



Review

Non-thermal plasma technology for organic contaminated soil remediation: A review

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HIGHLIGHTS

- The existing soil remediation technologies were reviewed.
- Non-thermal plasma is an attractive and promising technology for soil remediation.
- Non-thermal plasmas for organic contaminated soil remediation were reviewed.
- The influential factors on plasma remediation were discussed.
- The remediation mechanisms were elucidated.

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ABSTRACT

There is an increasing focus around the world on soil contamination by organic compounds due to its harmful effect on human health. Significant efforts have been devoted to the remediation of soil contaminated by organics, leading to the development of various remediation strategies, such as physical remediation, bioremediation, and chemical remediation. Recently, an attractive advanced oxidation process (AOP), non-thermal plasma technology, has drawn increasing attention for the remediation of organic contaminated soil due to the low energy consumption, rapid start-up and shutdown of the process, as well as a low requirement for the pretreatment process of soil, etc. In this work, the current situation of soil contamination by organic pollutants and the existing soil remediation methods were introduced. The research progresses of various non-thermal plasmas for organic contaminated soil remediation were presented, such as dielectric barrier discharge (DBD), pulsed corona plasma, and non-thermal gliding arc fluidized bed. The effects of different parameters (e.g., applied voltage, soil properties, type and feed flow rate of the carrier gas, as well as the reactor configuration) on the remediation performance of non-thermal plasmas were discussed. In addition, the possible degradation mechanisms of organic pollutants by non-thermal plasmas were analyzed.

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1. Introduction

As an indispensable part of the environment, soil plays a vital role in human's daily lives. Whereas, along with the acceleration of urbanization process and the rapid development of industry, the problem of soil contamination by organic pollution is growing more and more serious, attracting increasing attention worldwide. In most of countries, the land resources show worrying situations. Thirty three percent of the land is considered as moderately or highly degraded through erosion, salinization, hardening, acidification, and chemical contamination, etc. In China, the *Report on the national general survey of soil contamination (2014)* [1] showed that up to 36.3% of the sampling points (more than 5000 in total) contained excessive heavy metals and/or organic contaminants. The soil was contaminated primarily by organic, pesticide, and polycyclic aromatic hydrocarbons (PAHs). Cultivated land was shown to be the severest polluted, up to 19.4% of which was contaminated by organics (primary dichlorodiphenyltrichloroethane (DDT) and PAHs). In several districts of Hangzhou City, 100% of the farmland soil was detected to contain excessive DDT and the DDT residue levels in some places even exceeded 1 mg/kg [2]. For the farmlands in Shenyang City, the soil PAHs contents were shown to be up to 950–2790 µg/kg [3].

The contamination of industrial sites is also an issue of concern around the world. Suffered from different kinds of industrial pollutants (e.g., metallurgy, chemical industry, and dyeing), the contaminated soil normally contains a variety of organic compounds with quite high contents. For example, the soil around a coking plant in Beijing City was severely contaminated by PAHs, with a content of up to 144.8 mg/kg [4].

Unlike the atmospheric contamination and water contamination that are both easily observed, the soil contamination, which is commonly called the “invisible contamination”, is normally lagging and inconspicuous, and is consequently more harmful to human's health [5].

Soil can be polluted by a variety of sources, of which the following four routes are considered to be the most important.

- (1) Contamination from industrial waste emission. A large amount and a great variety of organic pollutants could be released into the soil either directly or indirectly due to the solid waste disposal process, compound leakage, and waste water discharge, etc., resulting in a severe contamination for the industrial sites [6].
- (2) Contamination from agricultural production. The cultivated land can be hardened because of the improper use of chemical pesticides and fertilizer in agricultural production. The used pesticides and fertilizer are partly absorbed by the crops or decomposed, but most of them remain in the soil, destroying the soil structure. Pesticide is primarily classified as organophosphorus and organochlorine. The residual pesticide is mostly highly toxic as well as unfavorably biodegraded, and therefore easily snakes its way up the food chain into human body, bringing tremendous threats to human health [7].
- (3) Contamination from sewage irrigation. In addition to some nutrients that necessary for plant growth, there are also various pollutants in the sewage. The soil is easily deteriorated with long time excessive sewage irrigation [8].
- (4) Contamination from atmospheric deposition. The traffic exhaust, fuel burning, as well as industrial gases and dust, etc. can lead to an air pollution with a large amount of organic contaminants. The organic contaminants could then move to the soil through various methods, such as dry deposition and precipitation, resulting in a soil contamination [9].

In this work, a brief review on the existing technologies for organic contaminated soil remediation is provided at first, in order to elucidate the current status of this hot issue. Emphasis is then placed on an emerging advanced oxidation process (AOP) technology, non-thermal plasma technology. Several typical non-thermal plasma sources for the remediation of organic contaminated soil are introduced. The effects of different important parameters (e.g., applied voltage, reactor configuration, soil properties, as well as the type and feed flow rate of the carrier gas) on the remediation performance have been discussed. In addition, the possible mech-

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