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Destabilization of water-organic dispersions under the influence of an electron beam

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HIGHLIGHTS

- Electron beaming produces coagulation in aqueous dispersions.
- Decelerating the incident electrons in bulk of dispersion aggravates coagulation.
- Thin-layer beaming, de-electrifying or acidifying the samples improves coagulation.

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ABSTRACT

Influence of an irradiation on aqueous dispersions of starch, lignin and humic acids has been investigated using monoenergetic and multienergetic electron beams. As shown, coagulation and sedimentation of dispersed solids were initiated in the irradiated samples, however in neutral dispersions the multi-energetic beam had a smaller effect compared to a monoenergetic beam. As supposed, the coagulation slowdown effect is caused by formation and repulsion of singlycharged and multiply-charged micelles during electron deceleration and capture directly in the bulk of dispersion.

1. Introduction

Organic dispersions quite often are present at real wastewater, side by side with the dissolved pollutions. Respectively, to be in good repute, electron-beam wastewater treatment should be able to eliminate at once both the dissolved and dispersed impurities.

The low-energy and medium-energy accelerators (Woods and Pikaev, 1994; Berejka et al., 2014) are economically preferable for practical wastewater treatment. To minimize barren losses of beam energy, the thickness of wastewater layer is usually equated to a range of electrons (RE). However the irradiation of dispersions by low-energy electrons could result in negative consequences. The undesirable effect could be probable when incident electrons are being decelerated completely inside exposed layer and, accordingly, uncompensated negative charge is collecting in the bulk of wastewater.

The effect of charge accumulation upon radiation-induced coagulation of starch, lignin and humic acids in aqueous dispersions has been studied in the present work.

2. Materials and methods

2.1. Solutions

Corn starch, the hydrolytic pine lignin ("Polyphepan" from Scientek) and humic acids (from "ACROS", boiling point > 573 K) were dispergated in distilled water. Starch was immixed into warm water (40 °C) to prepare suspension or into boiling water to prepare hydrogel. Suspensions of lignin (80 mg/dm^3) and humic acids (20 mg/dm^3) were prepared in warm water and then were acidified to pH 2.5, using $HClO_4$.

2.2. Irradiation

Two electron accelerators and, respectively, two irradiation

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modes, were applied: the mode **I**-a uniform irradiation of sample whose thickness is much less than RE; the mode **II**-a non-uniform irradiation of sample whose thickness is comparable to RE.

In mode **I** the UELV-10-10T linear accelerator generating a horizontal monoenergy beam (8 MeV, 40 mm RE in water) was applied. Open test tubes (15 mm bore diameter) were used for samples irradiation. Incident electrons underwent only partial deceleration because of enough small thickness of the sample relative to RE.

The mode **II** has been adapted to use the URT-1 thyratron-based accelerator (Sokovnin and Balezin, 2006) generating a vertical beam whose initial energy is distributed monotonously from 0 to 1 MeV. The maximum RE in water is about 2.5 mm and almost scalingdown of absorbed dose along solution depth is characteristic for mode **II**. Respectively, open Petri dishes were used for the beaming. The thickness of exposed solution layer was within 1–3 mm.

Comparative experiments in both modes were performed at equal access of air and at the identical average dose rate within 1–3 kGy/s.

2.3. Measurements

Phenazine dye-doped copolymer film standard reference material SO PD(F)R-5/50 [GSO (Certified Reference Material) no. 7875-2000] was used as dosimeter. Optical measurements were performed using «Cary-100» UV–vis spectrophotometer. Transmittance of the samples $T=I/I_0$ (I and I_0 being intensities of transmitted and incident light), expressed in figured as -$\log_{10}$T, displays both real light absorption and scattering. Turbidity was analyzed by Turb 550 IR turbidimeter and standard dispersions (0.1–1000 NTU). Turbidity and optical spectra were measured in 10 and 15 min after an irradiation, respectively.

3. Results

3.1. Starch dispersions

Initially both suspension and gel of starch (1–3 wt%) represent dull-whitish viscous liquids of low transparency. Optical transmittance and turbidity of gel are invariable during several days whereas suspension is stable some hours.

The suspension and gel become transparent even at rather small doses (≤ 3 kGy). The distinguishable filamentary and flakelike particles arise and gradually precipitate. Viscosity of both varieties decreases to values typical of water or dilute solutions.

In mode **I**, increase in transmittance of suspension is accompanied by emersion of the absorption band at $\lambda_{max} \approx 260$ nm typical for carbonyl-containing compounds (Fig. 1 a). Optical transmission increases in visible region and decreases in UV region with increasing the dose (up to ≈ 50 kGy). Changes in turbidity and transmittance at $\lambda \geq 330$ nm correlate among themselves (Figs. 1 and 2).

The gel irradiated via mode **I** becomes more transparent also, however the effect differs from that in the suspension (Fig. 1 b). For example, transmittance in UV region at high dose becomes even lower than in initial gel. Observed turbidity decreases effectively at low doses and is almost invariable at doses ≥ 10 kGy (Fig. 2 b).

In comparison with mode **I**, the mode **II** provides more sluggish coagulation as well as lower transmittance of the irradiated dispersions (Fig. 1). Absorption band at $\lambda_{max} \approx 260$ nm becomes less noticeable. Turbidity of suspension and gel depends both on a dose and on a thickness of layer. Compared to unirradiated sample, turbidity of irradiated gel (Fig. 2) becomes higher at any dose.

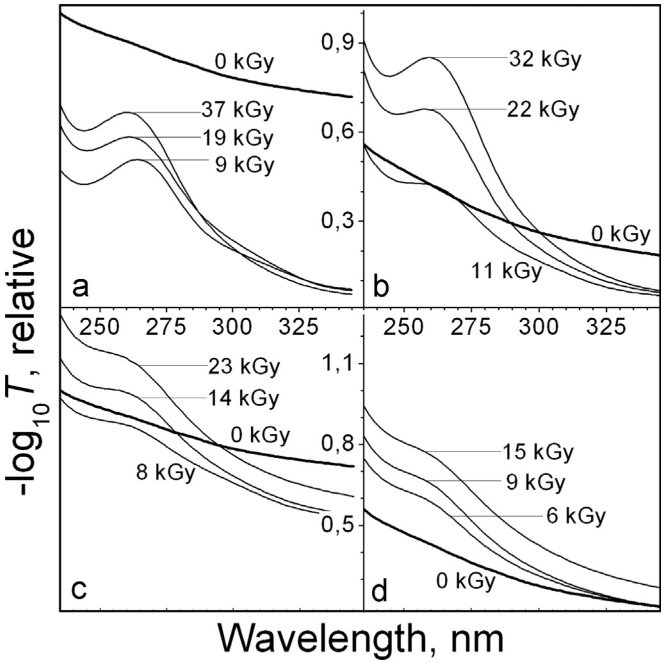

Fig. 1. Dose effects on optical spectra of 2 wt% starch suspension (a, c) and 2 wt% starch gel (b, d) irradiated in mode **I** (a, b) and **II** (c, d, 2 mm thickness).

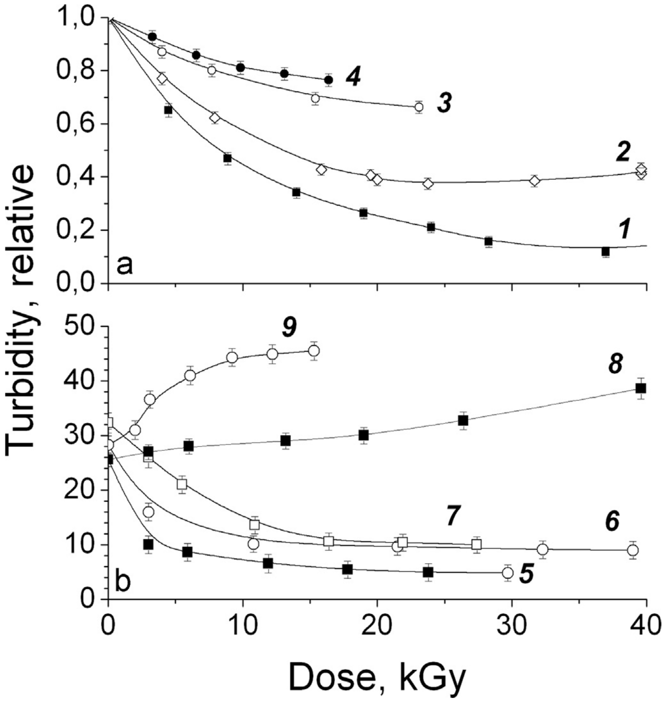

Fig. 2. Dose effect on turbidity of the starch suspension (a) and gel (b) irradiated in mode **I** (1,5–7) and **II** (2–4, 8 and 9): layer thickness-1 (2), 2 (3, 5–9) and 3 (4) mm; the starch content-1 wt% (5 and 8), 2 wt% (1–4, 6 and 9) and 3 wt% (7).

3.2. Dispersions of humic acids and lignin

Humic acids (HAs) possess a high susceptibility to irradiation in neutral (Makarov et al., 2014), acidified and alkaline solutions. Increase in transmittance both in UV and in visible region is observed as a result of beaming at mode **I** (Fig. 3). Effect of high doses upon visible region is feebler than upon UV one. Increase in optical transmission takes place side by side with sedimentation of suspended particles. The essential decrease of UV transmittance is