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TOXICITY OF TEXTILE EFFLUENTS TREATED BY ELECTRON BEAM TECHNOLOGY

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ABSTRACT

The textile industry uses expressive amount of water during the production and generate effluents that contain residuals of dyes, surfactants, peroxides, acids and salts, and toxicity. In addition, the textile effluents are commonly colored, because the dyes used in fibers dyeing usually have low fixation and high solubility. Many of the mentioned products are not easily removed, requiring additional treatment steps. Advanced Oxidative Processes, such as electron beam irradiantion (EBI), can be a good alternative to reduction of organic pollutants from effluents. Therefore, studies on these contaminants in aquatic environment are important for assessing their impacts on ecosystems and water quality. The objective of this study was to evaluate the toxicity of textile effluents treated with EBI. The doses of 2.5 kGy and 5.0 kGy were used. The toxicity assays were performed with *Daphnia similis* organisms, exposed to samples during 48 hours, and the results expressed by EC50 (median effective concentration). For the textile effluent, EC 50% values ranged from: 2.95 ±0.13 (raw effluent) until 20.90 ±1.48 (irradiated effluent, at 5kGy). The EBI treatment was effective for toxicity reduction, with efficiency higher than 60% (2.5 kGy) and 80% (5.0 kGy). The study of organic and inorganic contaminants, presents in these effluents, demonstred EC 50 values below 5%. These results demonstrate high toxicity of contaminants from textile effluents for aquatic organisms (*D. similis*, cladocera). Similar data was observed for the raw effluent. These values are relevant for thinking radiation as a possible technology for such a type of effluent.

1. INTRODUCTION

A significant number of emerging pollutants (EPs) resulting from point and diffuse pollution is present in the aquatic environment. The principal classes of EPs are: pharmaceuticals (urban, stock farming), pesticides (agriculture), disinfection by-products (urban, industry), wood preservation and industrial chemicals (industry) [1]. In this last class (industrial chemicals) one can highlight the compounds present in various effluents, such as textiles.

The textile effluent are critical because they have contaminants, such as dyestuff, surfactants, dispersants, acids, alkalis, bleaching agents, humectants, among other compounds. Many of them have the characteristic of high solubility and low degradability, which confer difficult removal by conventional treatments and contribute to the high toxicity of these effluents [2, 3].

The World Bank estimates that 17% until 20% of aquatic pollution it is from the textile industry and 72 toxic chemicals have been identified in textile effluents. In aquatic environment, the presence of these substances affects important parameters of the water, such as: dissolved oxygen, turbidity and color. Due to low biodegradability, some compounds may accumulate at food chain; others may cause acute and chronic effects to aquatic biota, and also may induce mutagenicity. These compounds may undergo chemical changes under environmental conditions (biological or photochemical degradation), and the transformation products may be more toxic and carcinogenic than the original compound [4, 5].

Regarding dyes and textile effluents, in aquatic organisms, Borrely et al. [6], demonstrated toxicity of effluent with reactive dye C.I. Blue 222 for *Daphnia similis*, *Vibrio fischeri* and *Brachionus plicatilis.* Darsana et al. [7], reported toxicity of reactive dye Red 120 for *Daphnia magna*. In fish, *Danio rerio* and *Gambusia affinis,* were reported *g*enotoxicity, enzymatic changes and oxidative stress [8, 9, 10]. In other organisms, such as rats and mice, for example, many studies reported alterations in hematopoietic and reproductive systems, and histopathological lesions in heart, kidneys, lungs and intestinal epithelium, for example [9, 11, 12].
Due to the complexity of these effluents, Advanced Oxidative Processes, auxiliary to biological treatment, are an alternative for the degradation of the organic and inorganic compounds present in these effluents. The Electron Beam Irradiation is a possible technology in this case, many authors demonstrated the decreased of different parameters such as: toxicity, chemical oxygen demand, total organic carbon and color with doses up until 9 kGy [6, 13,14,15,16] .

The objective of this study was to determine the efficacy of EBI (electron beam irradiation) for reducing whole toxicity of textile effluents.

2. METHODOLOGY

Preparation of samples: the real effluent was obtained by dyeings of cotton during textile processing at Textile Chemistry Laboratory of School of Technology SENAI Antoine Skaf. Those effluents represent the complete cotton colouring process (bleaching, dyeing and washing). Reactive Red 239 was applied.

Electron Beam Irradiation: aqueous solutions and liquid effluents were irradiated at Radiation Technology Center (CTR/IPEN), with electron beam accelerator (Dynamitron model). The machine parameters were: 1.4 MeV (fixed energy), conveyor speed 6.72 $m.min^{-1}$ and variable electric current according to required doses (2.5 kGy and 5.0 kGy).

Acute Toxicity Assay**:** the acute toxicity tests followed the Brazilian Technical Standard (ABNT-NBR) methods, using the crustacean *Daphnia similis* (ABNT NBR 12713) [17]. The *Daphnia similis* assay was based on the exposure of young individuals to five concentrations of the test substance, over a period of 48 hours, and immobility of the organisms was the measured end point. The analyses were based on the EC 50(%), which is the effective median concentration that causes effect to 50% of the exposed organisms. All toxicity assays were performed in triplicate. The toxicity removal (%) were calculated as follow:

$$TR(\%) = \left(\frac{(EC50_0 - EC50_i)}{EC50_0} \right) \times 100$$

$EC50_o$= Toxicity of solution before irradiation
$EC50_i$= Toxicity of solution after irradiation

3. RESULTS AND DISCUSSION

Whole effluents, containing reactive dye red 239, were exposed to dafnids, before and after irradiation. The results are show in figure 1. A significant reduction on toxicity effects to *Daphnia similis* was obtained by irradiation, EC 50% 2.95±0.13 without treatment and EC50% 9.27 ±0.41 (2.5 kGy) and 20.90 ±1.48 (5 kGy). The efficiency of electron beam treatment to reduce toxicity was presented in figure 2.

We have also determined the toxicity of some compounds present in textile effluents, such as surfactants, humectants and hydrogen peroxide. All the values were similar (EC50 up to 5%), while EC50% = 2.95 ±0.13 was the value for whole effluent.

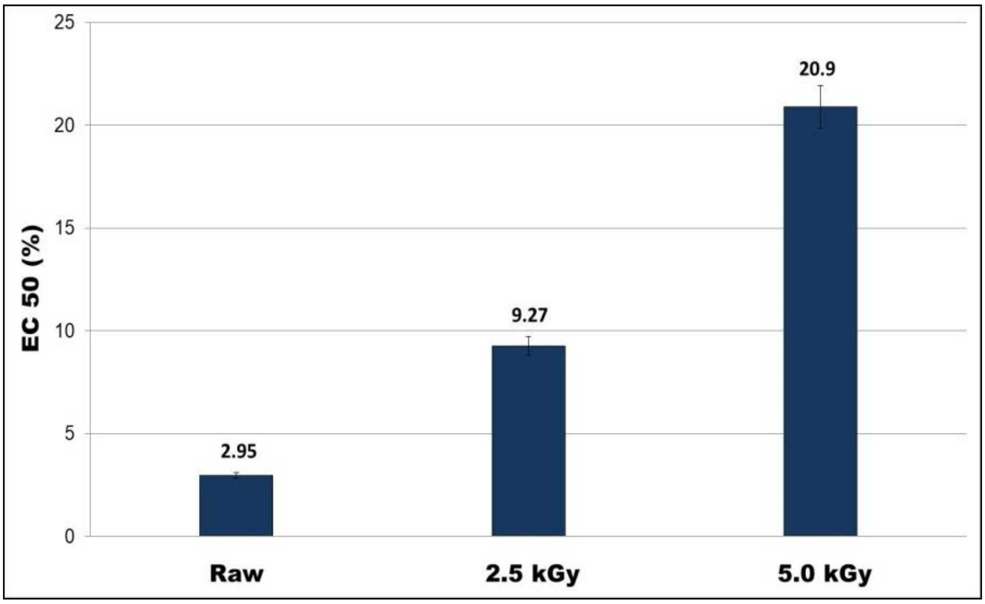

Figure 1: Acute toxicity to *D. similis*: the red effluent after electron beam irradiation.

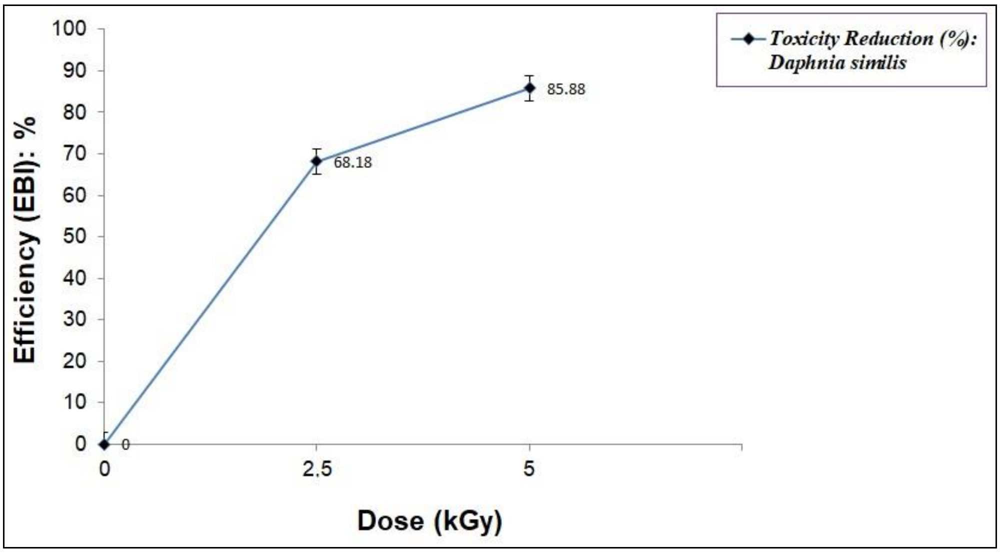

Figure 2: Efficiency (%) of Electron Beam in toxicity reduction of textile effluent to *D. similis*.

Many authors discuss about the toxicity of dyes and textile effluents, in table 1, are presented some works about this assunt, for differents organisms and similar to this study.

Table 1: Dyes and textile effluent toxicity for differents organisms.

Organisms	Toxicity: EC 50% values	Effluent characteristic	Reference
D. similis ***B. plicatilis*** ***V. fischeri***	8.73 – 14.61	With reactive dye Blue 222.	6
D. magna	10.40	With reactive dye Red 120.	7
L. aequinoctialis ***G. affinis***	0.7 – 35.3	To different steps of dyeing in textile industry complex (Sanganer, Jaipur: Indian).	8
D. magna ***L. Sativum*** ***C. sativus*** ***P. subcapitata***	2.2 – 7.2	Simulate effluents produced during cotton, wool and leather dyeing processes, prepared using mixtures of dyes, such as: Rbu222, RR195, ABk210, Abu62, DrR80.	18
V. fischeri ***D. subspicatus***	1.4 – 28.1	From textile industry complex (China).	19
D. similis	0.61-4.58	Mixture with acid, reactive and disperse dyes, such as: RY145, AO67, DY235.	21
D. similis	2.95 (±0.13)	With reactive dye Red 239.	**Present study**

Regarding the EC50 values exposed in table 1, note that the low values indicate the high toxicity of these effluent and contaminants. For the whole organisms these samples were toxic, with EC50 below 35%. The worst cases, were reported by Sharma et al. [8] with EC50% 0.7 to *L. aequinoctialis* and by Rosa et al. [21], with EC50% 0.61 to *D. Similis*.

To daphnids, similar to the EC50% values of this study, Tigini et al. [18] reported 7.2%; Borrely et al. [6] 9.81% and Darsana *et al*. [7] 10.40%. In analyzes of three colouration process, Rosa et al. [21], demonstrated values of EC50% for *D. similis* to 0.61 (effluent with acid dyes); 4.58 (effluent with reactive dyes) and 1.71 (effluent with disperse dyes). Pinheiro [22] evidenced the toxicity of Remazol Orange 3R to to *D. similis* (EC50=0.54 mg L^{-1}).

Textile discharges have also been mentioned as genotoxic agents and inductor of general alterations in *Danio rerio* and *Gambusia affinis,* including: decreased swimming activity in embryos, deposition of dyes in gills and internal organs, enzymatic changes and oxidative stress, bleaching of the eyes [8,10].

Toxicity removal results for irradiated effluents were demonstrated by Borrely *et al*. [6] for textile effluent with dye RB222: efficiency of 34.55% for *D. similis* and 47.83% for *B. plicatilis* (2.5 kGy). For *V. fischeri* the dose of 5 kGy presented better result with an efficiency of 57.29%. Already, in effluent containing reactive dye Yellow 160, efficiency of approximately 18% with 2.5 kGy was reported [23]. Pinheiro [22], showed reduction of 82.95% to acute toxicity for *V. fischeri* exposed to Reactive Orange 3R and to 71.26% for *D. similis*, at 10 kGy. In present study, the efficiency to toxicity reduction for *D. similis* was higher than 68% (2.5 kGy) and 85% (5.0 kGy) (Figure 2).

In relation to treatment of textile effluents with Electron Beam Irradiation, different studies were organized in table 2.

Borrely et al. [6] points out a reduction of more than 90% in color from the dose of 2.5 kGy for effluent containing Reactive Blue 222 and Vahdat et al. [15] obtained, for Direct Black 22, 100% of color removal with 6 kGy. Pinheiro [22] demonstrated that at the dose of 10 kGy the removal efficiency of the color was higher than 95% for the dyes Remazol Black B and Remazol Orange 3R. To solution with reactive Dye Yellow 160 was reported reduction more than 85% with 7.5 kGy [23].

In relation to COD and TOC, Abdou et al. [16], showed reduction of 45% and 42%, respectively, with 7 kGy, to dye solution with Direct Blue 4GL. To dye C.I. Direct Black 22, COD removal percentage was 32% when the absorbed dose from 9 kGy [15].

These studies demonstrated the efficiency of Electron Beam Irradiation for reducing color, toxicity, chemical oxygen demand, biochemical oxygen demand, and other parameters, in these effluents. The use of doses up until 10 kGy with good results, it is important for the use of this technology to treat real effluents. Since the low doses indicates lower cost to industry.

Table 2: Studies with irradiation for effluents and textile dyes.

Study	Radiation dose range (kGy)	Reference
Color, COD and pH of dye Direct Black 22	0.1 - 9	15
TOC, Color, COD and pH of differents textile dyes in solution, with the presence and absence of H_2O_2 (C.I. Direct Blue 4GL; Reactive yellow 3RF; C.I.Direct Green 5GLL and C.I. Reactive Blue RB19)	0.5 - 7	16
Color and toxicity of dyes Black B and Orange 3R (*D. similis*, *V. fischeri* e *B. glabrata*)	0.5- 10	22
Toxicity of textile effluent containing Reactive Blue 222 (*D. similis*, *V. fischeri* e *B. plicatilis*)	0.5 - 10	20
Color and toxicity of different textile effluents (*D. similis*, *V. fischeri* e *B. plicatilis*)	0.5 - 20	6
Toxicity and color of textile effluent containing reactive Yellow 160 (*D. similis*, *V. fischeri)*	1-5	23
Toxicity of textile effluent containing reactive Red 239 (*D. similis*)	2.5-5	**Present Study**

Legend: COD= Chemical Oxygen Demand; BOD= Biochemical Oxygen Demand; TOC= Total Organic Carbon.

4. CONCLUSIONS

EC-50 values obtained during this study include these effluents as high toxic, for the raw effluent exposed to *D. Similis*. It was demonstrated a significant reduction of the whole toxicity after EB irradiation. The evaluation of toxicity individually for groups of chemicals in the effluents, as well as for the textile effluents, can subsidize action plans to assist the maintenance and preservation of water bodies.

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