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Treatment of industrial effluents using electron beam accelerator and adsorption with activated carbon: a comparative study

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Abstract

This paper presents preliminary results of a study that compares the use of electron beam processing and activated carbon adsorption to clean up a standardized organic aqueous solution and a real industrial effluent. The electron beam treatment was performed in a batch system using the IPEN's Electron Beam Accelerators from Radiation Dynamics Inc., Dynamitron 37.5 kW. The granular activated carbon removal treatment was performed using charcoal made from wood "pinus". If the adequate irradiation dose is delivered to the organic pollutant, it is possible to conclude for the studied compounds that the Electron Beam Process is similar to the activated carbon process in organic removal efficiency.

Keywords: Electron beam accelerator; Activated charcoal; Organic compound degradation; Industrial effluents and advanced oxidation process

1. Introduction

The industrial growth and population increase have resulted in the release of different pollutant compounds in the environment. Industrial wastewater without an efficient treatment is becoming a serious problem in industrialized areas, hazardous regulations are becoming more restrictive and technologies, which do not destroy these products, are becoming less acceptable.

Among the conventional techniques used to reduce the volume and toxicity of the effluents, the granular activated carbon is widely used to treat mixtures of organic compounds in industrial effluents, however, this technique just transfers the contaminant from liquid to solid phase and the contaminated phase needs to be reactivated or has to be replaced and properly stored with a high cost.

The use of industrial electron beam accelerators is an emerging technology in Advanced Oxidation Process for industrial effluents treatment (Duarte, 2002; Rela et al., 2000; Sampa et al., 1995).

Several objectives were established for this study, in order to predict how the electron beam treatment of industrial effluents, can be considered an available and competitive technology as actually the granular activated carbon has demonstrated its effectiveness in removing organic contaminants in water treatment plants.

The preliminary results of this study are presented where seven organic compounds were chosen as surrogate standards to represent a wide variety of organic pollutants which may be present in water and in a sample of a real effluent from a petrochemical plant.

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2. Experimental procedures

The seven compounds used in standard aqueous solution were selected as surrogates, representing a wide variety of compounds commonly found in water. The surrogate standard solutions were prepared by dissolving high purity chemical reagents in distilled and deionized water and real samples from petroleum industrial effluent were characterized with more than 156 organic compounds and among them, 3 with higher concentration, were selected to study the removal in both processes.

The concentration of organic compounds was measured before and after irradiation and after activated charcoal treatment using a Gas Chromatograph connected to a Mass Spectrometer, Shimadzu, model GCMS QP-5000, with a capillary DB5 column and with concentrator system type head space, helium gas and a volume of 20 ml.

Electron beam treatment was performed at room temperature (around 25°C) at IPEN's Electron Beam Accelerators from Radiation Dynamics Inc., Dynamitron 37.5 kW (1.5 MeV and 25 mA) in a batch system using Pyrex glass vessels.

The granular activated carbon, made from wood "pinus" granular type from FBC—Fábrica Brasileira de Catalizadores LTDA, was used and had the following characteristics: iodine number of 800 mg/g of dried base, apparent density of 0.30 g/cm^3, moisture as packed 5% ash content 6% and passing 325 mesh 60%.

The granular activated carbon process was performed in fixed-bed absorber glass column (3.8 cm internal diameter and 17.5 cm length) and the utilized EBCT (empty bed contact time) was 3 min.

Table 1
Organic compounds removal by irradiation and by granular activated carbon (GAC)

Compound (%)	Dose (kGy)					GAC
	5	10	20	30	50	
Benzene	93	97	99	99	>99	>99
Toluene	89	99	>99	>99	>99	>99
1,2 Dichlorethene	89	94	96	99	>99	>99
Chloroform	96	97	98	99	>99	>99
Bromoform	99	>99	>99	>99	>99	>99
Trichlorethylene	99	99	>99	>99	>99	>99
Methyl isobutyl ketone	76	94	97	>99	>99	>99

3. Results and discussion

3.1. Surrogate standard solution

Table 1 shows the results of efficiency in organic removal using the electron beam technology where the samples were irradiated in different doses and the results of the activated carbon process using a fixed bed column (Fig. 1).

3.2. Real effluent

Table 2 shows the results of organic removal and the selected compounds presented in the real effluent sample using both the mentioned processes (Fig. 2).

3.3. Costs

The irradiation experiments performed allow selecting the dose of 20 kGy as reasonable results for the surrogate standard solution and the dose of 50 kGy for the real effluent.

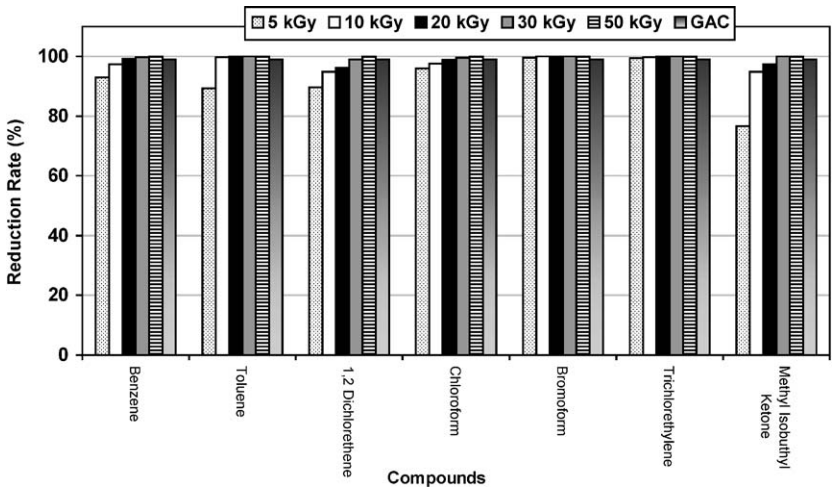

Fig. 1. Organic compounds removal by irradiation and by granular activated carbon (GAC).

Table 2
Degradation of organic compounds from petrochemical effluent using electron beam process and granular activated carbon (GAC)

Compound (ppm)	Dose (kGy)						GAC
	0	50	60	70	80	100	
Benzene	11.00	0.04	0.04	0.04	0.03	0.03	0.03
Toluene	3.20	0.11	0.11	0.13	0.15	0.08	0.11
Xylene	10.30	0.15	0.15	0.18	0.18	0.11	0.15

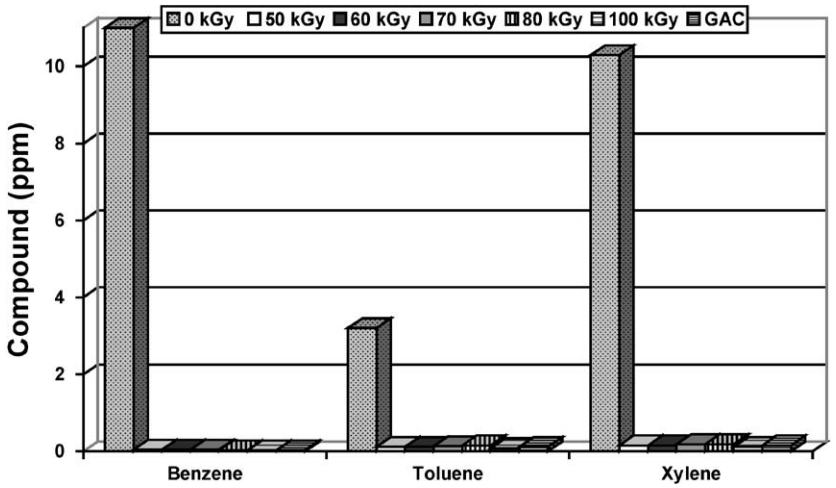

Fig. 2. Degradation of organic compounds from petrochemical effluent using electron beam process and granular activated carbon (GAC).

According to the previous studies (Rela, 2003) on determining the efficiency of irradiation process and the dose values selected above is estimated the following cost for Electron Beam Treatment:

- Surrogate standard solution: US$10.8/m^3 (dose 20 kGy)
- Real effluent: US$27.0/m^3 (dose 50 kGy)

It is important to point out that the dose for the real effluents was not optimized and according to the results, lower doses, below 50 kGy, would be reasonable for the organic compounds reduction.

The paper from Adams and Clark (1989) for granular activated carbon shows in a conservative way for a small plant (1 mgd) the costs ranging from US$0.26/m^3 to US$0.07/m^3.

4. Conclusion

If adequate irradiation dose was delivered to the organic pollutant, it is possible to conclude for the studied compounds that the electron beam process shows organic removal efficiency similar to that of activated carbon process.

Concerning costs, more studies should be performed, the preliminary results show that the granular activated carbon process (GAC), due to its simplicity, is more advantageous than the electron beam process but it should take in to account that the contaminants were transferred to the granular activated carbon, with the regulations becoming more restrictive, it is necessary to consider the high temperature incineration of the spent carbon to ensure a proper ultimate disposal, increasing the cost of the GAC processes.

The electron beam is still an emerging technology and the optimization of the irradiation devices and electron beam machine along the time will certainly reduce the unit processing costs.

Acknowledgements

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