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Radiation processing of wastewater evaluated by toxicity assays

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Abstract

Biological assays have been applied to industrial effluents and sewage influents, from distinct sites, before and after being submitted to ionizing radiation treatment. The objective of this study was to evaluate the efficiency of radiation, mainly electron beam accelerator, for the acute toxicity removal. The selected sampling presented a very toxic level and the radiation process was efficient for toxicity removal for 87.7% of irradiated samples. The sewage influents required lower radiation doses to reduce toxicity when compared to raw industrial effluents. © 2000 Elsevier Science Ltd. All rights reserved.

Keywords: Wastewater; Acute toxicity; Radiation dose; Electron beam accelerator

1. Introduction

Ionizing radiation has been shown to be effective for destroying environmental contaminants from sewage, sludge and wastewater. The Nuclear Research Institute, IPEN-São Paulo has applied an Electron Beam Accelerator, EBA, for the quality improvement of effluents and influents from different industries and sewage plants, respectively. The performance of the technology has been evaluated by toxicity tests with aquatic organisms. Biological assays have been routinely used to assess the toxicity of effluent samples before and after irradiation. Tested organisms were the bacteria *Vibrio fisheri*-MICROTOX® System, manufactured by Microbics Corporation (1994) the microcrustacean *Daphnia similis* and sea urchin *Lytechinus variegatus*. All effluent and influent samples were tested with the Microtox system and some of them confirmed with the other two toxicity tests. The data were discussed according to the toxicity rank, established by Bulich (1982).

2. Material and methods

Thirty wastewater samples were collected from different sites, as presented in Table 1. The acute toxicity evaluation was carried out for irradiated and unirradiated samples. Several radiation doses were applied

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Table 1
Range of toxicity according to the sampling sites and related industrial activities and radiation dose effects (preliminary results)

Site number and industrial activity	Range of toxicity for raw sample EC-50 for Microtox (*V. fischeri*) (concentration %)	Dose (kGy) and EC-50% (benefits by dose)
01. WWTP[a] A Sewage prevalence *Site 1*	6.52(4.98–7.23)–20.28 (14.5–28.3) $n = 3$; Average: 11.33 ± 7.75[b]	3.0 kGy ⇒ 45.45% for Microtox (*V. fischeri*)
02. WWTP B Industrial effluent prevalence *Site 2*	2.24(1.87–2.67)–15.81 (13.49–18.62) $n = 10$; Average: 9.28 ± 5.27	6.0 kGy ⇒ 45.45%; for *V. fischeri*, except when EC-50 was < 5.0% for unirradiated sewage, it required higher doses
03. Industry 1 Produced Water Petrol extraction activities *Site 3*	2.59 (1.77–3.80)–14.64 (12.76–16.90) $n = 4$ Average: 2.10 ± 0.31, for *V. fischeri* Average: 2.95 ± 3.35, for *Lytechinus variegatus*	9.0 kGy ⇒ 1.74% for *V. fischeri* and 1.56% for *L. variegatus* No improvement, except for the first experiment with cobalt-60 (9.0 kGy ⇒ from 2.59% to 26.03%)
04. Industry 2 Chemical Pharmaceutical *Site 4*	0.10 (0.08–0.14)–0.61 (0.29–1.31) $n = 2$	9.0 kGy ⇒ 0.30% 40.0 kGy ⇒ 0.83% No improvement
05. Industry 3 Textile *Site 5*	1.65 (1.52–1.78)–12.71 (7.30–23.10) $n = 2$	10.0 kGy ⇒ 45.45% for *V. fischeri* 10.0 kGy ⇒ 66.20% (*D. similis*)
06. Complex mixture of industrial effluents *Site 6*	0.71 (0.51–0.99)–10.27 (9.85–16.11) $n = 9$ Average: 2.24 ± 1.43, for *V. fischeri* Bacteria Average: 2.42 ± 1.95, for *D. similis*	20.0 kGy ⇒ 20.33% No improvement for doses up to 20.0 kGy

[a] WWTP — Wastewater treatment Plant.
[b] n — number of sampling.

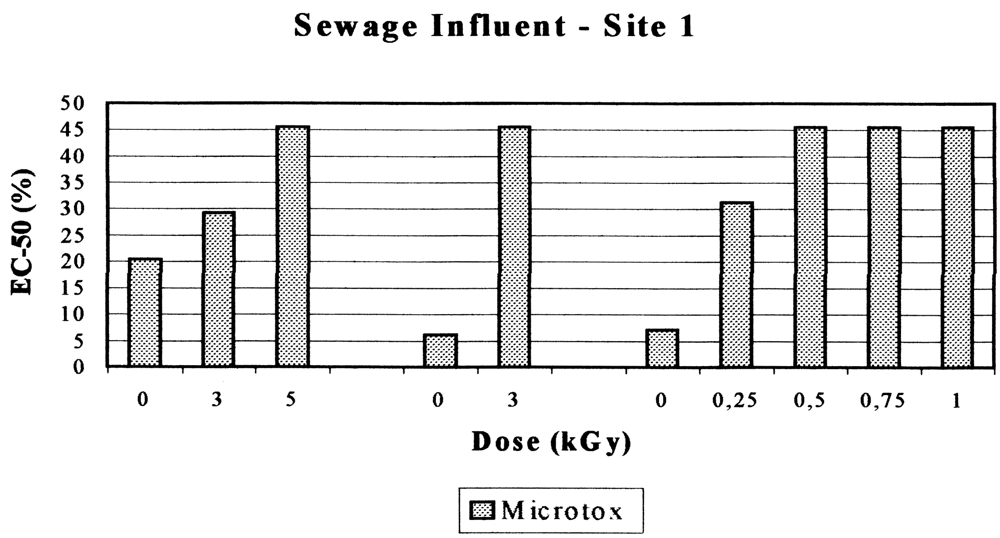

Fig. 1. Radiation effects on acute toxicity evaluated by Microtox tests applied to untreated and irradiated sewage influent from Site 1.

by a Dynamitron EBA, from RDI Inc., 1.5 MeV, variable current, in batch system. Few samples were irradiated with ^{60}Co, Gamma cell — 10,000 Ci activity.

Acute toxicity response was expressed as EC-50 value, which means the sample concentration that reduces the measured effect by 50%. The tested organisms and methods were the following: (a) Bacteria *Vibrio fischeri*, Microtox System® — Basic Test Protocol — 15 min exposure; (b) Sea urchin *Lytechinus variegatus* (Fertilization test): 80 min exposure, measuring acute sublethal effects, for samples discharged into the sea (Nipper et al., 1993); (c) Microcrustacean *Daphnia similis*, acute test for 48 h exposure, all of them in standard conditions.

Two different statistical analyses were applied for the EC-50 calculations. For Microtox Tests the statistical method was a linear regression, using the sample concentrations versus the gamma effect. Note that this gamma is the ratio of light lost to light remaining after exposure of the reagent to a sample and in this case

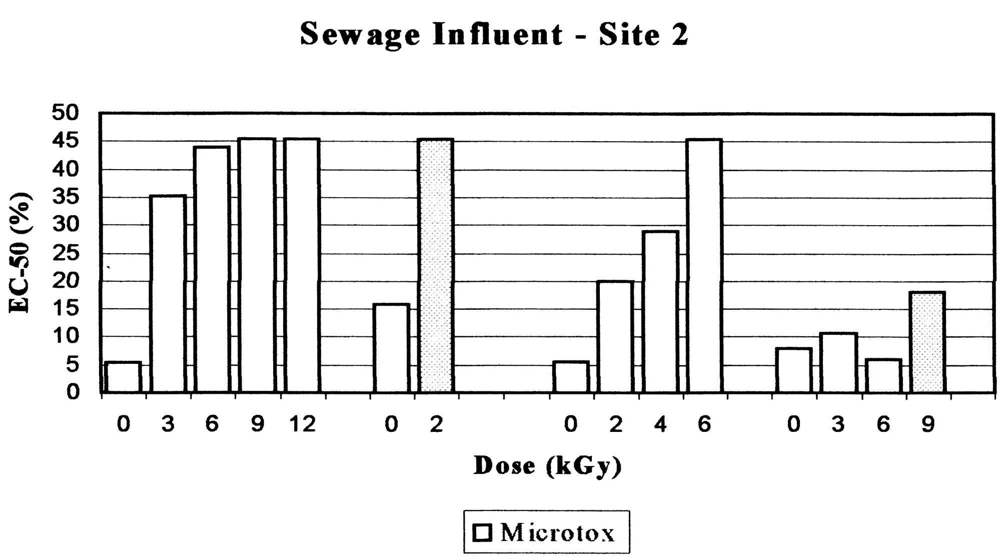

Fig. 2. Radiation effects on acute toxicity evaluated by Microtox tests applied to untreated and irradiated sewage influent from Site 2.

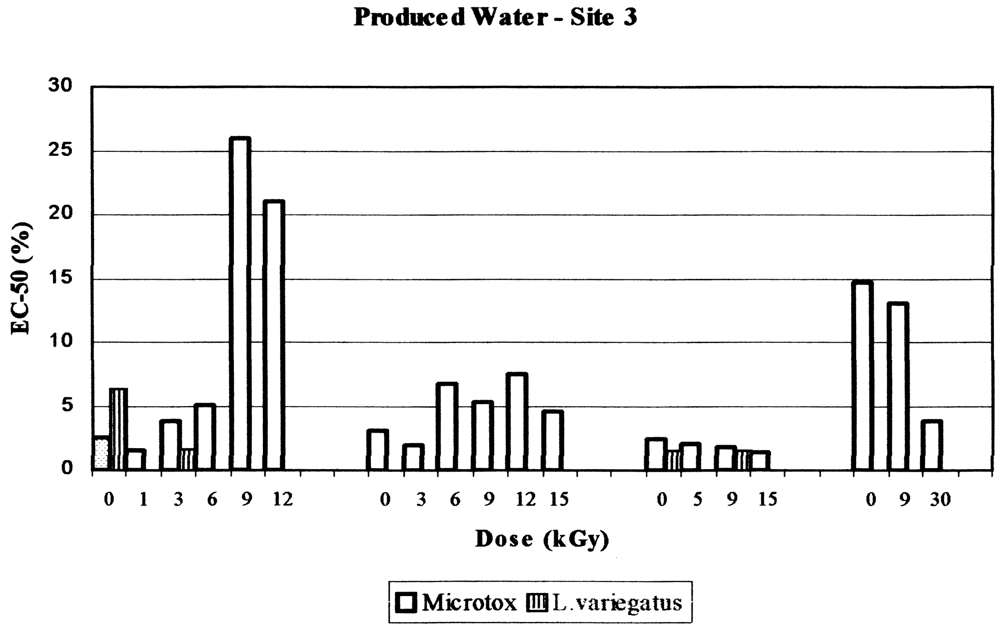

Fig. 3. Radiation effects on acute toxicity evaluated by Microtox and *L. variegatus* fertilization tests applied to untreated and irradiated produced water from Site 3.

the EC-50 is the concentration at which Gamma equals 1, that is, the light lost equals the light remaining (Microbics Corporation, 1994). For fertilization tests (*L. variegatus*) and mobility tests (*D. similis*), the EC-50 values were determined by Trimmed Spearman–Karber method (American Public Health Association, 1995).

3. Results and discussion

All samples submitted to radiation presented originally a very high level of toxicity according to the range presented in Table 1. For some sampling sites the range of toxicity was wide, which is common when related to real influents, but still very toxic. It was

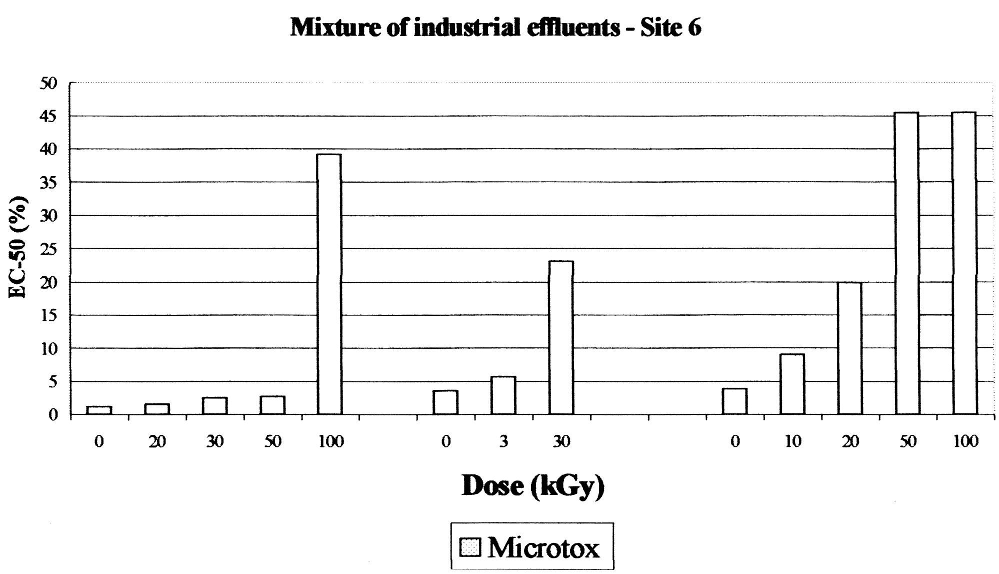

Fig. 4. Radiation effects on acute toxicity evaluated by Microtox tests applied to untreated and irradiated complex mixture of industrial effluents from Site 6.

clear that the toxicity removal efficiency depended on its initial concentration as well as on the origin of the sampling.

Figs. 1 and 2 show that for toxicity removal, radiation effect was more efficient for the sewage samples compared to raw industrial effluents. The plant where sewage was prevalent required doses lower than 3.0 kGy and the plant where industrial effluent was prevalent required higher doses (9.0–15.0 kGy).

The effluents from the petrol extraction activities, or produced water, did not present toxicity removal by irradiation for most of the experiments. A previous experiment was carried out using gamma and electron radiation and only for the first sampling the gamma radiation increased the EC-50 value from 2.59% to 26.03%, for Microtox Test, shown in Fig. 3 and Table 1. It is important to note that the lower the EC-50 the higher the toxicity.

No improvement was obtained for the effluents from industries 1 and 2 although only few and preliminary experiments were carried out, according to Table 1. Otherwise, complex mixture of industrial effluents required doses from 30.0 kGy to 100.0 kGy, especially when raw samples were extremely toxic with EC-50 values lower than 1.0% up to 4.0%, as shown by Fig. 4.

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