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Ecological Risk of Soil Heavy Metal and Organic Pollutants Combined Pollution

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ABSTRACT

This paper focuses on soil pollution. It points out that soil is the fundamental resource for human survival and the construction of civilization, and its pollution problem is severe. It elaborates on the types of single soil pollution and combined soil pollution, emphasizes that combined pollution is the main form and causes huge harm. For example, the combined pollution of heavy metals and organic pollutants is common in various pollution sources, which can change soil microorganisms, affect plant growth and endanger human health. It also mentions the ecological risks of combined pollution at the food chain level and the related research technical means. Finally, it shows that soil combined pollution has become the main form, the ecological risk assessment based on the food chain or food web is more realistic, and the development of molecular technologies provides new methods for evaluating its ecological risks.

KEYWORDS

Soil combined pollution; Ecological risks; Heavy metals and organic pollutants; Molecular technologies.

1. INTRODUCTION

Soil constitutes the fundamental resource upon which human survival, prosperity, and the construction of civilization are contingent (Zhao Qiguo and Luo Yongming, 2015). The soil subsystem is the most dynamic stratum within the Earth's surface system, serving as the pivotal element that interconnects the atmosphere, hydrosphere, lithosphere, and biosphere, and is accountable for approximately 90% of environmental pollution across various dimensions. Presently, there is a growing acknowledgment that adequate protection of the soil environment is crucial, parallel to the efforts in maintaining the integrity of the atmosphere and water bodies. Nonetheless, with China's economic expansion, particularly in the aftermath of the reform and opening-up policy, the issue of soil pollution, particularly the complexity of soil composite pollution, has escalated in severity and is expanding from localized to regional scales. This poses a severe threat to the safety of agricultural produce, ecological security, and the health of human habitation environments, thereby impacting the sustainability and stability of China's economic and social progress.

2. SOIL COMBINED POLLUTION AND SOIL SINGLE POLLUTION

Soil pollution refers to the situation where harmful chemicals or elements are present in soil at higher levels than normal, negatively affecting its chemical biological, and physical characteristics (Jia et al., 2018). Single soil pollution can be divided into two types: inorganic pollution and organic pollution. Inorganic pollution mainly includes heavy metals, acid-base substances, etc., while organic pollution mainly includes organic pesticides, petroleum, synthetic detergents, etc. Combined pollution refers to the phenomenon that two or more kinds of pollutants work together to disturb plants or systems and cause damage(Agricultural Environmental Protection - 2002, Vol. 02). Soil combined pollution represents the predominant form of soil contamination and constitutes a significant risk to soil ecosystems. Unlike isolated pollution events, the environmental impacts of single soil pollutants exhibit variability due to the interactions among these contaminants. In 1939, Bliss introduced a classification system for the combined effects of pollutants, which includes additive effect, synergistic effect, independent action and antagonistic four types. The understanding of these combined effects has gained gradual acceptance among researchers (Zhou Dongmei et al., 2004). Additive effect refers to a mixture of chemical substances, the combined action of which produces the toxicity of the sum of the toxicity of each individual substance. The synergistic effect represents the toxicity of the combined action of many chemical substances, which is greater than the sum of the toxicity of each individual substance. Antagonism refers to the simultaneous action of two or more chemical substances on an organism, the result of which is that the toxicity of each chemical substance on the organism is weakened, and the toxicity of its combined effect is less than the sum of the toxicity of the individual chemical substances. Independent action refers to the way, way, position and mechanism of the action of each single chemical substance on the body are different, and when the combined action on a certain body, the action in the body does not affect each other. However, it often appears that the body's resistance is reduced after the action of a toxic substance, and the toxicity is significantly enhanced when another poison is re-acted. The environmental implications of various soil combined pollution cannot be fully elucidated through the mechanisms of individual pollutants, rendering previous evaluation criteria, which were based on single pollution, inadequate for accurately depicting soil environmental health. Consequently, the investigation into composite pollution has emerged as a crucial aspect of environmental scientific advancement.

The risk of soil combined pollution lies not only in the destruction of the structure and function of the soil ecosystem by a single pollutant, but also in the complex interaction among various pollutants, which will cause immeasurable impact on the ecosystem and even the human beings living in it. A number of studies have shown that the presence of combined pollution greatly increases the impact of pollutants on ecosystems (Liu et al., 2015; Zhu Jiang, 2008; Wang Fenghua et al., 2018; Lu Yixin et al., 2019). Therefore, in-depth research on the interaction mechanism of soil combined pollution and its ecological risks is of great significance for controlling the risk of soil combined pollution and protecting human health.

3. THE COMBINED POLLUTION OF HEAVY METALS AND ORGANIC POLLUTANTS IS A SERIOUS CHALLENGE FOR SOIL SCIENCE

The combined pollution of heavy metals and organic pollutants in soil is very common. For example, the pollution caused by sewage treatment plant sludge, municipal solid waste and industrial wastewater is mostly inorganic-organic composite pollution. Antibiotics, polychlorinated biphenyls and polycyclic aromatic hydrocarbons (PAHs), as typical organic pollutants, are commonly combined with heavy metals in soil environment, which has attracted extensive attention in the field of soil combined pollution research. For example, heavy metals are usually widely used as feed additives in aquaculture and aquaculture, and livestock excrement and sediment from aquaculture are usually applied to soil as agricultural organic fertilizers, or organic fertilizers contaminated by antibiotics are applied to soil contaminated by heavy metals. Combined contamination of soil heavy metals with antibiotics and their resistance genes (Yu et al., 2017; Zhang Junya et al., 2015). Regarding the effects of heavy metal pollution and antibiotics on soil, studies have shown that there is a synergistic toxic effect between metals and antibiotics, that is, the combined action of two or more pollutants will make the toxicity more significant. In turn, the metabolic process of soil microorganisms in degrading these pollutants will also be affected by their interactions. For example, in the process of breaking down antibiotics, some microbes also absorb metals in the soil; Conversely, the presence of certain metals may also interfere with the microbial breakdown of antibiotics. Therefore, the complex effects of heavy metals and antibiotics on soil are due to the interactions between many factors, which are often difficult to accurately predict through a single model or experiment. The combined pollution of heavy metals and antibiotics may cause serious damage to soil ecosystem. First, pollutants can change the type and number of soil microorganisms, which in turn affects soil fertility. Second, the overuse of antibiotics may lead to the rise of drug-resistant bacteria in the soil, which further exacerbates the public health problem. In addition, this combined pollution can also interfere with the growth and development of plants in the soil, resulting in reduced agricultural yields. At the same time, some pollutants may enter the human body through biological amplification, posing a potential threat to human health. As for the effects of heavy metals and polychlorinated biphenyls (PCBs) combined pollution on soil, when heavy metals and PCBs co-exist in the soil medium, their interaction may lead to more complex environmental effects. For example, heavy metals may promote the migration of PCBs in the soil through various mechanisms, thereby increasing the concentration of PCBs in the soil solution, and thus aggravating the ecotoxicity of PCBs. On the contrary, PCBs may also interfere with the adsorption and biogeochemical transformation of heavy metals in soil media, and affect the environmental behavior and bioavailability of heavy metals. The complex effect of this interaction undoubtedly increases the complexity and challenge of soil pollution control. Pah pollution cannot be ignored either. These compounds are produced during combustion and are often emitted with the use of oil, coal and wood. In soil, PAHs can cause biotoxicity, affect plant growth, and even destroy soil structure. Long-term consumption of foods contaminated with PAHs may lead to cancer, birth defects and other chronic diseases. The deterioration of soil environment is more serious when heavy metals and PAHs are polluted. On the one hand, heavy metals may enhance the toxicity of PAHs, making them more destructive to soil ecosystems. On the other hand, the interaction of the two pollutants may lead to a synergistic effect that makes the organisms in the soil more toxic and have a greater impact. In agricultural production, the combined pollution of heavy metals and polycyclic aromatic hydrocarbons will lead to the decrease of crop yield and the damage of quality. Contaminated agricultural products may contain excessive amounts of heavy metals and polycyclic aromatic hydrocarbons, posing a threat to human health. At the same time, it may also lead farmers to reduce the use of contaminated land, further aggravating the waste of land resources. In addition, because e-waste contains a variety of toxic and harmful substances, including lead, mercury, cadmium, chromium, polychlorinated biphenyls and polybrominated biphenyls, etc., there is often composite pollution of heavy metals and polychlorinated biphenyls in farmland soil in e-waste affected areas (Tu Chen et al., 2012). Sewage irrigation has been widely used in North China as a means of sewage reuse, but long-term sewage irrigation often causes complex pollution of heavy metals and polycyclic aromatic hydrocarbons in farmland soil (Han Wenhui et al., 2016). At the same time, agricultural films are used in the agricultural production process, resulting in microplastic pollution in farmland soil, especially in the soil of facility agriculture where microplastic pollution is the most common (Rillig, 2012). The unique properties of the surface of microplastics can be used as carriers for adsorption of organic pollutants or heavy metals. Therefore, the ecological effect of heavy metal and organic pollutants combined pollution in soil is affected.

4. ECOLOGICAL RISKS OF HEAVY METALS AND ORGANIC POLLUTANTS AND THEIR TRANSFORMATION PRODUCTS

4.1. Ecological risk of compound pollution at food level

Heavy metals and organic pollutants do great harm to the function of soil ecosystem and its organisms. The ecological toxicity of heavy metals and organic pollutants to soil organisms at the individual level has been systematically studied in the world to explain their potential ecological risks, and an ecological risk assessment system has been established based on these studies. However, the organisms in soil do not exist alone. In the actual natural environment, a complex network structure is constructed among soil organisms to exert their ecological functions. When a pollutant affects one individual, it will naturally affect other organisms through effects such as trophic cascade, and interactions between organisms (such as predation, competition, etc.) will also change the effect of pollutants on organisms. Our previous studies have shown that predation between soil animal hoppers and predatory mites can improve the tolerance of prey hoppers to the heavy metal cadmium compared with exposure to a single species (Zhu et al., 2016). A similar phenomenon has been found in the study of some organic pollutants such as ivermectin (Jensen and Scott-Fordsmand, 2012; Schnug et al., 2014). In the study of emerging pollutants microplastics, it was found that the existence of predation will accelerate the migration and diffusion ability of soil animals and insects to microplastics (Zhu et al., 2018b), which will inevitably affect the ecological risk of organic pollutants adsorbed by them. All these indicate that the risk assessment based on the ecotoxic effects of a single individual can no longer meet the actual risk prediction of pollutants, so it is very necessary to establish an ecological risk assessment system based on the food chain or food web.

4.2. Technical means of ecological risk research of combined pollution

With the progress of molecular technology, more genotoxicity indicators have been revealed at the individual level in the world, but the research on genotoxicity indicators in China is very insufficient. With the popularization of high-throughput sequencing, the research of pollutants on soil animal gut microbes has been increasing in recent years. A number of studies have shown that soil animal gut microbes are more sensitive to pollutants such as heavy metals and antibiotics than traditional indicators such as reproductive rate and mortality (Kim et al., 2016; Zhu et al., 2018a; Zhu et al., 2018c; Wang et al., 2019b). Therefore, through the systematic study of the response of soil intestinal microorganisms under the combined pollution system, more sensitive biological indicators can be mined. In recent years, with the development of multi-omics technologies such as metabolome, macrotranscriptome and macroproteome, there have been multi-directional studies in the world to explore the biological mechanism of soil biological response to pollutants through multi-omics methods (Simoes et al., 2019; Gomes et al., 2013). Therefore, we must accelerate the application of multi-omics technology to the study of soil biological response under combined pollution conditions, and explore the molecular mechanism of its ecological effects.

5. CONCLUSIONS AND PROSPECTS

Soil composite pollution is becoming the most important form of soil pollution and poses a potential threat to soil ecosystem. Under the condition of combined pollution, there will be complex interactions among various pollutants, which will cause more serious impacts on the ecosystem. The ecological risk assessment system based on the food chain or food web can reflect the ecological risk of combined pollution more truly than the risk assessment based on the ecotoxic effect of individual level. In recent years, the rapid development of molecular technologies such as high-throughput sequencing, high-throughput chip and multi-omics provide a new method for scientific assessment of ecological risks of soil composite pollution.

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