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Whole acute toxicity removal from industrial and domestic effluents treated by electron beam radiation: emphasis on anionic surfactants

M.C.F. Moraes[a,*], M.F Romanelli[a], H.C. Sena[b], G. Pasqualini da Silva[a], M.H.O. Sampa[a], S.I. Borrely[a]

[a] *Instituto de Pesquisas Energéticas e Nucleares-IPEN-CNEN/SP, Av. Professor Lineu Prestes, 2242, Cidade Universitária São Paulo 05508-000, Brazil*
[b] *Companhia de Saneamento Básico do Estado de São Paulo – SABESP, Av. Professor Lineu Prestes, 2242, Cidade Universitária São Paulo 05508-000, Brazil*

Abstract

Electron beam radiation has been applied to improve real industrial and domestic effluents received by Suzano wastewater treatment plant. Radiation efficacy has been evaluated as toxicity reduction, using two biological assays. Three sites were sampled and submitted for toxicity assays, anionic surfactant determination and electron beam irradiation. This paper shows the reduction of acute toxicity for both test-organisms, the marine bacteria *Vibrio fischeri* and the crustacean *Daphnia similis*. The raw toxic effluents exibitted from 0.6 ppm up to 11.67 ppm for anionic surfactant before being treated by the electron beam. Radiation processing resulted in reduction of the acute toxicity as well as surfactant removal. The final biological effluent was in general less toxic than other sites but the presence of anionic surfactants was evidenced.

1. Introduction

The quality of aquatic environments is deteriorating due to raw and toxic effluent discharges. Detergents are an important source of pollution and often transferred to waterways by industrial and domestic effluents.

Among the impacts caused by detergents in the water are: propagation of algae due to phosphate; it inhibits carbon dioxide gas from leaving the water and at the same time inhibits oxygen from dissolving in the water (not favorable to biodegradation); selection of micro-organisms (anaerobic prevalence); foam formation and aquatic toxicity. Several kinds of synthetic detergents may have a negative impact on water and in particular, aquatic organisms that are dependent on waters, especially those who depend on aquatic superficial tension (Rand, 1995).

Concerning detergents, Brazilian Regulation is favourable only for biodegradable substances (Portaria n° 112, de 14 de maio de 1982, do Ministério da Saúde), nevertheless relatively high concentrations of anionic surfactants are found in natural waters and even at wastewater treatment plants (WWTP). Several biological assays have been proposed as eco-toxicity assessment for impacted environments, to evaluate the adverse effects of a mixture of pollutants (SMA, 2000). Major ecological studies are done with daphnids, bacteria and fishes (Borrely, 2001).

Ionizing radiation has been considered for special kinds of effluents and the present paper concerns radiation processing for anionic surfactants as a possible way to reduce toxicity. The electron beam efficacy for several organics was performed by Duarte (1999).

*Corresponding author. Fax: +55-11-3816-91-86.
E-mail address: mariacristinafm@uol.com.br (M.C.F. Moraes).

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The aim of the present paper is to evaluate the effects of ionizing radiation as a possible technology to treat wastewater in order to reduce anionic surfactants. This study included electron irradiation applied to industrial and raw wastewater and acute toxicity evaluation. Anionic surfactants and dissolved total organic carbon were also determined.

The objective of this present paper was to study the viability of electron beam radiation for treating wastewater contaminated with detergents. The data were based on Suzano Wastewater Treatment Plant. Suzano, São Paulo, which is one of the most industrial sites in this region where very toxic influents are discharged to the WWTP. Three basic activities were developed as follows.

2. Methodology

2.1. Sampling

The samples were collected from a chemical pharmaceutical industry and to a municipal wastewater treatment plant there industrial effluent were discharged. The study included 20 samples from four different sites and three campaigns. All samples were composite (four subsamples a day, according to the average flow).

2.2. Irradiation

The radiation doses were applied at Centro de Tecnologia das Radiações, CTR—IPEN, with a Dynamitron Electron Beam Accelerator (EBA) from RDI Inc. The machine energy was 1.5 MeV and the variable current 37.5 kW. For these experiments, the energy was fixed in 1.4 MeV. Batch irradiation was performed for these effluents which were inside a pyrex vessel.

2.3. Toxicity assays

The acute toxicity evaluation was carried out for irradiated and unirradiated samples. Radiation doses were 6, 10, 20 and 50 kGy, depending on the sample origin and initial contamination.

The tested organisms and method were the following: (a) Bacteria *Vibrio fischeri* with Microtox System—Basic Test Protocol—15 min exposure and (b) Microcrustacean *Daphnia similis*, acute test for 24 and 48 h exposure, all of them in standard condition. Acute toxicity response was expressed as EC50 value, which means the sample concentration reduced the measured effect by 50%.

Two statistical analyses were applied for the EC50 calculations. For Microtox® Tests with *V. fischeri*, the statistical method was a linear regression, using the sample concentration versus gamma effect parameter (ratio of light lost to light remaining after exposure of the reagent to a sample). 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 the EC-50 is the concentration at which Gamma equals I, that is the light lost equals the light remaining (Microbics Corporation, 1994). For mobility tests *D. similis*, the statistical method was Trimmed Sperman Karber, with Abbot (CETESB, 1987; NBR, 1993).

To analyze direct numbers and EC50 was transformed into Toxic Unit (TU = 100/EC50). Comparing TUs from samples treated and untreated, the removal efficiency was calculated.

2.4. Anionic surfactant determination

The surfactant content was determined by methylene blue active substances (MBAS), the organic blue phase was photometrically measured at 652 nm (SHIMADZU, UV-1601) according to APHA, 1995.

3. Results and discussion

Toxicity results as well as radiation efficiency are summarized in Table 1. Observing the toxic units (TU) it is possible to verify that industrial effluents were worst for bacteria *V. fischeri* than for the crustaceans.

Results showed that for industrial effluents 20 kGy resulted in 70% and 73% toxicity removal for *V. fischeri* and *D. similis*, respectively. A similar result was obtained for industrial effluents during campaign 3 (C-3) 70% removal for *V. fischeri*. Nevertheless this last result is extremely important if the TU considered as 888.3, is much higher than the first, before being treated by radiation. Sewage detoxification presented the same level of removal but the initial responses were less aggressive than the industrial effluents. One result obtained for sewage irradiated with 6.0 kGy resulted in toxicity increasing but Daphnia result did not confirm the presence of toxicity. For the last studied site (Guaió) radiation efficiency was lower than the other and it can be related to the initial toxicity lower concentrations. Samples collected at this site have already received previous treatment at the station.

The anionic surfactant concentration before radiation treatment was from 0.67 ppm up to 11.57 ppm and as evidenced by Fig. 1 the reduction was determined by 57% and 95% according to the increasing initial concentration, respectively.

Experimental studies are still been performed and other detergents determination have been tried and also a method to remove the surfactant as sub-samples treatment and toxicity evaluation are in the current stage.

Table 1
Effects of radiation on acute toxicity

Sample and Dose (I) (kGy)	C-1				C-2				C-3			
	V. fischeri		*D. similis*		*V. fischeri*		*D. similis*		*V. fischeri*		*D. similis*	
	TU	RE(%)	TU	RE (%)	TU	RE (%)	TU	RE (%)	TU	RE (%)	TU	RE (%)
EInd	100	—	24.9	—	—	—	—	—	888.3	—	20.0	—
EInd (I20)	30.3	70	6.7	73.00	—	—	—	—	250	70	—	—
EInd (I50)	—	—	—	—	—	—	—	—	111	86.60	21	−8
Sewage (Sw)	5.6	—	3.5	—	1	—	10	—	8.5	—	3.6	—
Sw (I6)	2.54	54.60	1	71.40	2.2	−119	1	100	—	—	—	—
Sw (I10)	—	—	—	—	—	—	—	—	2.2	74.50	1	72.20
Guaió	—	—	—	—	3.6	—	7.2	—	6.8	—	64	—
Guaió (I6)	—	—	—	—	2.2	40	4	44.40	—	—	—	—
Guaió (I10)	—	—	—	—	—	—	—	—	2.19	68.20	100	−58

TU = Toxic unit (100 / EC50).
C-1; C-2; C-3—different campaigns.
Note a negative effect of 6.0 kGy for *V. fischeri* not confirmed for *D. similis*—confirmation and search for the ideal dose for all the tested organisms is necessary.

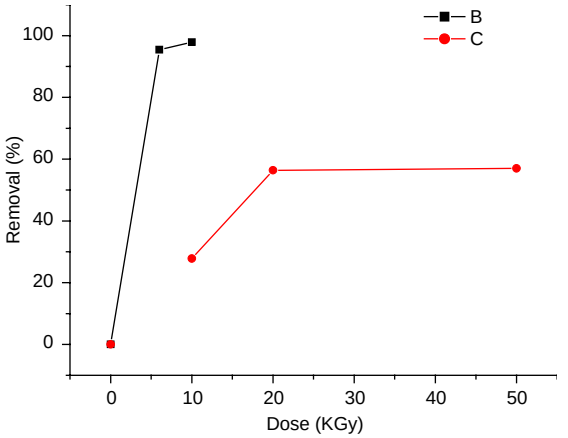

Fig. 1. Effect of irradiation on the anionic surfactant removal (B—sewage influent and C—industrial effluent).

4. Conclusion

Radiation can be applied successfully for surfactant reduction on wastewater. An average reduction of 79% was obtained for anionic surfactant containing from 8 to 1387 ppm before radiation treatment. The acute toxicity is partially related to anionic surfactants.

References

APHA/AWWA/WPCF, 1995. Standard Methods for the Examination of Water and Wastewater, 19th edição. American Public Health Association, New York.

Borrely, S.I, 2001. Redução da toxicidade aguda de efluentes industriais e domésticos tratados por irradiação por feixes de elétrons avaliada com as espécies *V. fischeri, D. similis* e *P. reticulata*. 2001. Tese (Doutorado)—Instituto de Pesquisas Energéticas e Nucleares, São Paulo.

Duarte, C.L., 1999. Aplicação do processo avançado de oxidação por feixe de elétrons na degradação de compostos orgânicos presentes em efluentes industriais. Tese de (Doutorado)—Instituto de Pesquisas Energéticas e Nucleares, São Paulo.

Rand, G.M., 1995. Fundamental of Aquatic Toxicology: effects, environmental fate and risk assesment, 2nd edition. Taylor & Francis, London.