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LUMINESCENT ANALYSIS OF E-BEAM INDUCED TRANSFORMATION OF PHENOL IN THE PRESENCE OF HUMIC SUBSTANCES

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Abstract. Using luminescence spectroscopy and absorption spectra, the conversion of phenol in aqueous solution without and with the present of humic and fulvic acids under electron beam was studied. The UV technology and electron beam were evaluated using the energy efficiency index. The phenol conversion efficiency values were higher after electron beam treatment than after UV treatment.

1. INTRODUCTION

Phenols are a very common type of industrial wastewater contaminants. Many studies have shown that the presence of humic acids can reduce the removal kinetics of contaminants at environmentally significant concentrations. However, there are other studies with opposite results. But the mechanism of interaction between the transformation of humic substances and pollutants remains unclear and deserves further study. Plasma-chemical processes occurring under the influence of a pulsed electron beam on organic compounds in water, including at the liquid-air interface, are poorly studied. Under the influence of the beam, active centers (free radicals, ions, or excited molecules) appear and conditions favorable for chain [see Solomonov et al., 2006] and branched chain processes in air are formed [see Mesyats et al., 2001]. Electron beam irradiation is a form of non-thermal technology that is widely used to solve various agricultural problems such as inactivating foodborne pathogens, suppressing tuber germination, delaying ripening of harvested produce, and controlling postharvest losses caused by insect and fungal infections [see Nguyen et al., 2021; Villarreal-Lozoya et al., 2009; Gul et al., 2022; Elias et al., 2020]. Scientific articles concerning irradiation of various biological systems with electron-beam (e-beam) doses have become quite frequent today. This is due to the search for optimal storage conditions for agricultural products and the evaluation of the effect of the e-beam on the health of living organisms.

2. MATERIALS AND METHOD

In our research, we irradiated a 1mM aqueous solution of phenol with electron beam. Then the phenol transformation in aqueous solution without and with the addition of humic and fulvic acids under electron beam was studied using luminescence spectroscopy and absorption spectra. Humic substances sample MK-2-1 (humic and fulvic acids, degree of dehydration 15%) was isolated from the upper peat from the high-marsh part of the deposit (Mezensky district, Arkhangelsk region, Russia). The debituminized peat was poured with 0.1 N NaOH (in a ratio of 1: 50) and infused for 24 hours without heating under constant stirring on a laboratory shaker, then humates were separated from the solid residue by filtration and purified from excess NaOH by dialysis on cellophane membranes to pH 7.5-8.0. The concentration of the working solutions was brought to a value of 25 mg/L by dilution with distilled water. We expected that phenol would react with point OH-radicals formed during redox reactions in humic substances.

The irradiation experiments were carried out with a vertical e-beam from the RADAN-303 accelerator installed in the quantum electronics laboratory of the Institute of Electrophysics, Ural Branch of the Russian Academy of Sciences (Ekaterinburg, Russia). The electron energy was 170 keV, the number of irradiation pulses with a repetition rate of 1 Hz varied from 50 to 800. The design of the experimental setup for studying the effect of an electron beam on aqueous solutions of organic substances is given in detail in [see Tchaikovskaya et al. 2023; Solomonov et al., 2016]. In the laboratory apparatus, solutions were exposed to a vertically scanned beam in a continuous flow reactor (solution depth: 2 mm, width: 1.5 cm). When distilled water is replaced by phenol and phenol solution in the presence of humic acid MK-2-1, no new bands appear in the pulse cathodoluminescence spectrum. This indicates that the solution does not luminesce under electron irradiation in the region of 300÷900 nm. However, a decrease in the intensity of the above bands with increasing number of irradiation pulses was recorded.

3. RESULTS AND DISCUSSION

Fluorescence spectra of an aqueous solution of phenol in the presence of humic acid MK-2-1 15% before and after electron beam irradiation are shown in Figure 1. With increasing number of irradiation pulses there is a consistent decrease in fluorescence intensity at 300, 475 and 575 nm (Figure 1). The band around 300 is

the fluorescence of phenol. The band around 475 nm is the fluorescence of the complex of humic and fulvic acids (Figure 2).
We did not notice any changes in the fluorescence intensity of this band after exposure to the electron beam. Therefore, we can claim that humic and fulvic acids MK-2-1 can be easily processed. According to data obtained from fluorescence excitation spectra, the fluorescence band around 475 nm is formed mainly by structures in MK-2-1 absorbing in the region at 325 and 250 nm. The band around 575 nm is the fluorescence of the phenol complex with humic and fulvic acids MK-2-1 (Figure 1). According to fluorescent analysis it was found that during irradiation with an e-beam, the addition of MK-2-1 promoted a 2-fold increase in phenol transformation compared to aqueous solution (Figure 1).

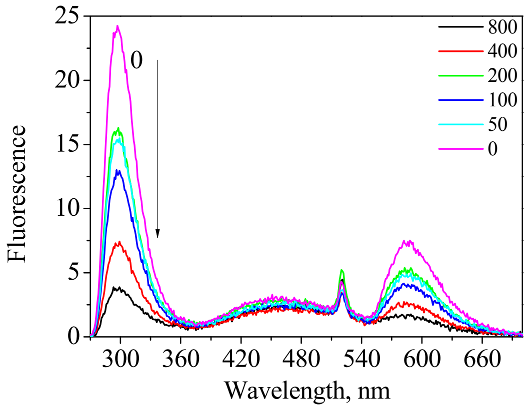

Figure 1: Fluorescence spectra of aqueous solution of phenol in the presence of humic acid MK-2-1 before irradiation (0 pulse) and after e-beam irradiation. The number of pulses is indicated in the inset. The arrow indicates the direction of change in fluorescence intensity. Fluorescence excitation wavelength is 260 nm.

UV technology and electron beam were evaluated by us using the electrical energy efficiency index. The two treatments were compared for the same systems: phenol+water, phenol + water + MK-2-1 at the same concentration. The phenol transformation efficiency values were higher after electron beam than after UV treatment. Moreover UV radiation was not at all effective for phenol attrition. Addition of MK-1 to the aqueous phenol solution did not result in any phenol transformation under UV treatment. The electron beam method had the disadvantage that constant power was required to operate the device, even when the beam was turned off. Nevertheless, compared to the UV treatment, we achieved phenol transformation under the action of the electron beam in the presence of MK-2-1.

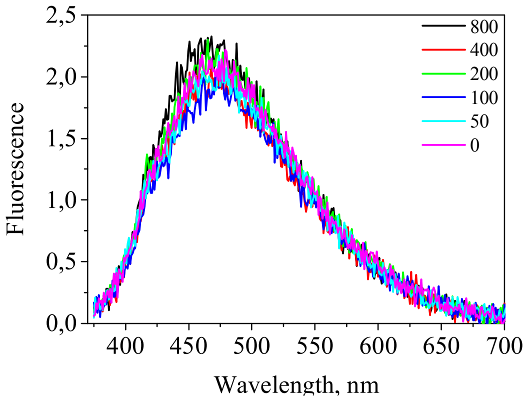

Figure 2: Fluorescence spectra of aqueous solution of humic acid MK-2-1 before irradiation (0 pulse) and after e-beam irradiation. The number of pulses is indicated in the inset. Fluorescence excitation wavelength is 365 nm.

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