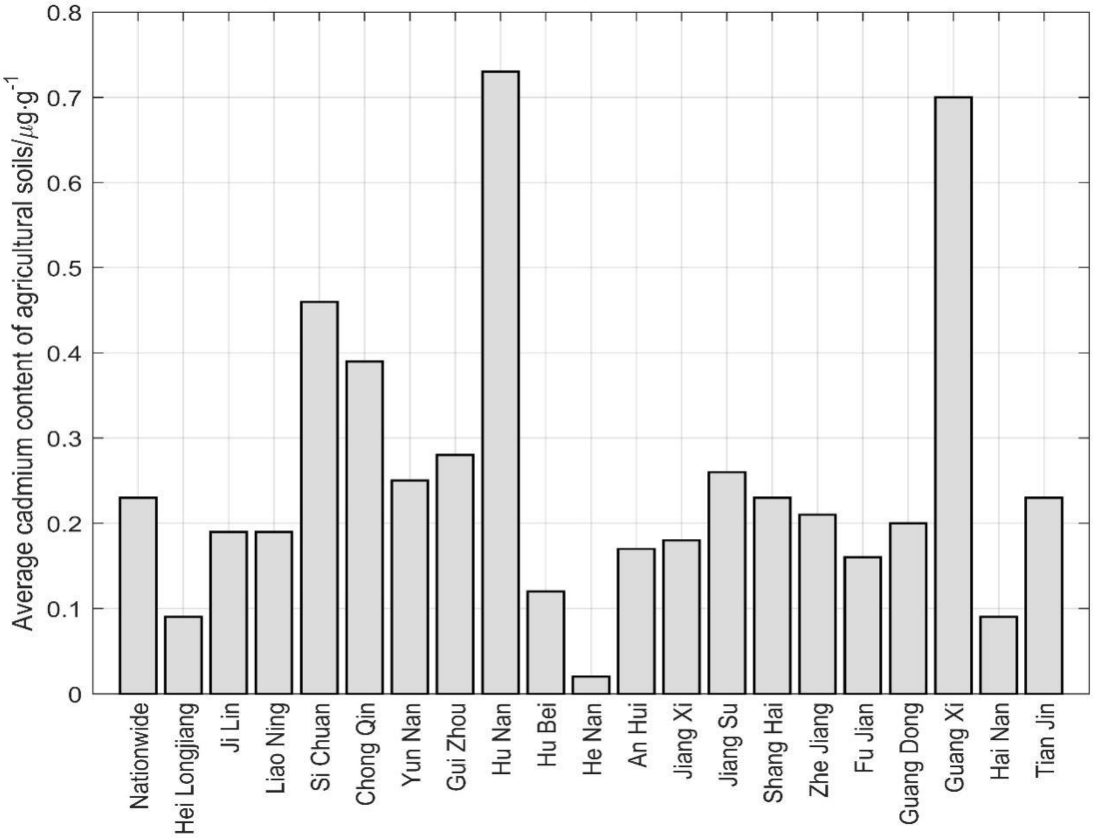

Fig. 1 Advantages and disadvantages of soil cadmium pollution prevention and control technology (Picture credit: Original)

2.2. Advantages and Disadvantages of Soil Cadmium Pollution Prevention and Control Technology

Physical control technology, chemical control technology, biological control technology, and agronomic control technology each have many methods to prevent and control cadmium pollution. For example, the soil replacement method in physical control technology uses physical methods to replace contaminated soil and replace it with clean soil, fill the sand and gravel in, excavate the soil within a certain range of the foundation, replace it with sand, stone, and other materials, and compact it (or compaction, vibration) in layers to serve as the foundation's bearing layer. It is a traditional shallow foundation treatment method. The disadvantage of this method is that the cost is too high. On the other hand, chemical control technologies such as adding amendments can quickly reduce the bioavailability of cadmium and can be applied in different soil types. However, its specific shortcomings are also obvious, and some chemical additives may introduce new pollutants. Regular monitoring and maintenance are required to ensure long-lasting results and can be costly, especially for large areas of contamination. Biological control technology, such as earthworms to improve cadmium-contaminated soil, has low cost, a short reaction cycle, and is relatively safer and more environmentally friendly, but it has strict requirements for certain environmental conditions. Finally, there is agronomic control technology, such as the study of the impact of the F1 generation of hybridization of two ecological types of Solanums nigrum on the accumulation of cadmium in tree tomatoes. It is possible to achieve an environmentally friendly and efficient solution, but it still needs to have its action conditions, etc. Conduct further research etc. Therefore, the advantages and disadvantages of prevention and control technologies can be roughly summarized as shown in Figure 2.

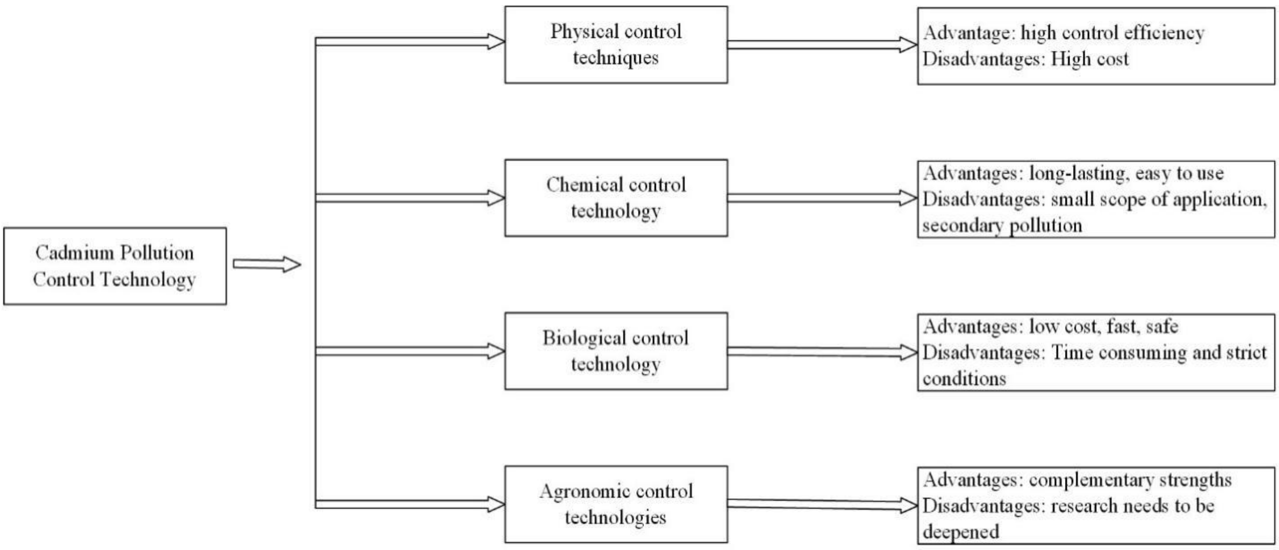

Fig. 2 Advantages and disadvantages of soil cadmium pollution prevention and control technology (Picture credit: Original)

2.3. Hazards of Soil Cadmium Pollution

The hazards of soil cadmium pollution are shown in Figure 3. When the cadmium content in the soil exceeds the standard, it will first affect the normal growth of plants. Cadmium will affect the light and enzyme activity of the plant itself, reducing the plant's ability to absorb various nutrients and water in the soil. It leads to nutritional metabolism disorders, affects the growth status and yield of plants, and then affects the yield of agricultural production [2]. Secondly, when animals and humans consume food with excessive cadmium, it will poison the bones, liver, kidneys, immune system, etc. in the body, causing diabetes, hypertension, and other diseases. In the case of long-term intake of cadmium, can cause cancer.

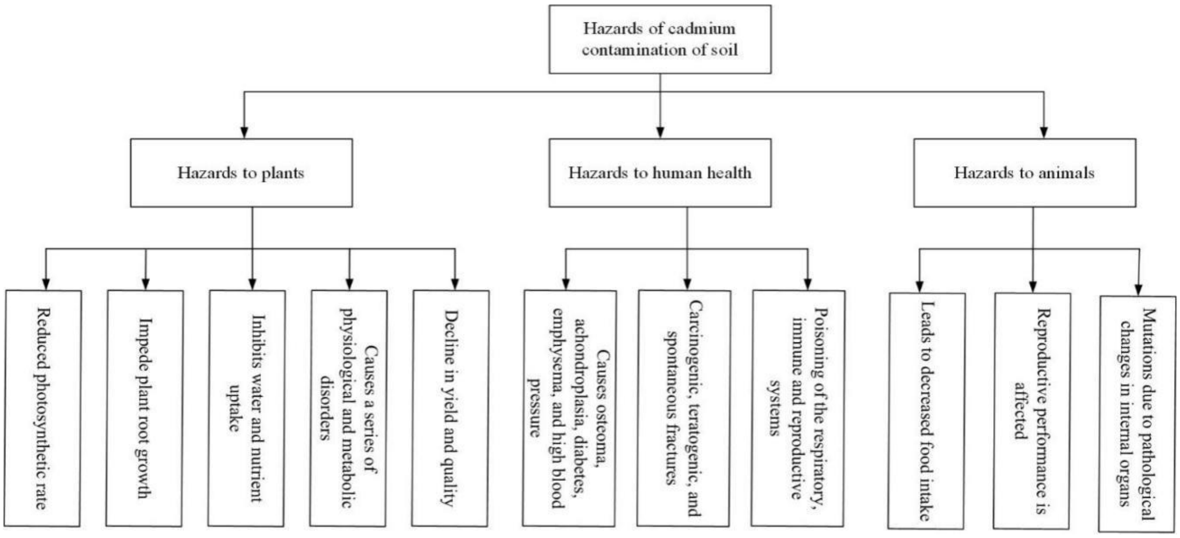

Fig. 3 Soil cadmium pollution hazards (Picture credit: Original)

3. Overall Characteristics of Bioremediation Technology

3.1. Bioremediation Technology is a Sustainable Method of Soil Pollution Control

It uses plants, microorganisms, and other organisms to absorb, dilute, and decompose harmful substances in the soil for soil remediation and pollutant removal, which can improve the pollution status of the agricultural soil environment to a certain extent. Bioremediation technology increases the microbial community in the soil by introducing suitable microorganisms or plants, thereby promoting the decomposition of soil organic matter and the release of nutrients and improving soil fertility and productivity. The metabolism of microorganisms or the absorption of plants converts harmful substances in the soil into harmless substances or absorbs and fix them in plants, reducing the content of harmful substances in the soil. Bioremediation technology increases the vegetation coverage and organic matter content on the soil surface, improves the structure and air permeability of the soil, and increases the moisture and water retention capacity of the soil while increasing the diversity and quantity of soil microorganisms, enhancing the soil's ecosystem functions, and improving the soil's resistance. sex and adaptability, making it more stable and healthier. In short, the impact of bioremediation technology on agricultural soil environmental pollution is multifaceted. It can reduce the content of harmful substances in the soil, improve soil fertility, increase soil moisture and water retention capacity, and enhance soil ecological functions and resistance. Agricultural production provides a sustainable approach to soil management.

3.2. Research Status of Bioremediation Technology Exploration Progress

As the largest group of microorganisms, bacteria themselves and the various substances they produce are widely involved in various reactions in water, soil, slag, sediment, and other environments, thereby affecting the migration and transformation of many elements. It remediates heavy metal pollution in the soil through adsorption and enrichment of heavy metals, redox, mineralization and precipitation, leaching, plant synergy, etc. [2]. Langley et al. pointed out that Pseudomonas can enrich Au in cells. Within, Cu is adsorbed on its surface, effectively reducing the mobility of heavy metals [3]. Chen Ming et al. used Gram-positive bacteria A-7 isolated from sludge to treat wastewater from a smelter and found that almost all Pb2+ and Zn2+ were removed [4]. This finding has strong reference significance for the treatment of wastewater from similar heavy metal-polluted smelters at the same time, it provides a direction for finding dominant repair bacteria. Bacteria can perform joint repair with plants, using their functions to directly repair pollutants or indirectly repair pollutants by strengthening plant functions, overcoming the limitations of single repair, and achieving collaborative repair or step-by-step repair [5-7].

4. Discussion of Repair Technology

4.1. Phytoremediation Technology

Phytoenrichment remediation technology is a method of remediating heavy metals in soil through plants by utilizing the ability of plants to absorb and enrich heavy metals. For cadmium remediation, phytoenrichment remediation technology mainly involves the processes of plant absorption, transport, accumulation and fixation. As shown in the mechanism diagram below, Figure 4 is the repair mechanism of cadmium by plant enrichment repair technology: 1 Absorption: The roots of plants absorb cadmium ions in the soil through root hairs. This uptake process generally depends on soil pH, the chemical form of cadmium, and plant root characteristics. 2. Transport: Once absorbed, cadmium ions will enter the plant's vascular system through the plant's root system and be transported to the above-ground parts of the plant along with the plant's water flow and nutrient transport. 3. Accumulation: *Cadmium ions will accumulate in different tissues and cells in plants, including roots, stems, leaves, etc. Some plants have a high bioaccumulation capacity for cadmium and are called "cadmium hyperaccumulators." 4. Immobilization: Some of the accumulated cadmium may become immobilized in the cell walls of plant cells, thereby slowing or preventing its further migration into edible parts of the plant. This helps reduce the passage of cadmium through the food chain. 5. Biogeochemical interaction: Some plants secrete substances through the rhizosphere, such as organic acids, which can promote the dissolution or chelation of cadmium in the soil, thereby increasing the bioavailability of cadmium and improving the absorption capacity of plants. 6. Plant selection and improvement: To improve the remediation effect, scientists usually select or improve plant varieties with higher cadmium accumulation ability or enhance the plant's tolerance and accumulation ability of heavy metals through genetic engineering methods [7]. It should be noted that phytoenrichment remediation technology is not suitable for all environments and all plants. Its effect may be affected by various factors such as soil characteristics, plant species selection, and environmental conditions. In addition, phytoenrichment remediation techniques are generally suitable for soils with mild to moderate cadmium contamination. For highly contaminated soils, it may be necessary to combine other remediation techniques to achieve better results.

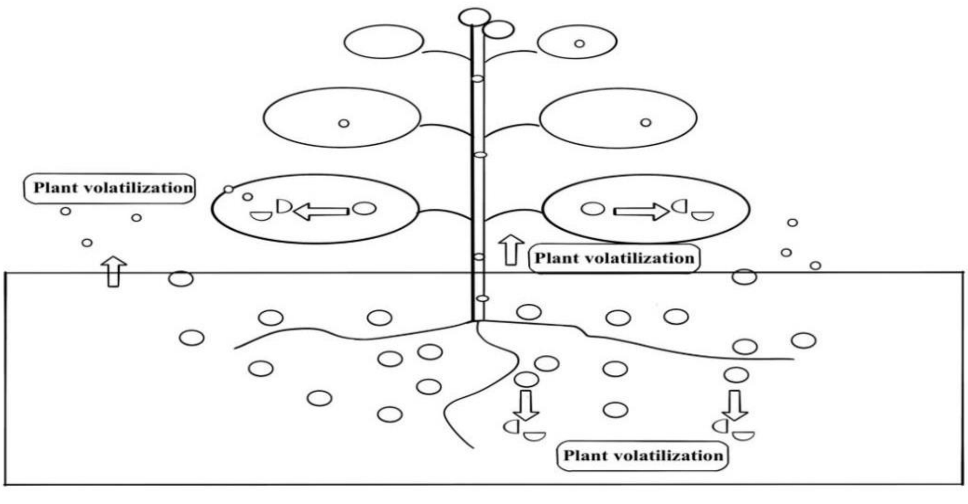

Fig. 4 Phytoremediation mechanism of heavy metal contaminated soil (Picture credit: Original)

4.2. Application of Plant Combination Technology

To overcome the limitations of single microorganisms in remediating heavy metal pollution, combined microbial and plant remediation technologies have been widely used. This technology combines phytoremediation technology and microbial remediation technology to remediate heavy metal soil, that is, using the absorption of plants and the metabolism of microorganisms to remove heavy metal elements in the soil. Plant photosynthesis, root exudates, and fallen leaf residues can all provide nutrients for microorganisms [8], and microorganisms can activate heavy metals and help plants absorb beneficial elements from the soil. For example, tobacco rhizosphere + Pseudomonas fluorescens (more efficient than phytoremediation technology).

4.3. Microbial Remediation Method

Microbial remediation technology is to metabolically reduce the effectiveness of pollutants in contaminated soil by artificially cultivating microorganisms or utilizing the characteristics of certain microorganisms [9]. Microbial remediation technology, as a new environmental remediation technology, has been successfully used in the remediation of soil pollution such as oil pollution, organic matter pollution, and heavy metal pollution. For contaminated soil, microbial remediation technology is a relatively effective means of treatment. Its remediation cost is lower than physical remediation and chemical remediation, and its destructiveness to the soil environment is extremely low. The pollutants required for plant growth are completely degraded, and no secondary chemicals are produced. Second pollution, the treatment is in place, the operation is simple, and the removal rate can reach more than 99%.

4.3.1 Bacterial Remediation Technology

Alcaligenes and resistant bacteria are generally used for heavy metal soil remediation. For example, potted plants + Alcaligenes can weaken the toxicity of C (r chromium) elements; when there are no Cd (cadmium) and Pb (lead) in the soil, resistant bacteria can enhance the plant's ability to absorb heavy metal elements. The specific applications are as follows: (1) Bacillus cereus can often reach an adsorption rate of 98.9% when treating Mn on slag [10]. This is because surface chemical functional groups such as carboxyl groups, amide groups, and phosphate groups of Bacillus cereus can undergo ion exchange or complexation with Mn, thereby adsorbing Mn on the surface or inside the bacteria. (2) Bacillus thuringiensis absorbed Cd in soil with a pH of 7.42 and an organic matter content of 1.83%, increasing the mushroom biomass from 26.68% to 43.58%, and the Cd accumulation to 14.29% to 97.67%. This is because Bacillus thuringiensis can produce 1-aminocyclopropyl-1-carboxylic acid (ACC) deaminase, indole-3-acetic acid (IAA), siderophores and other growth-promoting factors, which stimulate the activity of antioxidant enzymes. This reduces the effect of Cd poisoning mushrooms, promotes the continuous growth of mushrooms, and increases the biomass of mushroom fruiting bodies or mycelium [11].

4.3.2 Application of Fungal Remediation Technology

Fungi have better soil remediation effects than bacteria due to their large contact surface, fast growth, and low soil environmental requirements. At present, fungi such as yeast, Trichoderma, Penicillium, and mycorrhizal fungi are generally used for heavy metal adsorption. For highly contaminated soils, a combination of remediation techniques may be required. The author also collected data and found some microorganisms that can fix passivated cadmium ions, as shown in Table 1 below.

Table 1. Phytoremediation mechanism of heavy metal contaminated.

category	Representative strains	Fixed passivation mechanism	Data Sources
hydrochloride reducing bacteria	SRB SRB	SRB reduces SO_4^{2-} to S_2 and combines with Cd^{2+} to form metal precipitation. Under certain environmental conditions down, passivated to crystal	Literature [12] Literature [13]
Urease bacteria	Bacillus sp.GZ-22 Enterobacter cloacae EMB19 AchromobacterxylosoxidansLAX2	The metabolites of urease-producing bacteria are $C0_3^{2-}$ and $NH^{4+,}$ which can increase the pH value in the environment. Cd^{2+} interacts with $C0_3^{2-\text{ to produce}}$ $CdCO_{3,}$ which is passivated into crystals under certain environmental conditions.	Literature [14] Document [15] Literature [16]
Phosphate solubilizing bacteria	Pseudomonas sp. IV-111-16 Bacillus sp.ML1-2 Gallionella.Fw	Phosphatase can hydrolyze organic phosphate into inorganic phosphate, which then reacts with Cd^{2+} to form cadmium phosphate precipitation.	Literature [17]
Iron-manganese oxidizing bacteria	Pseudomonas sp.YGL	Iron-manganese oxidizing bacteria are microorganisms that can oxidize low-valent iron and manganese into high-valent iron and manganese. Hydrates or oxides formed by high-valence iron and manganese respectively can effectively adsorb free heavy metals.	Literature [18] Document [19]

4.4. Animal Restoration Technology

Animal remediation technology refers to the use of some lower animals in the soil and the microorganisms in their bodies to degrade or transform harmful substances and fundamentally remove pollutants [19]. The soil itself has microorganisms that degrade harmful substances but under the disturbance of various pollutants,

The microorganisms in the soil gradually die, not only unable to degrade harmful substances but also causing harmful substances to precipitate into the soil, reducing soil fertility. Therefore, technicians can use animal remediation technology to control soil pollution and improve fertility. However, this remediation technology has limitations. It can only be applied to soil contaminated by organic matter and pesticides and cannot remediate soil contaminated by heavy metals.

Currently, earthworms are the most commonly used animals in domestic animal restoration technology. As a natural native animal, earthworms not only have tenacious vitality, but also can transform heavy metal pollutants in the soil through their biological activities such as eating, digging, and excretion, thereby reducing the biological toxicity of heavy metal pollutants in the soil. Although the use of earthworms for animal remediation of heavy metal-contaminated soil has the advantages of strong decontamination ability and high economic and environmental value, the scope of soil remediation is also limited due to the limited activity range of earthworms. The earthworm remediation process includes the absorption, transformation, and degradation of pollutants, and the mechanisms involved are divided into intrinsic and extrinsic mechanisms. The intrinsic mechanisms include improving soil physical and chemical properties, stimulating the growth of soil microorganisms, affecting microbial activity and metabolism, and increasing plant absorption rates. The external mechanisms include the physiological activities of earthworms, the impact of earthworms on the form, migration, and bioavailability of pollutants, etc. The research results of using earthworms to remediate heavy metal pollution are shown in Figure 5.

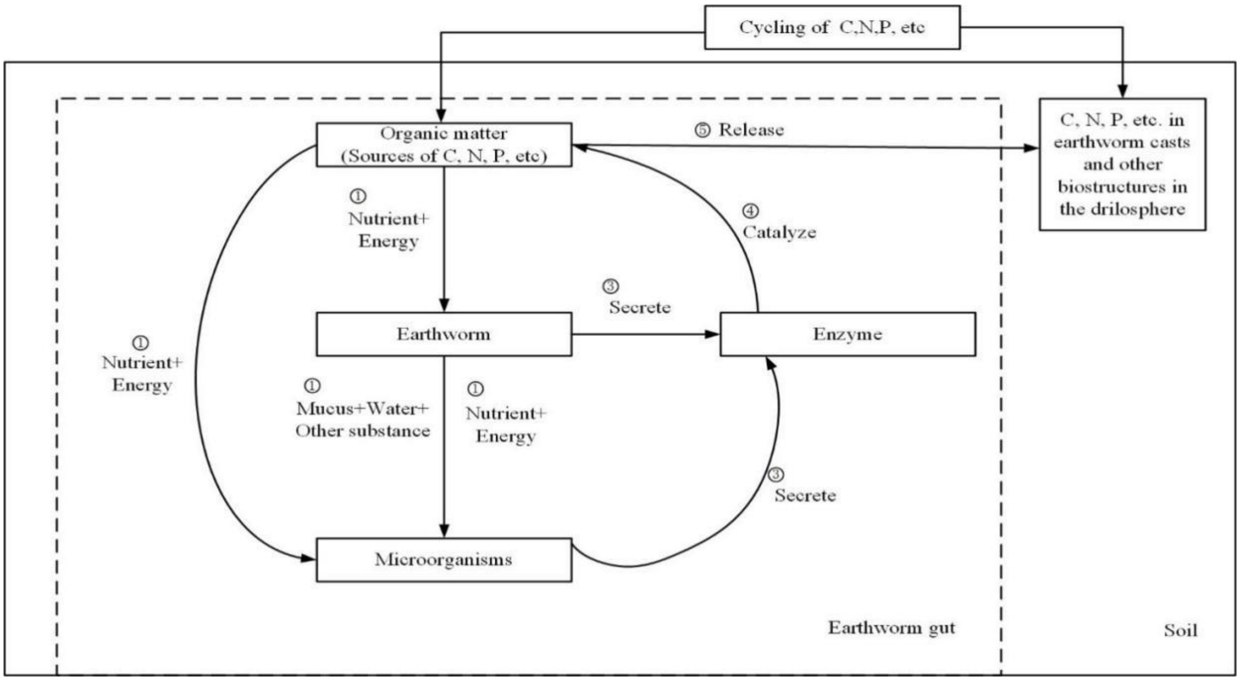

Fig. 5 Mechanism of earthworm remediation of heavy metal pollution (Picture credit: Original)

5. Conclusion

Bioremediation is currently undergoing innovative research and discovery in many aspects. This report aims to briefly summarize the research on several bioremediation methods through specific experiments and mechanisms. In the future, bioremediation technology should focus on the treatment cycle and conduct further research on the final treatment of materials to avoid secondary pollution, strengthen the prevention and control of soil cadmium pollution, and master more scientific soil cadmium pollution prevention and control technologies. If necessary, a variety of different prevention and control technologies can be comprehensively applied and matched to enhance soil cadmium pollution. pollution prevention effect. In the future, further research and application of genetic engineering techniques may lead to more robust plants and microorganisms that improve their ability to remediate pollutants while mitigating the impact on surrounding ecosystems. Focus on the comprehensive use of various scientific and technological means to improve the restoration effect while maximizing the protection and promotion of the health of the ecosystem.

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