Journal of Electrostatics 80 (2016) 69–75

Contents lists available at ScienceDirect

Journal of Electrostatics

journal homepage: www.elsevier.com/locate/elstat

Organic compounds removal in soil in a seven-needle-to-net pulsed discharge plasma system

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ARTICLE INFO

Article history:
Received 5 November 2015
Received in revised form
15 January 2016
Accepted 7 February 2016
Available online 23 February 2016

Keywords:
Pulsed discharge plasma
Soil remediation
Pyrene
p-nitrophenol
Kaolin addition
Cr^{6+} addition

ABSTRACT

A pulsed discharge plasma (PDP) system (a seven-needle-to-net electrode geometry) was built to degrade pyrene and p-nitrophenol in soil. Pulse discharge time, contents of the pollutants in the soil, the initial pH value of the soil, Kaolin and Cr^{6+} addition on removal of pollutants was investigated. The obtained results show that 60 min was the better treatment time; removal of organic compounds decreased with the increase of the contents; removal of pyrene was higher at neutral pH condition, while p-nitrophenol has more oxidation in the basic soil; Kaolin and Cr^{6+} addition has positive effect on the organic compounds degradation.

1. Introduction

Soil is one of basic environmental elements and is also the material base for human being. However, soil has always been a receiving place for kinds of contaminants. With the upsurge in population and rapid development of industry, more and more solid wastes accumulate on the earth's surface, toxic effluents permeate into soil constantly, hazardous gas and floating dust fall upon soil with the rain, combined with the agricultural non-point source pollution, soil pollution has become a growing problem for human health as well as social development [1,2]. In China, almost all cultivated land, urban soil and mining soil are contaminated in varying degrees, remediation of contaminated soil accordingly become one hot spot issue in the field of environmental pollution control.

Soil pollution sources include the discharge of industrial wastes, the irrigation of sewage, the applications of pesticides and chemicals, and the pollution of heavy metals [3]. The pollutants in soil can be divided into organic compounds and inorganic compounds. Among them, the biorefractory organic contaminants, such as persistent organic pollutants (POPs), have the characteristics of high toxicity, persistence and accumulation. Polycyclic aromatic hydrocarbon (PAHs), polychlorinated biphenyl (PCB) and chlorophenol are typical POPs. China is a big country in production and use of these POPs, much polluted land are generated consequently during the manufacture and circulation process of the POPs [4–6]. The accumulated POPs in soil are detrimental and they can deposit in crops and then enter the ecological cycle. The whole process can ultimately trigger mutagenic and carcinogenic effect on human being. In addition to the harmful impact of organic compounds in soil on the ecological environment and human health, the other physical or chemical processes of the pollutants in the soil, including adsorption of the pollutants on the soil, internal chemical reaction among the pollutants (organic compounds-organic compounds, organic compounds-inorganic compounds, and inorganic compounds-inorganic compounds), and reaction between microorganism and the pollutants, will induce more hazardous impact on the environment as well as the human being [7]. Heavy metal belongs to the inorganic compounds, which also have the interaction with the organic compounds in the soil [8]. Therefore, it could be more practical by investigating the remediation process of the soil contaminated by organic compounds in presence of heavy metals.

For the methods applied on soil remediation, bioremediation,

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http://dx.doi.org/10.1016/j.elstat.2016.02.002
0304-3886/

physical remediation and chemical remediation are three kinds of primary methods used for remediating the contaminated soil. However, every existing technology has its own defects during the application process, especially for the degradation of organic compounds in the soil: microbial remediation can cause negative effect on soil structure; photoremediation process takes a long period; electrokinetic remediation is the accumulation process of pollutants, which cannot contribute to the oxidation and reduction of the pollutants; the inadequate reaction of the traditional chemical process for organic compounds polluted soil treatment will produce more toxic byproducts and then leads the further environment deterioration. Summarizing the above problems exist in soil remediation, the best solution for removing organic compounds from the soil is to facilitate the mineralization of the pollutants quickly and efficiently [9]. At present, the optimal technologies used for organic compounds' mineralization are advanced oxidation technologies (AOTs), the technologies can utilize the ·OH, which has high oxidation potential, to oxidize the refractory organic pollutants and then to achieve the total mineralization of the pollutants. Many AOTs have been applied in treating the organic compounds in the aquatic environments successfully [10–15], and some AOTs have been used in oxidizing the organic compounds in the soil as well [9,16–18]. As one of AOTs, the technology of pulsed discharge plasma (PDP) has been proved to be able to oxidize the unbiodegradable organic compounds in the used water [19–24]. Furthermore, in recent researches carried out by Jie Li et al., the PDP process can also degrade the organic compounds in the soil [25–28]. In their papers, all the tested pollutants, involving pentachlorophenol and nitrophenol etc., can be oxidized efficiently in the PDP system. These results proved the feasibility of the PDP for organic compounds degradation in soil.

Based on the increasing deterioration of soil pollution and the effectiveness of PDP on organic compounds degradation in soil, a seven-needle-to-net PDP system was developed in the paper and then used on degrading pyrene and p-nitrophenol in the soil. Some critical factors, including treatment time, pollutants content in the soil, the initial pH value of the soil on the removal of pyrene and p-nitrophenol in the soil were firstly investigated to clarify the optimal degradation of organic compounds in the established PDP system within different operation conditions. As heavy metals often exist in the soil accompany organic compounds, so the influence of Cr^{6+} addition on the removal of organic compounds was also investigated in the research to show the effect of Cr^{6+} addition on remediation of the soil contaminated by the pyrene and the p-nitrophenol. In addition to this, clay is one of important composition of the soil and the effect of clay hence could not be neglected in a soil remediation process by the PDP. Therefore, Kaolin was chosen as a typical clay in the research for investigating the effect of Kaolin addition on the removal efficiency of the organic compounds in the soil. Researches carried out in the paper were based on our former works on organic compounds degradation in soil in the PDP system with net-to-net electrodes geometry [29]. As some practical factors (Cr^{6+} and Kaolin addition) were considered in the soil remediation system by the PDP, the research hence can provide some experimental basis for the further development of the PDP technology in remediation of the soil contaminated by organic compounds.

2. Experimental

2.1. Preparation of the contaminated soil

In the paper, the soil did not contain pollutants was called the original soil. The procedure for preparing the soil containing different contents of pyrene (100 mg/kg, 200 mg/kg and 300 mg/kg) was same. For the preparation of the contaminated soil with 100 mg/kg pyrene, 500 g of the original soil was firstly added into a conical flask with 1000 mL capacity, 50 mL acetone solution with 1000 mg/L pyrene was secondly added into the conical flask and then added 450 mL acetone. Mixture of the original soil, pyrene and acetone then vibrated in the vapor-bathing constant temperature vibrator for about 4 h. After the vibration, the mixture was then put into the fuming cupboard for about 12 h until the acetone dried out completely. Lastly, the soil was ground to a sieve with 2 mm aperture. The screened soil was stored for the further use. The procedure for preparing the soil contaminated by the pyrene-Cr^{6+} mixture was same with the above method but Cr^{6+} solution with certain concentration needed to be added into the soil during the preparation process.

The procedure for preparing p-nitrophenol polluted soil was same with the method for pyrene polluted soil preparation.

2.2. PDP system used for the soil remediation

Fig. 1 displays a schematic diagram of the PDP system used for the organic compounds degradation in the soil. The system consisted of a pulse high-voltage power supply, an electrical monitoring system and a reactor. The pulse power supply has same parameters as those of our previous work [29]. The reactor was made of a plexiglass tube, the inter diameter of the reactor was 80 mm, the outer diameter was 110 mm and the height of the reactor was 115 mm. The electrode geometry was multi-needle-to-net form, the discharge anodes were seven stainless needles, which were stainless syringe needle of 12#. The discharge anodes were distributed evenly on a silicone circular plate with 95 mm diameter and the distance between each anodes was 25 mm. Fig. 2 shows the distribution diagram of the discharge anodes in the PDP system. The ground cathode was a stainless net (120 μm aperture diameter), which fixed on a plexiglass disc (80 mm diameter). The distance between each needle electrodes was 25 mm. The gap between the anodes and the cathode was fixed at 10 mm in all experiments carried out in the research. The electrical monitoring system was a combination of an oscilloscope (LeCroy WaveJet 354A), a high voltage probe (Tektronix P6015A) and a current probe (Tektronix P6021). In the soil remediation system by the PDP, the typical wave forms of pulse voltage and current are shown in Fig. 3. The gas flew into the remediation system through the gas inlet and

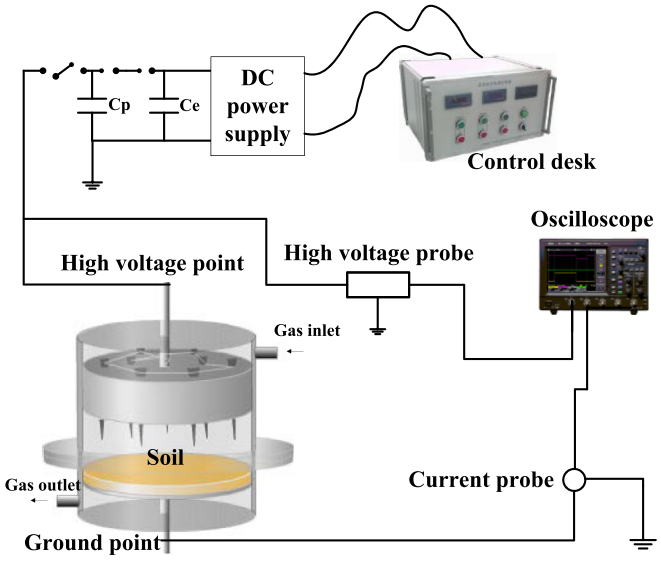

Fig. 1. Schematic diagram of the PDP system for the soil remediation.