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RESEARCH PAPER

Characteristic Study of Dissolved Organic Matter for Electron Transfer Capacity during Initial Landfill Stage

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Abstract: To investigate the evolution law and influenced factors of dissolved organic matter (DOM) for electron transfer capacity during initial landfill stage, DOM was extracted from landfill wastes at different depth. Shewanella oneidensis MR-1 and citrate iron (FeCit) were used as electron donor and electron acceptor to measure electron donating capacity, electron accepting capacity and electron shuttling capacity, respectively. Afterwards, the influenced factors of electron transfer capacity were studied by spectral analysis. The results showed that protein-like components and humic-like components were able to transfer electrons, and they also accepted electrons from microorganisms. Electron donating capacity and electron accepting capacity increased firstly and then decreased. However, electron shuttling capacity increased persistently during the landfill process. Protein-like components were the main components of dissolved organic matter during the initial landfill stage, and it was mainly responsible for the electron donoring capacity and electron accepting capacity of DOM. Electron shuttling capacity resulted from humic-like components during the cyclic redox process. Electron shuttling capacity persistently increased during the landfill process based on humic-like components generated during the stage.

Key Words: Dissolved organic matter; Reduction capacity; Electron shuttling capacity; Three-dimensional fluorescence spectrum

1 Introduction

With the acceleration of industrialization and urbanization in China, the generation rate of municipal solid wastes (MSW) was increasing. Landfill had been used as the main way in waste disposal because of its simplicity and affordability. In China, more than 60% of municipal solid waste (MSW) were disposed by landfills in 2012[1,2]. The MSW landfill leachate consists of a large quantity of harmful material such as organic contaminant and heavy metals, and they might reach the soil and groundwater through leaching rainfall, infiltration and other ways. So the MSW landfill leachate was a severe problem in ecosystem and human health due to its highly toxic of organic contaminant and heavy metals[3–5].

Dissolved organic matter (DOM) was generated during MSW degradation process. In recent years, the research showed that DOM mainly consisted of the protein-like substance in the initial stage of landfill, and the humic-like substances were the main components of DOM generating in the middle and later stages of landfill[6–8]. DOM exists wildly in natural ecosystem, which has redox capacity in the geobiochemical circulation. DOM can accept electrons during microorganism metabolism process under redox condition. The reduced DOM transfers electrons to the iron mineral. As can be seen from modern spectral technology, quinone group was the main reason that why DOM had electron shuttle capacity[9–11]. The redox behavior of DOM had drawn significant attention. Yuan *et al*[12] indicated that DOM was

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able to improve microbial reduction of Cr(VI), and Zhu *et al*[13] found that DOM enhanced degradation of nitrobenzene. In the complex environment for the degradation of landfill waste, there were not only electron donors, such as microorganisms, but also organic contaminant and heavy metals which acted as electron acceptor. So this study had significant meaning.

Until now, the reducing capacity of DOM from natural ecological system has been well studied. However, reducing capacity of DOM which was separated from MSW was seldom investigated. The depth of landfill was proportional to the time of landfill. The objectives of this study are to investigate the electron transfer capacity of the landfill-derived DOM, and analyze the influence of the electron transfer capacity on composition and structure change of DOM. Through studying electron transfer capacity of DOM during initial stage of landfill, the process of organic pollutant degradation and heavy metals transformation will be well known. Therefore, this work was able to provide scientific evidence in the area of identifying environmental waste risk.

2 Experimental

2.1 Instruments and reagents

Dissolved organic carbon content was measured by an Analytik Jena Multi N/C 2100 TOC analyzer (Analytik Jena, Germany).The fluorescence and UV-Vis spectra were measured using F-7000 luminescence spectrophotometer (Hitachi, Japan) and UV-1700 PC spectrophotometer (Shimadzu, Japan). Sodium lactate and ferric citrate (FeCit) were analytically pure and purchased from Sinopharm. Shewanella oneidensis MR-1 were obtained from Wuhan Culture Collection Center (China). The Mili-Q ultrapure water was used in this work.

2.2 Landfill samples

Three samples were collected from the Asuwei sanitary landfill site located in Beijing, China. The landfill began its operation in 1994 mainly for municipal solid wastes. The samples were collected in site where MSW was landfilled for 2 years and 0–2, 2–4 and 4–6 layers of wastes (about 5–10 kg) were collected in the site. The samples were collected by quartering and then stored at 4 ºC in laboratory.

2.3 Extraction of DOM

The samples were extracted using ultrapure water (1:10 ratio)[14], and then shaken for 24 h in a horizontal shaker at room temperature. The extracts were centrifuged at 12000 rpm for 20 min and filtered through a 0.45-μm membrane filter. The filtrates were measured with a TOC analyzer total organic carbon expressed by the dissolved organic carbon.

2.4 Reducing capacity of DOM

2.4.1 Electron donating capacity of DOM

Electron donating capacity (EDC) implied that DOM provide the number of electrons when it was used as electron donator[15]. DOM and ferric citrate were added simultaneously in a brown bottle, and the final concentrations of them were fixed to 15 mg L^{-1} and 0.5 mM, respectively. The mixture were followed with 20 min of N_2 bubbling and then shocked for 24 h at 30 ºC under dark condition. Besides, ferric citrate was not added in the blank experiment. Phenanthroline colorimetry was used to measure the content of ferrous iron. The experiment was repeated twice. EDC was calculated on the basis of the content of ferrous iron.

2.4.2 Electron accepting capacity of DOM

Electron accepting capacity (EAC) implied the quantity of electrons number when DOM was used as electron acceptor[15]. Shewanella oneidensis MR-1 was cultured in LB culture medium at 30 ºC. Logarithmic phase of Shewanella oneidensis MR-1 was centrifuged at 12000 rpm for 20 min at 30 ºC and then this bacteria solution was stored at 4 ºC. DOM, bacteria solution and sodium lactate were added and mixed in a brown bottle and the final concentration of DOM and sodium lactate were fixed to 15 mg L^{-1} and 0.5 mM, respectively. The mixture was blown with 20 min of N_2 bubbling and then shocked for 24 h at 30 ºC in dark. The solution was filtered through a 0.22-μm membrane filter and fixed with 20 mL of ferric citrate (1 mM) in the brown bottle. The mixture was shocked for 24 h in dark and electron transfer capacity (ETC) was calculated by measuring the content of ferrous iron in the reaction system. Repeat the experiment twice. EAC was equal to difference value of EDC and ETC.

2.4.3 Electron shuttling capacity of DOM

Electron shuttling capacity (ESC) means the quantity of electrons number when DOM was used as electron shuttler[15,16]. In the electron shuttling capacity test, 5 mL of bacteria solution, 10 mL of DOM (60 mg L^{-1}), 5 mL of sodium lactate (electron donor, 20 mM) and 20 mL of ferric citrate (1 mM) were mixed in a brown bottle. The mixture was blown with 20 min of N_2 bubbling and then shocked for 24 h at 30 ºC in dark. ETC was calculated by measuring the content of ferrous iron in the reaction system. Ferric citrate was not added in the blank experiment. Repeat the experiment 2 times.

2.5 Spectral analysis

2.5.1 UV-Vis spectra