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Development of an up-flow irradiation device for electron beam wastewater treatment

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Abstract

Electron beam irradiation processing is an available technology to treat sludge, groundwater, surface water and industrial and municipal wastewater. The use of this technology into environmental areas has moved slowly because industry and government are always conservative in the adoption of new processes, especially when they can not observe the efficiency and cost effectiveness of a treatment in a full scale facility.

In this direction the hydraulic system where the water is presented to the electron beam governs the efficacy of this technology. The present work is based on the development of the irradiation device, an up-flow delivery system that alleviates the dependence of energy transfer to the stream with the beam accelerating voltage (penetration capability).

In this work a series of experiments were performed to establish the relationships between accelerating voltage ranging from 0.5 to 1.5 MeV, current, water flow and deposited dose in order to optimize the operating parameters and the selection of a cost-effective commercial electron beam.

Keywords: Electron beam wastewater treatment; Organic compound degradation; Electron beam accelerator; Radiation processing industrial wastewater

1. Introduction

Electron beam irradiation processing is an available technology to treat sludge, groundwater, surface water and industrial and municipal wastewater (Waite, 1996). The use of this technology in the environmental area has moved slowly because industry and government are always conservative in the adoption of new processes, especially when they can not observe the efficiency and cost effectiveness of a treatment in a full scale facility.

The present work has been developed in the IPEN-CNEN/SP wastewater treatment pilot plant (Sampa et al., 1995) that is used to study the removal and degrading efficiency of toxic and refractory pollutants, mainly from industrial origins (organic compounds) and also to be used as scale-up for the design of commercial plants. The main goal of this plant is to optimize the irradiation system to get a high efficiency with low electron beam (EB) energy in order to reduce the costs of the facility including the EB machine and irradiation vault.

2. Objective

The hydraulic system where the water is presented

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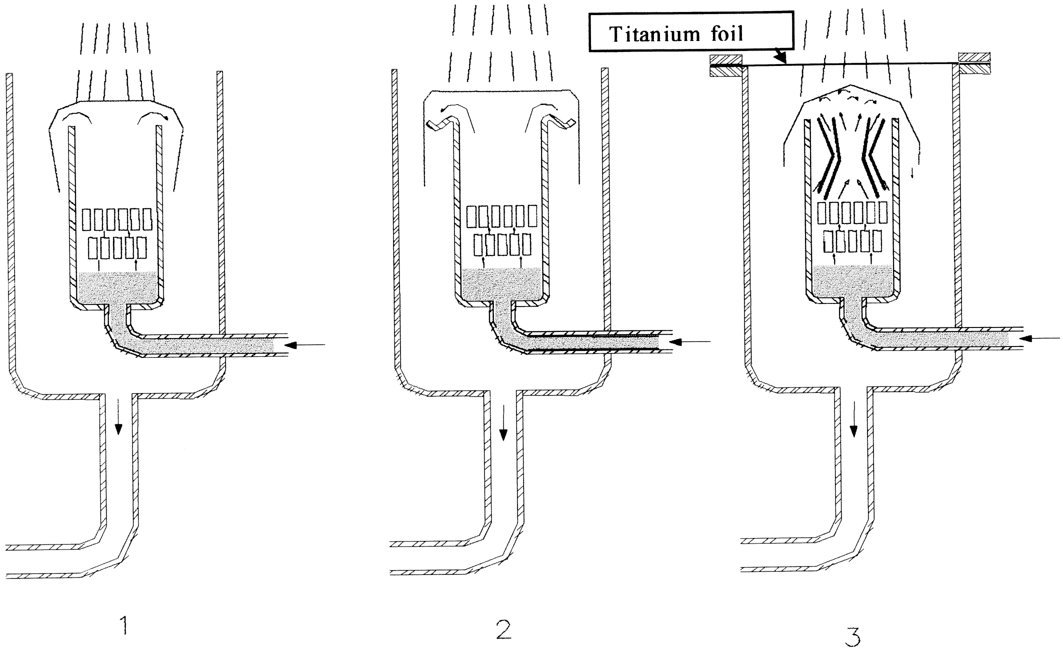

Fig. 1. Models of up-flow stream irradiation devices.

to the electron beam governs the efficiency of this technology. The present work is based on the **development of an up-flow irradiation device**, that by its configuration, theoretically alleviates the dependence of energy transfer to the stream with the beam accelerating voltage (penetration capability).

3. Irradiation devices

Using an Electron Beam Accelerator (1.5 MeV, 37.5 kW) a sequence of experiments were performed in a wastewater treatment pilot plant to establish the relationships between accelerating voltage ranging from

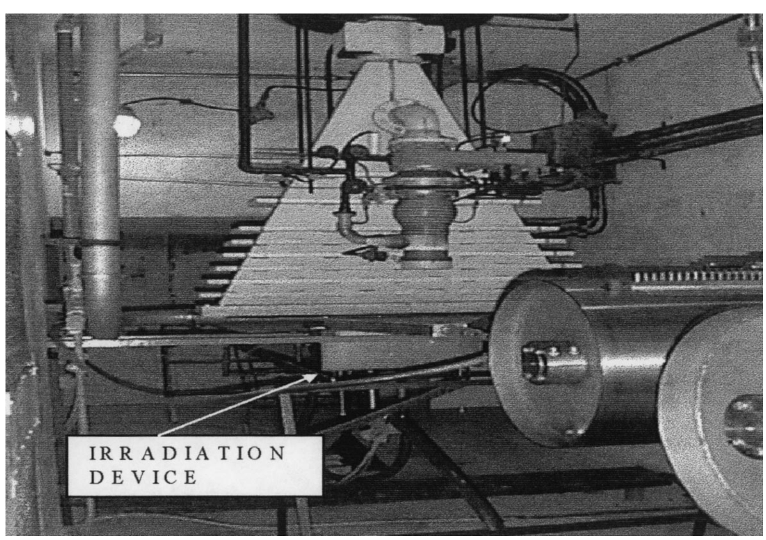

Fig. 2. External view of the irradiation device.

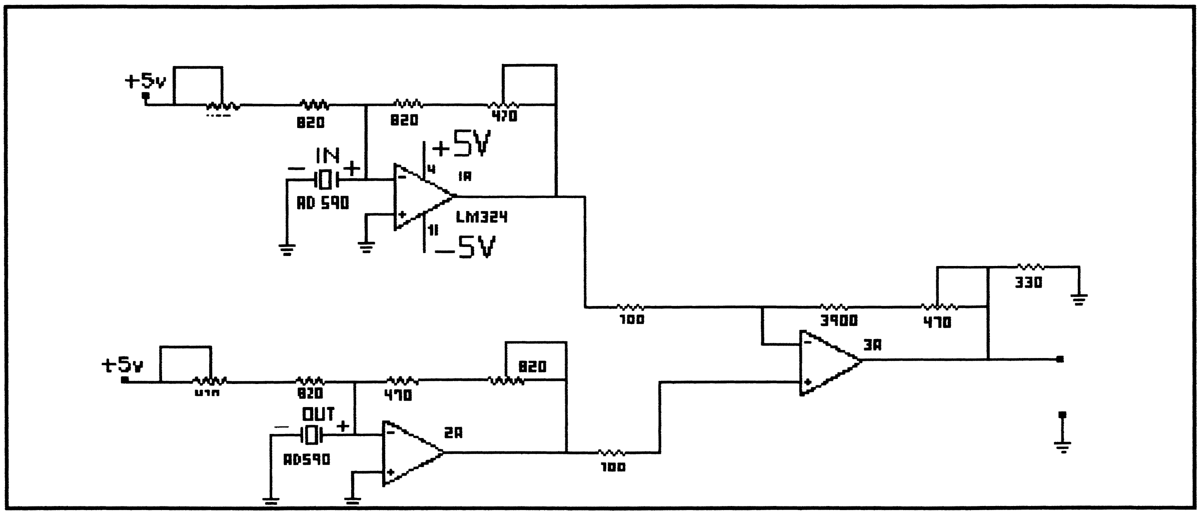

Fig. 3. Dosimetric system electric circuit diagram.

0.5 to 1.5 MeV; electron beam current intensity, stream flow and delivered dose, in order to optimize the operating parameters for the selection of the electron beam machine.

Three models of the up-flow stream irradiation device were tested; the models are represented in Fig. 1. The sequence of the development started with model 1 which was up graded to models 2 and 3. Model 3, fitted with a 40 μm titanium foil window, allows the irradiation device to work as a closed system, where in this configuration hazardous liquids can be processed in a safe condition, avoiding the spread of gaseous by-products to the environment. Fig. 2 shows the placement of the irradiation device under the EB machine.

4. Dosimetric system

For a better control of parameters involved during the liquid waste radiation processing, it was developed on an on-line calorimetric system (Costa and Rela, 1997), where the absorbed dose is obtained by measuring the temperature difference of the water stream before and after the irradiation device.

The dosimetric system is based on two Wire Current Output Temperature Transducer, WCOTT, from Intersil (Intersil–General Electric Co., 1987), located in the influent and in the effluent pipes respectively, separated by 35 cm before and after the irradiation device. The temperature transducers are connected via an interface to a PC that continuously reads and records the temperatures and transforms the values to the equivalent dose delivered to the stream. Fig. 3 shows the electric circuit diagram.

To evaluate the consistency of the dose registered by the calorimetric system, experiments were performed using an aqueous chemical dosimeter, where the colour degradation of a commercial textile dye named "Duacouro" similar to Acid Red 265 was measured by the UV-Visible spectrophotometer at 500 nm (Duarte et al., 1999).

5. Results

For each irradiation device a series of tests were carried out in different operating conditions with the pur-

Table 1
Efficiency of the prototypes

	Model 1	Model 2	Model 3	
			Open system	Self-contained system
EB energy (MeV)	1.5	1.5	1.5	1.5
Flow (L/min)	45	45	54	54
Efficiency (%)	33	72	76	67

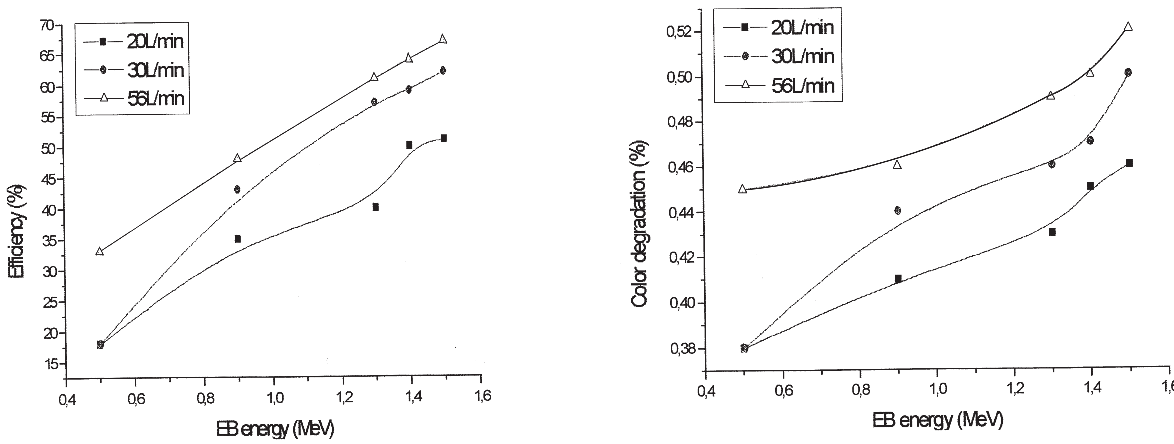

Fig. 4. Efficiency of the irradiation device and the colour dye degradation as a function of electron beam energy.

pose to determine the maximum efficiency of the system. The efficiency was determined by the relation between the absorbed dose of the stream registered in the calorimeter and the delivered dose from electron beam accelerator (without losses). Using the experience of 200 h of the IPEN's pilot plant the best results of the efficiency for the developed irradiation prototypes are shown in Table 1.

Besides offering the best efficiency, model 3 becomes a versatile device where different kinds of effluents can be processed, especially hazardous wastes. The tests were performed in two configurations: without the titanium foil window becoming the hydraulic circuit opened to the environment and fitted with the foil becoming a self-contained system.

All the efficiency tests were done simultaneously with dye degradation tests. Fig. 4 shows the efficiency of the irradiation device and the colour dye degradation as a function of electron beam energy under the same radiation processing conditions for the self-contained configuration.

Based on the results of model 3 (self-contained system) a preliminary evaluation cost was performed. Considering the use of an EB machine (1.5 MeV, 60 kW) to process 70 m^3/h and delivering 2 kGy to the stream the unitary cost was estimated to be about US$ 1.2/m^3.

6. Discussion

Based on these results the dose measured with the calorimetric system follows the same tendency as the colour dye degradation, consistent with the evaluation of energy transfer from the electron beam to the stream.

Concerning the selection of the appropriate electron beam to be used in a large-scale facility, these results can be used for an economical feasibility study of the process.

In a preliminary study considering a delivered dose of 2 kGy to process a flow rate of 70 m^3/h and using an industrial 1.5 MeV Electron Beam at 60 kW the estimated process cost is US$ 1.2/m^3.

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