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Application of electron beam irradiation combined to conventional treatment to treat industrial effluents

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Abstract

A preliminary study to combine electron beam irradiation process with biological treatment was carried out. Experiments were conducted using samples from a governmental wastewater treatment plant (WTP) that receives about 20% of industrial wastewater, with the objective of destroying the refractory organic pollutants and to obtain a better performance of this plant. Samples from five different steps of WTP were collected and irradiated in the electron beam accelerator in a batch system with 5.0, 10.0 and 20.0 kGy doses. The main results showed a removal of 99% of all organic compound analysed in the industrial receiver unit (IRU) effluent and in the coarse bar screen (CBS) effluent with a 20 kGy dose, and for the medium bar screen (MBS) and primary sedimentation (PS) effluent a 10 kGy dose was sufficient. In the case of final effluent (FE), a dose of 5 kGy removed the remaining organic compounds and dyes present after biological treatment.

Keywords: Industrial wastewater treatment; Electron beam accelerator; Radiation processing

1. Introduction

The Institute for Energy and Nuclear Research (IPEN) started the development of an alternative technology for wastewater and industrial effluent treatment, submitting the material to high-energy electrons beam. The objective of this program is to study the removal and degradation efficiency of toxic and refractory organic pollutants and the disinfecting of pathogenic micro-organisms in wastewater and to apply it in industries and governmental wastewater treatment plants (Sampa et al., 1995; Duarte et al., 1997).

Experiments were conducted with actual samples from the governmental wastewater treatment plant (WTP) in Sao Paulo that has a processing capacity of 1.5 m^3/s, receiving domestic and industrial wastewater from five cities. About 20% of the wastewater in this plant is from the chemical, pharmaceutical, textile and dye industries, and the final effluent goes into the River Tiete. This plant has a secondary treatment using activated sludge and the treatment process has two phases: liquid and solid (sludge).

The influent of the WTP changes every day and depending on the concentration and toxicity of the organic compounds, all the micro-organisms from the biological treatment are killed, requiring a long time to recover the biological treatment and compromising the good performance of the plant. The final effluent

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Table 1
Average of the conventional parameters in different steps of WTP and deviation during the studied time

COD (mgO_2/l)	BOD (mgO_2/l)	TOC (mg/l)	Total solid (mg/l)	Total volatile solid (mg/l)	pH
IRU					
1482 ± 525	895 ± 322	330 ± 74	3599 ± 982	624 ± 237	8.3 ± 0.3
CBS					
1044 ± 547	544 ± 183	212 ± 79	1648 ± 1025	352 ± 224	7.4 ± 0.2
MBS					
635 ± 118	291 ± 52	465 ± 278	1691 ± 690	583 ± 328	7.5 ± 0.4
PS					
696 ± 396	409 ± 266	428 ± 245	1333 ± 377	450 ± 284	7.8 ± 0.5
FE					
177 ± 65	32 ± 14	185 ± 133	1263 ± 372	203 ± 109	7.8 ± 0.4

remains colored and contains some organic compounds even after the biological treatment, obstructing its reuse for industrial application.

Thus, IPEN and the Sao Paulo Sanitation Company (SABESP) have established a program of preliminary experiments with the objective of using the electron beam technology to destroy the refractory organic pollutants and dyes and so achieve a better performance of this plant.

2. Experimental

Five points of WTPs were selected for sampling: from main industrial receiver unit influent (IRU), coarse bar screens effluent (CBS), medium bar screens effluent (MBS), primary sedimentation effluent (PS) and final effluent (FE). The points IRU and CBS receive exclusively effluent from industrial origin.

The composed samples (four samplings each 2 h) from each collecting point were collected during 8 months. The samples were irradiated at the IPEN's electron beam facility with a 1.5 MeV Dynamitron from Radiation Dynamics in a batch system, using Pyrex glass vessels, and the delivered doses were 5, 10 and 20 kGy. The irradiation parameters of electron beam accelerator were 4.0 mm of sample thickness, a scan of 112 cm (94.1%) and conveyor velocity of 6.72 m/min.

The evaluation of the irradiation treatment efficiency was performed by the chemical analysis of the duplicate samples before and after irradiation. The following analyses were performed:

- Total organic carbon (TOC) using total organic carbon analyzer, model TOC 5000A from Shimadzu;
- chemical oxygen demand (COD), biochemical oxygen demand (BOD), volatile solids dried at 550°C and total solids dried at 103–105°C; these parameters were analyzed according to the standard methods for the examination of water and wastewater (American Public Health Association, 1997);
- trihalomethanes (THMs), tetrachloroethylene (PCE), trichloroethylene (TCE) by gas chromatograph, model CG-90, with electron capture detector (ECD), after pentane extraction;
- benzene, toluene, xylene, phenol and others organic compounds were analyzed by gas chromatograph associated to mass spectrometer, model GCMS-QP 5000 from Shimadzu, after pentane extraction;
- organic acids by high-performance liquid chromatograph (HPLC), model LC10 from Shimadzu;
- absorption spectrum (700–200 nm) by Spectrophotometer, model UV-1601 from Shimadzu.

3. Results and discussion

The average concentrations of conventional parameters in different steps of WTP without irradiation are presented in the Table 1. It was verified that there were no significant changes in these values after irradiation and the reason of no change in the COD and BOD values may be the non-complete oxidation of organic material with the delivered doses.

The average concentration of main organic compounds present in different steps of the WTP, before and after electron beam irradiation, and the standard deviation in the 10 samplings are in the Table 2, the variation between the collects is about 50%. Most of the pH values decreased after irradiation. This is an expected result considering that the degradation of organic compounds generates smaller molecules of organic acids. For samples from IRU and CBS steps it was necessary for a 20 kGy dose to degrade about 99% of all organic compounds, but for the MBS and PS a 99% removal was obtained with a 10 kGy dose.

For the FE step, a dose of 5 kGy was enough to remove the remaining organic compounds (Fig. 1) and

Table 2
Average concentration of the main organic compounds present in different steps of WTP and the standard deviation during the studied period, before and after electron beam irradiation

Dose (kGy)	Chlorof. (μg/l)	Bromof. (μg/l)	Dichlorobromomethane (μg/l)	Dibromoclorometh ane (μg/l)	TCE (μg/l)	PCE (μg/l)	Benzene (μg/l)	Toluene (μg/l)	Xylene (μg/l)	Phenol (μg/l)
IRU										
0	925 ± 425	154 ± 75	206 ± 125	665 ± 324	178 ± 95	402 ± 187	1750 ± 824	2689 ± 823	6444 ± 2590	2800 ± 1250
10	490 ± 225	49 ± 25	75 ± 26	193 ± 95	56 ± 25	132 ± 74	654 ± 296	1675 ± 785	3076 ± 1459	3143 ± 2503
20	199 ± 20	< 20	< 20	53 ± 25	43 ± 15	43 ± 25	< 50	568 ± 259	387 ± 65	1987 ± 657
CBS										
0	647 ± 145	176 ± 98	159 ± 65	617 ± 321	120 ± 56	24 ± 10	2012 ± 1251	7750 ± 2799	3398 ± 1654	2237 ± 1167
10	126 ± 78	38 ± 21	32 ± 18	338 ± 154	63 ± 31	< 10	631 ± 259	4635 ± 1787	2043 ± 987	2765 ± 1345
20	69 ± 25	< 20	< 20	92 ± 25	36 ± 14	< 10	131 ± 31	1262 ± 678	893 ± 323	1893 ± 987
MBS										
0	992 ± 453	132 ± 78	296 ± 134	904 ± 421	235 ± 123	80 ± 31	860 ± 245	1990 ± 765	1310 ± 567	1500 ± 678
5	152 ± 79	41 ± 21	118 ± 76	613 ± 311	111 ± 25	12 ± 5	493 ± 198	453 ± 251	152 ± 34	2210 ± 998
10	< 10	32 ± 9	59 ± 9	161 ± 98	< 20	< 10	< 50	< 50	< 50	< 200
PS										
0	3331 ± 1250	< 20	< 20	< 20	460 ± 156	100 ± 67	767 ± 321	556 ± 125	890 ± 342	990 ± 432
5	470 ± 251				40 ± 25	< 10	< 50	254 ± 112	132 ± 67	1256 ± 521
10	156 ± 32				< 20			< 50	< 50	< 200
FE										
0	815 ± 123	< 20	< 20	< 20	76 ± 21	80 ± 34	325 ± 99	< 50	< 50	< 200
5	< 10				< 20	< 10	< 50			< 200
10	< 10									< 200

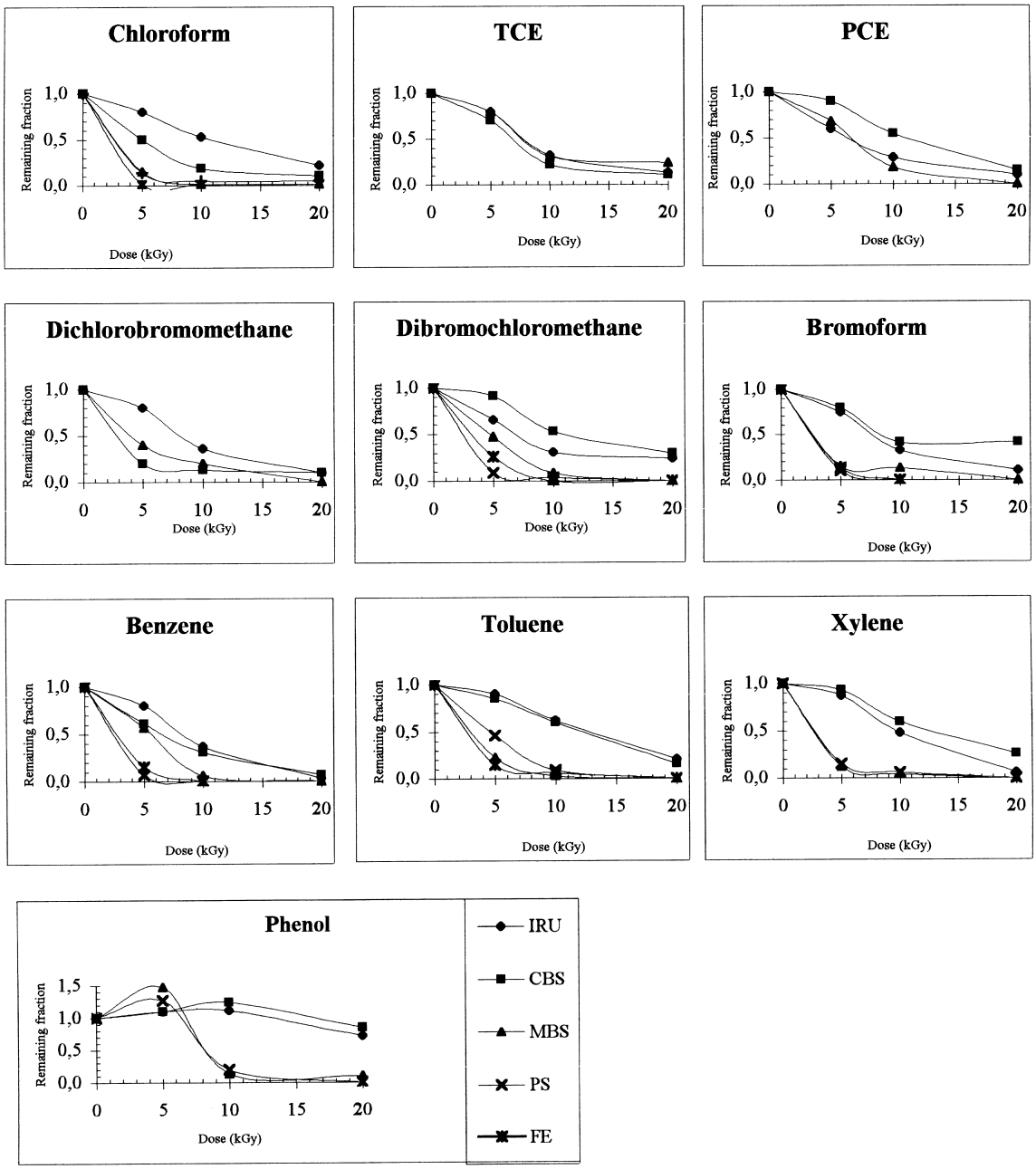

Fig. 1. Remaining fraction of organic compound after electron beam irradiation for the different steps of wastewater treatment plant. 1 = non irradiated; 2 = 5 kGy; 3 = 10 kGy; 4 = 20 kGy.

dyes (Fig. 2) present after biological treatment. In this last case it is important to point out the clarification of the sample after irradiation, because even after biological treatment the final effluent remains colored. The clarification of all steps of WTP after irradiation can be seen by the absorbance spectra (300–700 nm) shown in the Fig. 2.

The results of the mass spectrometry analysis showed that no different by-products were formed after irradiation, but a significant increase of organic

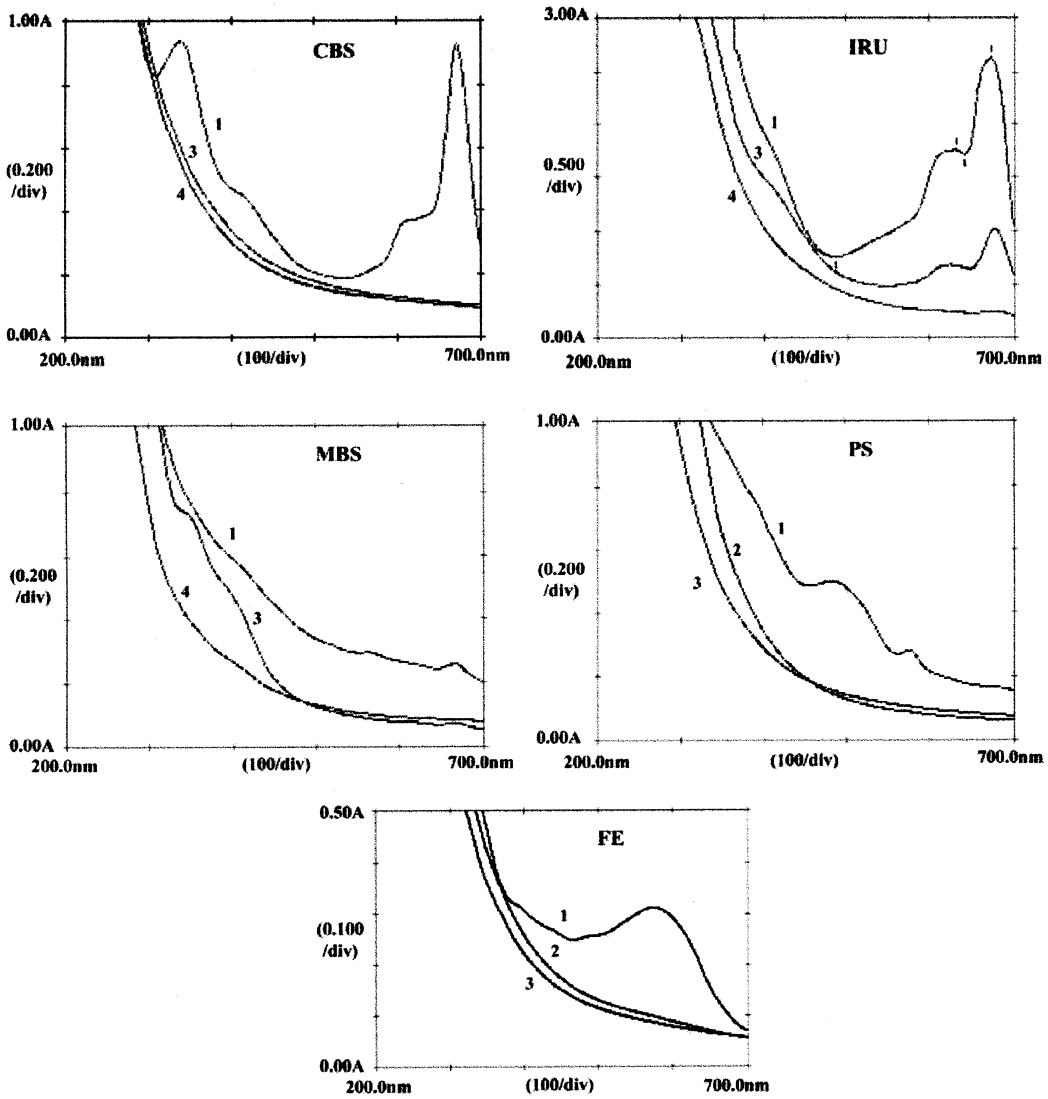

Fig. 2. Absorbance spectra (700–300 nm) after electron beam irradiation for the different steps of wastewater treatment plant.

acids at mg/L concentration, mainly oxalic, tartaric, ascorbic and formic acids, from IRU and CBS steps of WTP, was detected by liquid chromatography.

4. Conclusion

The electron beam irradiation has shown to be efficient at destroying aromatics organic compounds, trihalomethanes, PCE, TCE and others present in industrial effluent. Although the changes in the COD and BOD were not significant, the degradation of organic compounds became less toxic. The toxicity tests performed with these samples before and after irradiation confirmed this point (Borrely and Sampa, 1999).

In this WTP, there are two preliminary suggestions for the use of electron beam irradiation: using a 20 kGy dose in the reception of industrial effluent (IRU), with the objective of removal of the main organic compounds, dyes and reduce the toxicity and so obtain a better performance of the plant; and in the FE step, using a 5 kGy dose, making possible the reuse of treated wastewater for industrial applications.

The second stage of this study will be the application of irradiated samples from IRU directly to a pilot plant of biological treatment to confirm the expected better performance of biological treatment.

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