Effects of heavy metals on soil microbial community

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Abstract. Soil is one of the most important environmental natural resources for human beings living, which is of great significance to the quality of ecological environment and human health. The study of the function of arable soil microbes exposed to heavy metal pollution for a long time has a very important significance for the usage of farmland soil. In this paper, the effects of heavy metals on soil microbial community were reviewed. The main contents were as follows: the effects of soil microbes on soil ecosystems; the effects of heavy metals on soil microbial activity, soil enzyme activities and the composition of soil microbial community. In addition, a brief description of main methods of heavy metal detection for soil pollution is given, and the means of researching soil microbial community composition are introduced as well. Finally, it is concluded that the study of soil microbial community can well reflect the degree of soil heavy metal pollution and the impact of heavy metal pollution on soil ecology.

1. Introduction

Soil is the basic resource for human beings living, even in the modern social life, the soil is still the most fundamental elements of human production and the carrier which can link various human economic relationship together [1]. Heavy metal elements in chemistry generally refers to a metal with a density greater than 5.0 g/cm^3, including 45 elements such as Fe, Mn, Pb, Cu, Zn, Cd and Hg. The content of Fe, Mn in the soil is relatively high, generally, we do not consider their pollution effects. Soil heavy metals are divided into two categories from the biochemical characteristics: one is harmful to crops and humans and animals, such as Pb, Cd and Hg; the other benefits on the biological when in a constant, but when excessive, it will damage to biological, such as Cu, Zn, Mn and so on.

Heavy metal contamination is significantly different from many organic chemical pollutants. Many organic chemical pollutants can be achieved through the physical nature of their own physical, chemical or biological effects of self-purification, reduce its toxicity, the lifting of the original harm will be caused by pollutants. But heavy metals are generally rich, not easily leached by water, and have biological enrichment, what's more, they are difficult to degrade in the natural ecological environment.

Soil bacteria, fungi, actinomycetes, algae and other microorganisms, are responsible for the cycle of C, N, P, S and other elements in the nature, they promote the decomposition of material elements and nutrient conversion. At the same time, soil microbes are almost involved in all biochemical reactions in the soil. Soil microbes are often used as an important indicator of soil environmental quality because of their sensitivity to soil environmental conditions is greater than molluscs, large animals or plants. Through the soil microbial changes, whether the soil is contaminated, the extent of soil pollution, pollution effects and risks can be determined scientifically. The effect of heavy metal on soil microbial effect mainly includes the influence of heavy metals on soil microbial activity, the effect on soil enzyme activity and the composition of soil microbial community. Therefore, this paper also studied the effects of heavy metals on this three parts and hoped we can draw some important conclusions about how to control heavy metals pollution.

2. Effects of Soil Microbes on Soil Ecosystems

2.1 Effects of soil microbes on mineral metabolism

In soil ecosystems, microbes, as the most active part of the soil, have an important role in the transformation and storage of various nutrients. At the same time, they play a very significant role on the decomposition of organic matter, mineral decomposition and the release of nutrient. microbial organisms can be absorbed through the role of plant root system, providing a variety of nutrients for the plant effectively. In the agroecosystem, soil microbes mainly have two effects. First, the microorganisms themselves contain a certain amount of elements such as C, P and N, which can be regarded as an effective C, P, N source repository, thus it can adjust soil nutrients and store soil nutrients; on the other hand, micro-organisms through the transformation and promotion of the system's metabolic process can promote inorganic element to flow [2]. Carbon and other nutrients mineral decomposition and cycling in soil ecosystems are dominated by activities of microbes.

2.2 Effects of soil microorganism on crop growth

Microbes in the activities of life can transform inert nitrogen from the air into the ionic nitrogen that can be absorbed by the plants directly, it can ensure that the plant nitrogen nutrition. Microbes can decompose insoluble minerals in the soil during their life activities and convert them into soluble mineral compounds to help plants absorb various mineral elements. Some fungi hyphae and the root system of higher plants can form a union. The union is conducive to improving the resistance of plants in the adverse environment, and promotes plant growth. Soil microbes can degrade inorganic and organic pollutants, reduce the toxicity of pollutants to plants, and provide a good ecological environment for plant growth. Soil microbes can promote the organics to form humic acids around the roots, and promote plant growth and development. Soil microbes can produce some secondary metabolites that have some stimulating effects on the growth and development of plants. Rhizosphere soil microbes form a physical barrier around the roots of plants, protecting plant roots in this micro-ecological environment, reducing the invasion of pathogens and pests [3]. Plant rhizosphere-promoting bacteria can control crop susceptibility by fixing atmospheric nitrogen, producing plant hormones, promoting specific enzyme activities, and by producing antibiotics and some other substances that inhibit pathogens such as iron carriers and chelating media. Some microbial and microbial fertilizers, including dissolved phosphorus, can promote plant growth by increasing the fixation efficiency of biological nitrogen and the availability of substances that promote plant growth to increase the availability of trace elements such as iron and zinc. [4,5]

2.3 Effects of soil microbes on soil structure

The soil environment is a very complex system, including a variety of small environments with different physical and chemical gradients and discontinuous environmental conditions. Microbes adapt to the micro-environment and interact with other parts of the soil or sensitive boundaries to produce various interactions. Soil microbes play an important role in the formation of soil structure. Actinomycetes produce mycelia that allow soil particles to bind. Therefore, the content of actinomycetes in fertile soil is higher than that in barren soils [6]. The leading role of microbes are also different in different soils [7]. When microbial extracellular polysaccharides, microbes and soil are separated, it makes the combination of soil particles, which contributes to the formation of soil structures. The activity of organic matter during the polymerization process is conducive to the formation and production of soil humus. This effect can reduce the invasion of soil water, so that the soil can maintain a good penetration and contain enough air.

3. Effects of Heavy Metals on Soil Microbial Ecological Effects

Heavy metals are common and important refractory pollutants. The toxicity of heavy metals is primarily concerned with the bioavailability of metals, that is, the amount of organisms that are eventually absorbed into the body by absorption, migration and transformation [8]. High concentrations of heavy metals on the toxicity of microorganisms may have two reasons, heavy metals and microorganisms have a strong affinity, and it is easy with some biological macromolecules such as enzyme activity center, and electron-donating groups such as mercapto protein, nucleic acid base and phosphate combination, resulting in the inactivation of these biological macromolecules, more than the ability of organisms to bear, resulting in biological disease and death [9], from a short-term perspective, heavy metal pollution will lead to the degradation of microbiological diversity of those who lack the pressure on the outside world, and at the same time lead to those who can adapt to those pressures increased; secondly, due to heavy metals cannot be microbial degradation of the majority of ligand metallothionein. A large number of metallothionein and small molecules such as glycine and taurine are easy to accumulate with the food chain of enrichment and transmission, and will endanger all biological, especially human health and life safety.

3.1 Effects of heavy metals on soil microbial activity
Some heavy metals in the soil also have an effect on the growth of soil microbes [10]. Almost all soil biochemical reactions have the participation of soil microbes, which plays an important role in maintaining soil quality and plays an important role in the formation of soil organic matter and its decomposition of harmful substances, biochemical cycles and the formation of soil structure. Heavy soil contaminated soils have a negative effect on soil microbial properties, such as the underlying soil respiration rate and enzyme activity that depends on soil pH, organic matter and other chemical properties. Studies have shown that, in most cases, low concentrations of heavy metal contaminated soil are conducive to the release of CO_2, high concentrations of heavy metal pollution conditions, significant inhibition of soil respiration, severe heavy metal pollution can inhibit soil microbial activity, seriously threatening the soil ecosystem function.

3.2 Effects of heavy metals on soil enzyme activities
As the concentration of heavy metals increases, the activity of most enzymes is significantly reduced and the decrease in their activity may be caused directly by the interaction between the enzyme and the heavy metals, which is not associated with a reduction in microbes [11]. Heavy metals have a significant effect on soil enzyme activity. On the one hand, heavy metals have a direct effect on soil enzyme activity, so that the spatial structure of the active groups of the enzyme is destroyed. On the other hand, the growth and reproduction of microorganisms are inhibited, thus reducing the synthesis and metabolism of the microbial enzyme. There is a very close relationship between soil enzymes and soil microbes, and some microorganisms and enzymes secreted by microorganisms participate in the circulation of soil ecosystems and energy together.

3.3 Effects of heavy metals on soil microbial community composition
After the heavy metal into the soil, the primary impact is the amount of soil bacteria, fungi, actinomycetes and other microbial population. Heavy metals effect the microbial quality and quantity in the soil and at the same time, soil microbes on the heavy metal compounds with the reaction to the decomposition and the conversion. For example, Hg in the environment, there are a variety of valence (elemental mercury, inorganic Hg^{2+}, organic mercury compounds), organic synthesis of mercury in addition to artificial synthesis, some bacteria also have the ability to synthesize organic mercury.

Heavy metal contamination can produce different microbial community patterns. Even if many of the chemical and biological properties of the soil have changed greatly, there are many original microorganisms in the soil that are present in the microbial community [12]. Long-term heavy metal contaminated soil will choose those who can specifically adapt to polluted soil microbial population. The higher the content of organic carbon in severely polluted soils, the lower the efficiency of microbial populations in organic mineralization. This can be a simple indication of the impact of heavy metal pollution on soil microbial communities. [13]

4. Methods for the Detection of the Volume of Heavy Metals in Soils

In order to deeply understand the impact of heavy metals on the soil microbial community, then the detection of the major contaminated heavy metals in the soil is critical. Therefore, it is very important to understand the method of detecting heavy metals in soil. At present, the main heavy metal pollutants in soil include Pb, Cd, Zn, As, Cr and so on. Various research institutions at home and abroad as well as engaged in the analysis of the work, extensive research and development of heavy metal research, to find a lot of heavy metal detection methods. For example, determination of As, Cd, Pb, Cr, Zn and pollution in vegetables and soils by ICP-AES is reported. In recent years, the widely used detection methods are as follows: spectrophotometry, atomic absorption spectrometry, atomic fluorescence spectrometry [14], inductively coupled plasma mass spectrometry (ICP-MS) [15-16], inductively coupled plasma atomic emission spectrometry (ICP-AES) [17]. Each of the above methods have their own advantages and disadvantages, so recently, the use of various instruments complement each other, a variety of technologies is combined to solve a lot of problems.

5. Research Means of Soil Microbial Community Composition

After understanding some of the methods of detecting heavy metals, we need to understand some of the main means of studying the composition of soil microbial communities to find the impact of heavy metals on soil microbial communities. In recent years, the rapid development of molecular biology enables us that we can sensitively detect and identify the microbial community composition among the soil and other complex environment. The main methods of detection are as follows: 16S/18SrRNA/rDNA sequence analysis technology, which has been widely used in microbial identification and community research [18]; the method of studying the microbial community structure and cloning library of environmental samples; and the number of phosphorus fatty acids and species to estimate the number of microorganisms (PLFA) [19]. The restriction fragment length polymorphism based on 16S/18SrRNA sequence of microbes is widely used to analyze the genetic diversity, evolution and classification of microbes in complex environmental samples. These methods can solve the problem of the vast majority of microorganisms in complex habitat cannot be cultivated, but have certain defects and limitations. So in recent years, scientists are more likely to combine several methods to analyze the microbial community in the complex environments, so that the resulting analysis results are more accurate.

6. Conclusion

With the increase of population, the discharge of agricultural wastewater containing chemical fertilizers and the discharge of industrial waste water such as electroplating, metallurgy and chemical industry, soil ecosystem has been seriously affected by heavy metals. Due to the persistent, toxic and non-biodegradable nature of heavy metals, the problem of heavy metals in the soil has attracted increasing attention of researchers. In addition, since microbes are more sensitive to environmental stress than macro-organisms in soil ecosystems, they can also reflect changes in soil environment as early as possible and are therefore considered to be sensitive indicators in the soil. The use of some means to study the composition of microbial communities in the soil and the use of some detection methods to detect the heavy metal content in the soil can find the more accurate and specific relationship between them by comparison.

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