

Evaluation of toxicity reduction of sodium dodecyl sulfate submitted to electron beam radiation

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Abstract

Surfactants, as detergent active substances, are an important source of pollution causing biological adverse effects to aquatic organisms. Several data have been showing ecological disturbance due to the high concentration of surfactants on receiving waters and on wastewater treatment plants. Ionizing radiation has been proved as an effective technology to decompose organic substances and few papers have included ecotoxicological aspects. This paper shows the reduction of acute toxicity of a specific surfactant, sodium dodecyl sulfate (SDS), when diluted in distilled water and submitted to electron beam radiation. The study included two test-organisms, the marine bacteria *Vibrio fischeri* and the crustacean *Daphnia similis*. Radiation processing resulted in an important acute toxicity removal for both assays, which can be summarized between 70% and 96%, using 3.0, 6.0, 9.0 and 12.0 kGy as radiation doses. Nevertheless, lower doses demonstrated better effect than 9.0 and 12.0 kGy and the bacterium assay was more sensitive to SDS than crustacean assay.

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1. Introduction

Several classes of surfactants, as detergent active substances, are an important source of pollution causing biological adverse effects to aquatic organisms. When surfactants are present in the aquatic environment in relatively high concentrations they may cause ecological problems. A reasonably quantification of data shows this ecological disturbance due to surfactants on receiving waters and on wastewater treatment plants (Sandbacka et al., 2000; Zagatto and Goldstein, 1991).

Considering that biodegradability system is basic for effluent treatment, situations where very toxic effluents are present in the wastewater treatment plants, all the

system is affected. A pre-treatment is often necessary to avoid this occurrence (Borrely et al., 2000). Sodium dodecyl sulfate (SDS) is listed among the anionic surfactants more used in Brazil.

Ionizing radiation has been proved to be an effective technology to decompose organic substances and environmental contaminants from sewage, sludge and wastewater and few papers have included ecotoxicological aspects. The efficiency of the treatment process by ionizing radiation can be evaluated by toxicity tests, employing aquatic organisms (Borrely et al., 2000).

The aim of this work was to study the effect of ionizing radiation for the degradation of SDS, under an ecotoxicological approach. Two acute toxicity tests were applied in order to evaluate the efficiency of irradiation for reducing SDS toxicity. The tested organisms were a luminescent marine bacteria *Vibrio fischeri* and the freshwater microcrustacean *Daphnia similis*.

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2. Material and methods

Samples of surfactant were prepared by diluting SDS, from MallinckrodtOR[®], with distilled water up to a concentration of 100 mg/l. The evaluation of SDS toxicity was performed before and after the irradiation of the samples. An industrial electron accelerator, Dynamitron model, with a beam energy of 1.5 MeV and variable current up to 25 mA was used and radiation doses of 3.0, 6.0, 9.0 and 12.0 kGy were employed in the experiments. This accelerator is located at the Instituto de Pesquisas Energéticas e Nucleares—IPEN-CNEN/SP.

Young *D. similis* were exposed to different concentration of the surfactant, which ranged from 5.00 to 80.00 mg/l, during 24 h. The concentrations that could lead to the immobilization of 50% of the organisms (EC50) were calculated from the number of immobile organisms per sample concentration and later applying statistical tests, like the Trimmed Spearman Karber (APHA, 1995).

The experiment with bioluminescent bacteria *V. fischeri* was done with the Microtox[®] System, model M-500 from Microbics, exposing the samples to concentrations of SDS from 0.50 up to 45.45 mg/l during 15 min. The statistical analysis was carried out with a program developed by Microbics version 7.82, that calculates the values of EC50 based on a linear regression obtained by the reduction of the amount of light emitted by the microorganism after exposure and the sample concentration (CETESB, 1987).

The evaluation of irradiation process on the reduction of the acute toxicity of samples containing the surfactant was performed by transforming the obtained values of EC50 into Toxic Units (TU—that are directly proportional to the toxicity— $TU = 100/EC50$). The percentage of the reduction of acute toxicity between the raw and the irradiated sample were calculated from the TU values for each radiation dose applied.

The effects of electron irradiation on the pH were considered (pH electrode from Micronal-B374).

3. Results and discussion

Tables 1 and 2 and Fig. 1 summarize the results obtained for the toxicity tests.

The SDS surfactant showed high toxicity for *D. similis* (EC50 equals 11.48 mg/l) as well as for the test with *V. fischeri* (EC50 equals 2.09 mg/l). This means that luminescent bacteria are more sensitive to SDS.

The values of the EC50 increased with the application of radiation doses, showing an important reduction of samples toxicity, as it can be seen in Tables 1 and 2. The efficiency of the irradiation process for decreasing SDS acute toxicity can be evaluated from the two ecotox-

icological tests performed. The results showed a good correlation between them.

All radiation doses reduced the SDS toxicity. However, the more effective doses were 3.0 and 6.0 kGy, which represented a reduction percentage of acute toxicity of 83–92% and 84–96%, respectively. The higher doses 9.0 and 12.0 kGy resulted in a less effective removal (see Fig. 1).

Podzorova et al. (1998) studied ionizing radiation for reducing concentration of a synthetic surfactant. They applied doses ranging from 4 to 5 kGy, with an electron beam accelerator. At that time, they found from 0.2 up to 13.25 mg/l of surfactant in municipal wastewater, completely removed by radiation treatment.

In this present paper, the reduction action of SDS acute toxicity is evidenced by the degradation of this surfactant. The pH values measured during the samples irradiation varied between 6.20 and 3.38, as shown in Fig. 2. This reduction on the pH values can be explained by the production of acid compounds.

The radiation can directly interact with the organic molecule or can indirectly effect it, by producing highly reactive chemical species, the so-called free radicals. The lower pH values indicate the formation of organic acid after irradiation of the surfactant in distilled water (Moraes et al., 2002).

Table 1
Results of the acute toxicity tests with *D. similis* on the analysis of SDS surfactant

Dose (kGy)	SDS		
	Acute toxicity test with <i>D. similis</i> (24 h)		
	EC50%	TU	% Toxicity reduction
0	11.48	11.44	0
3.0	69.13	1.47	82.78
6.0	70.33	1.47	84.32
9.0	52.12	1.94	77.27
12.0	38.08	2.63	70.11

Table 2
Results of the acute toxicity tests with *V. fischeri* on the analysis of SDS surfactant

Dose (kGy)	SDS		
	Acute toxicity test with <i>V. fischeri</i> (15 min)		
	EC50%	UT	% Toxicity reduction
0	2.09	66.69	0
3.0	33.13	3.89	92.01
6.0	71.20	1.74	95.77
9.0	30.76	4.11	87.88
12.0	45.45	2.20	94.98

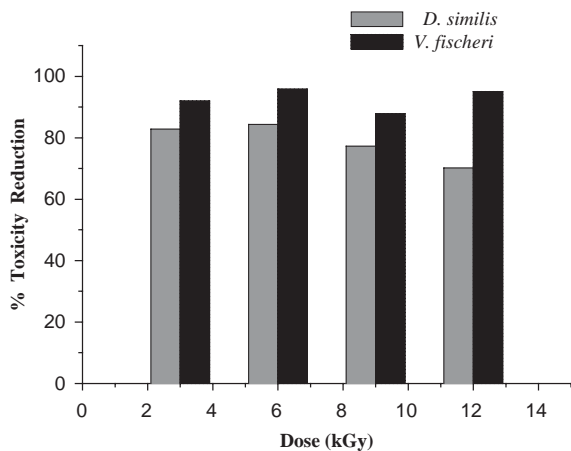


Fig. 1. Efficiency of the irradiation process with an electron beam on the reduction of the acute toxicity of SDS.

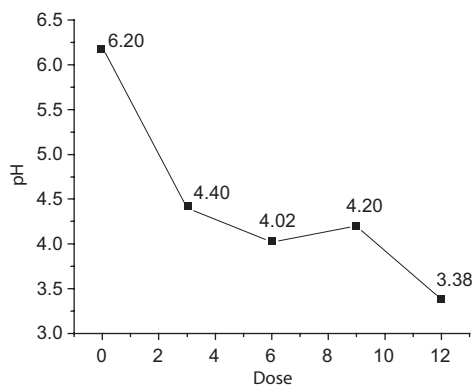


Fig. 2. pH versus radiation dose (kGy).

According to Rohrer (1975), the degradation of the surfactant when submitted to irradiation occurs by the attack of oxidizing species that are produced by the water radiolysis.

V. fischeri showed to be more sensitive to SDS when compared to *D. similis*. According to Gloxhuber (1980), the surfactant is able to solubilize the cellular membrane, depending on its concentration, causing then a bactericidal action. This factor may be responsible for the increasing sensitivity of these luminescent bacteria to SDS.

The ionizing radiation used in the present work proved to be an important tool for the reduction of acute toxicity caused by SDS. The high toxicity showed by SDS showed the necessity of developing new technologies for the effluent treatment, especially for surfactant producers.

4. Conclusion

It can be concluded that SDS surfactant is highly toxic for both tested organisms and that irradiation can contribute for reducing the toxic discharges into the wastewater systems. Concerning these results, it can be suggested 6.0 kGy as an ideal radiation dose. Forthcoming studies will include a new biological method classified as “DNA biomarker assay”, in order to confirm the benefits of ionizing radiation applied to this surfactant.

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