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Review

Organic contamination and remediation in the agricultural soils of China: A critical review

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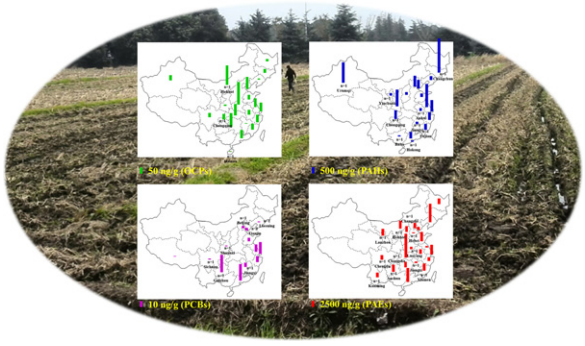
HIGHLIGHTS

- PAHs, OCPs, PAEs and PCBs were the primary pollutants in agricultural soil of China.
- Co-existence of organic contaminants was severe in prosperous regions.
- Integrated biological-chemical remediation technologies have potential prospects.
- Research priorities and insights for soil combined organic pollution were proposed.

GRAPHICAL ABSTRACT



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ABSTRACT

Soil pollution is a global problem in both developed and developing countries. Countries with rapidly developing economies such as China are faced with significant soil pollution problems due to accelerated industrialization and urbanization over the last decades. This paper provides an overview of published scientific data on soil pollution across China with particular focus on organic contamination in agricultural soils. Based on the related peer-reviewed papers published since 2000 (n = 203), we evaluated the priority organic contaminants across China, revealed their spatial and temporal distributions at the national scale, identified their possible sources and fates in soil, assessed their potential environmental risks, and presented the challenges in current remediation technologies regarding the combined organic pollution of agricultural soils. The primary pollutants in Northeast China were polycyclic aromatic hydrocarbons (PAHs) due to intensive fossil fuel combustion. The concentrations of organochlorine pesticides (OCPs) and phthalic acid esters (PAEs) were higher in North and Central China owing to concentrated agricultural activities. The levels of polychlorinated biphenyls (PCBs) were higher in East and South China primarily because of past industrial operations and improper electronic waste processing. The co-existence of organic contaminants was severe in the Yangtze River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei Region, which are the most populated and industrialized regions in China. Integrated biological-chemical remediation technologies, such as surfactant-enhanced bioremediation, have potential uses in the remediation of soil contaminated by multiple contaminants. This critical review highlighted several future research directions including combined pollution, interfacial interactions, food safety, bioavailability, ecological effects, and integrated remediation methods for combined organic pollution in soil.

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Contents

1. Introduction

The contamination of agricultural soil has been observed around the world due to the long-term application of pesticides, fertilizer, plastic film, wastewater irrigation, sewage application and other activities. Unlike contamination in industrial sites, agricultural soil pollution and its adverse impacts tend to be chronic. The cumulative loading of pollutants in agricultural soil may pose significant risks to the ecological functions of soils, plant growth, and eventually, human health. For example, nitrobenzene inhibited the growth of soybean seedlings and caused genotoxicity in soybean root tip cells (Guo et al., 2010). Polycyclic aromatic hydrocarbons (PAHs) were found to change the abundance of functional genes in soils (Han et al., 2014). Exposure to PAHs damaged both enzymatic and non-enzymatic antioxidant defenses and harmed human health (Garcon et al., 2001). Agricultural soils were often contaminated in large areas by combined and non-point source pollution, which are difficult to address through normal remediation operations.

The global occurrence and adverse effects of organic pollution have caused increasing public concern. Many organic contaminants (OCs), such as organochlorine pesticides (OCPs), polychlorinated biphenyls (PCBs), phthalate esters (PAEs), and PAHs, are characterized by high toxicity, persistence, and bioaccumulation in the environment (Pies et al., 2007; Sun et al., 2016c). Vast areas of farmland soils are an important reservoir for OCs (Zhang et al., 2013c; Zhong and Zhu, 2013), which can in turn serve as a secondary emission source to air and water (Bidleman and Leone, 2004; Tao et al., 2008; Cabrerizo et al., 2011). Many OCs in agricultural soils are difficult to degrade biologically under normal environmental conditions. The residues of OCs in agricultural soils can enter food chains and eventually present a potential risk to human health through trophic transfers (Fantke and Jolliet, 2015; Liu et al., 2016c).

As one of the major agricultural countries, China has extensive arable land areas (2.03 billion acres) with various soil types (e.g., Anthrosols and Histosols) (IUSS Working Group WRB, 2014) and a wide variety of soil contaminants. Thus, the national-scale summary in this review can serve as a representative example for addressing the problem of global agricultural soil pollution. Recently, the State Council of China published the Action Plan on Prevention and Control of Soil Pollution (The Central Government of the People's Republic of China, 2016). Understanding the spatial distribution and temporal trend of OCs in agricultural soils across China is necessary for devising pragmatic and enforceable legislation. The fate, source, and interfacial behavior of coexisting organic chemicals in soil should also be studied for efficient pollution control and soil remediation. The revealed spatiotemporal variations based on the published data can help to explain the combined pollution situation in agricultural soils and the effect of pollution regulation in China since 2000. There has been a large volume of literature on organic pollution in the agricultural soils of China. However, these surveys of varying scale (e.g., site-specific, city-wide, or regional-scale) have been scattered, and there is no clear understanding of the status of organic contamination in agriculture throughout China, given that the types of OCs vary across the vast farmland of the country. Most relevant studies have focused on a single class of OCs in a relatively small sampling area during a very short sampling period. A critical review is greatly needed to summarize the concentration levels and characteristics of combined organic pollution in agricultural soils at a national scale.

The primary pollutants in the densely populated regions of China have not been assessed. The priority contaminants that should be controlled would vary across different regions due to the disparity in industrial operations, agricultural practices, and economic development levels. For example, in the Yangtze River Delta, Pearl River Delta, and Beijing-Tianjin-Hebei Region, the combined contamination of pollutants may be more severe due to intensive industrial and urbanization activities. Some regions accommodate numerous electronic waste recycling sites or coal industry plants, whereas some regions are made up of large and intensive agricultural farmland. Reviewing the up-to-date literature can reveal the geographic distribution of OCs and inform the development of management plans for combined pollution. The source, fate, and risk of coexisting OCs in agricultural soils should be evaluated to reveal their different source-sink mechanisms and devise an effective control strategy. A low-cost and effective approach is essential for the remediation of extensive areas of polluted agricultural soils in addition to industry-impacted soil. The challenges involved in developing proper remediation technologies for soil contaminated with multiple organic contaminants need to be better understood and well addressed.

The present paper provides an extensive and critical review of studies on agricultural soils in China, particularly in addressing the recent literature regarding organic pollution. A total of 203 papers about organic contaminants in Chinese agricultural soils have been published since 2000, of which a total of 155 papers focused on the four classes of OCs (OCPs, PAHs, PCBs, and PAEs), implying that they are of significant concerns within the current research (Fig. S1). The objectives were to (a) reveal the concentration levels, regional characteristics, spatial distribution, and temporal variation of principal organic contaminants in the agricultural soils of China; (b) assess the development and challenges involved in remediation technologies for combined organic pollution in agricultural soils; and (c) identify and suggest possible future directions for research in this field.