

## APPLICATION OF HIGH POWER ELECTRON ACCELERATOR IN WASTEWATER TREATMENT \*

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### Abstract

A pilot plant for treating 1,000m<sup>3</sup>/day of dyeing wastewater with e-beam has been constructed and operated since 1998 in Daegu, Korea together with the biological treatment facility. The wastewater from various stages of the existing purification process has been treated with electron beam in this plant, and it gave rise to elaborate the optimal technology of the electron beam treatment of wastewater with increased reliability at instant changes in the composition of wastewater. Installation of the e-beam pilot plant resulted in decolorizing and destructive oxidation of organic impurities in wastewater, appreciable to reduction of chemical reagent consumption, in reduction of the treatment time, and in increase in flow rate limit of existing facilities by 30-40%. Industrial plant for treating 10,000m<sup>3</sup>/day each, based upon the pilot experimental result, has constructed and operated from 2005.

### INTRODUCTION

Electron beam treatment of wastewater leads to their purification from various pollutants. It is caused by the decomposition of pollutants as a result of their reactions with highly reactive species formed from water radiolysis: hydrated electron, OH free radical and H atom [1]. Sometimes such reactions are accompanied by the other processes, and the synergistic effect upon the use of combined methods such as electron beam with biological treatment, adsorption and others improves the effect of electron beam treatment of the wastewater purification.

In the process of electron-beam treatment of wastewater there are utilized chemical transformations of pollutants induced by ionizing radiation. At sufficiently high absorbed doses these transformations can result in complete decomposition (removal) of the substance. Under real conditions, i.e., at rather high content of pollutants in a wastewater and economically acceptable doses, partial decomposition of pollutant takes place as well as transformations of pollutant molecules that result in improving subsequent purification stages, efficiency of the process being notably influenced by irradiation conditions and wastewater composition [2].

### Wastewaters from Textile Dyeing Companies

The complex wastewater from textile dyeing companies in Daegu Dyeing Industrial Complex (DDIC) were

investigated in this study. DDIC includes about hundred factories occupying the area of 600,000m<sup>2</sup>. Purification of the wastewater is performed by union wastewater treatment facilities (chemical treatment and 2 steps of biological treatment). Current facility treats up to 80,000m<sup>3</sup> of wastewater per day, extracting thereby up to 500m<sup>3</sup> of sludge. Rather high cost of purification results from high contamination of water with various dyes and ultra-dispersed solids.

Overall characteristics of influent wastewater, 5 day's biological oxygen demand (BOD<sub>5</sub>), chemical oxygen demand measured by permanganate method (COD<sub>Mn</sub>), suspended solid (S/S) are presented in Table 1.

Table 1 : Typical characteristics of DDIC wastewater

| Parameter                 | pH      | BOD <sub>5</sub><br>(mg/l) | COD <sub>Mn</sub><br>(mg/l) | S/S<br>(mg/l) | Color<br>units |
|---------------------------|---------|----------------------------|-----------------------------|---------------|----------------|
| Raw                       | 12      | 2,000                      | 900                         | 100           | 1,000          |
| Chemical                  | 6.8~7.5 | 1,700                      | 450                         | 50            | 500            |
| After 1 <sup>st</sup> Bio | 7.0~8.0 | 1,300                      | 250                         | 50            | 400            |
| After 2 <sup>nd</sup> Bio | 7.0~8.0 | 50                         | 80                          | 50            | 250            |

### MATERIALS AND METHODS

#### Laboratory-scale Feasibility Study

In the experiments, electron accelerator of 1 MeV, 40kW with the dose rate of 40kGy/s is used. To carry out the experiments, the laboratory unit was constructed for irradiation under flow conditions. The initial water is placed in storage vessel, which serves as saturator-equalizer. Wastewater from the vessel was moved with controlled consumption by pump to multi-jet nozzle. Diameter of each jet was equal to 4 min; it is equal to the range of 1 MeV electrons in water. The rate of wastewater moving at the exit of the nozzle was controlled within the range of 2-4 m/s (it corresponded to the rate of wastewater in the industrial plant under design). The wastewater injected directed in parallel each other in horizontal plane; their flight length was equal to ~1.5 m (at the initial rate 3m/s).

The results of laboratory investigations showed the electron beam treatment of wastewater to be perspective for its purification (Figure 1). The most significant improvements result in decolorizing and destructive oxidation of organic impurities in wastewater. Installation of the radiation treatment on the stage of chemical treatment or immediately before biological treatment may results in appreciable reduction of chemical reagent consumption, in reduction of the

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treatment time, and in increase in flow rate limit of existing facilities by 30-40%.

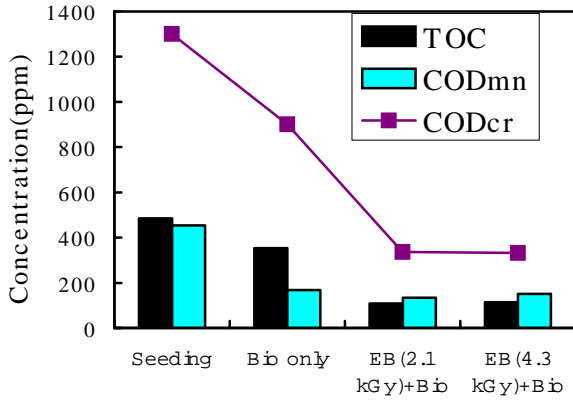


Figure 1 : Combined effect of e-beam and bio-treatment

### Construction of Pilot Plan

Being convinced with the feasibility of laboratory scale tests, a pilot plant for a large-scale test (flow rate of 1,000m<sup>3</sup> per day) of wastewater has constructed in October 1998 and operated with the electron accelerator of 1MeV, 40kW (Figure 2). The size of extraction window is 1500mm in width and Titanium foil is used for window material. For the uniform irradiation of water, nozzle type injector with the width of 1500mm was introduced. The wastewater is injected under the e-beam irradiation area through the injector to obtain the adequate penetration depth. The speed of injection could be varied upon the dose and dose rate. Once the wastewater has passed under the irradiation area, then directly into the biological treatment system.

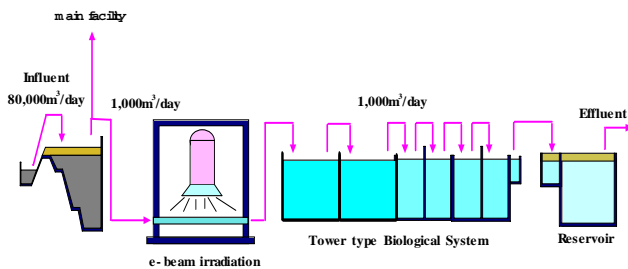


Figure 2: Schematic diagram of Pilot Plant with e-beam

## RESULTS AND DISCUSSION

### Result of pilot plant operation

Pilot plant inlet flow is a mixture of two flows: raw wastewater from dyeing process and wastewater from polyester fibre production enriched with Terephthalic acid (TPA) and Ethylene glycol (EG); relative flow rate of the latter being 6-8% of total inlet flow rate. It follows that the main (if not the only) result of electron-beam treatment of pilot plant influent would be radiolytical transformations of TPA which can improve its removal by biological treatment. Radiolytical transformations of

other initially present compounds, if those take place at all, can proceed via radical or molecular products from TPA.

As concerns changes in TOC, COD<sub>Cr</sub>, and BOD<sub>5</sub> during biological treatment, from the data presented in Figure 3 it follows that preliminary electron-beam treatment make it possible to reduce bio-treatment time twice at the same degree of removal. Coincident results were obtained in a separate set of experiments on the same pilot plant but with reduced wastewater flow rate (~130 l/day). In this case inlet flow was divided into two flows: the first one passed only biological treatment while the second one passed electron-beam treatment, then biological treatment with reduced hydraulic retention time (HRT). Averaged for one month's period decrease in TOC values amounted 72%, for the first flow (48h HRT bio-treatment), and 78%, for the second flow (1 kGy electron-beam treatment followed by 24 h HRT bio-treatment).

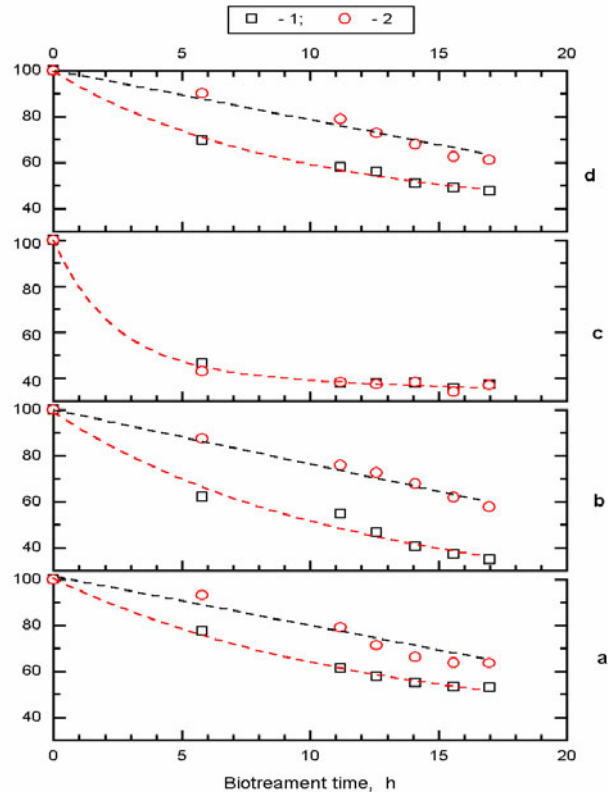


Figure 3: Effect of irradiation and biological treatment: a-TOC; b-COD<sub>Cr</sub>; c-COD<sub>Mn</sub>; and d-BOD. 1- after EB treatment; 2- without EB treatment

Irradiation at comparatively low doses (several Greys) for this case does not change total amount of biodegradable substance characterized by BOD<sub>5</sub>, but convert part of it into easier digestible form. This is confirmed, also, by the data presented in Figure 4 where one can see that decrease in TOC, COD<sub>Cr</sub>, and BOD<sub>5</sub> during biological treatment is close to linear one for non-irradiated wastewater, while for electron beam treated

wastewater the decrease is faster at the beginning of bio-treatment and decelerates during the process [3].

### Construction of Industrial Plant

On the evaluation of economies and efficiency of pilot scale electron beam treatment facility, industrial scale plant for treating textile dyeing wastewater has constructed from 2003 to 2005 for

- decreasing the amount of chemical reagent up to 50%
- improving the removal efficiency of harmful organic impurities by 30%
- decreasing the retention time in Bio-treatment facility

According to the data obtained in laboratory and pilot plant experiments with DDIC wastewater, the optimum absorbed dose for electron-beam treatment was chosen to be near 1 kGy. For those purpose 400 kW electron accelerators with three separate irradiators was installed as a source of ionizing radiation. The plant is located on the area of existing wastewater treatment facility in DDIC and to have treatment capacity 10,000 cubic meters of wastewater a day using one 1MeV, 400kW accelerator, and combined with existing bio- treatment facility.

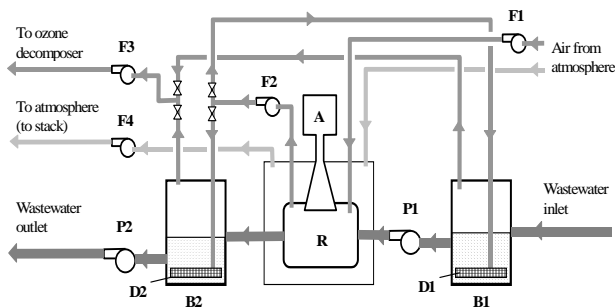


Figure 4 : Simplified technological scheme of the plant. F1-F4 – fans, P1-P2 – pumps, D1/D2 – Diffusers, A – Accelerator, R – Reactor, B1/B2 – 1st & 2ndary basins.

Total technological scheme of the installation on of electron-beam treatment is presented in Figure 5. It includes three principal technological chains: wastewater flow, cooling/ozonizing air flow, and ventilating air flow. Coordinated functioning of those chains is assured by monitoring and control systems.

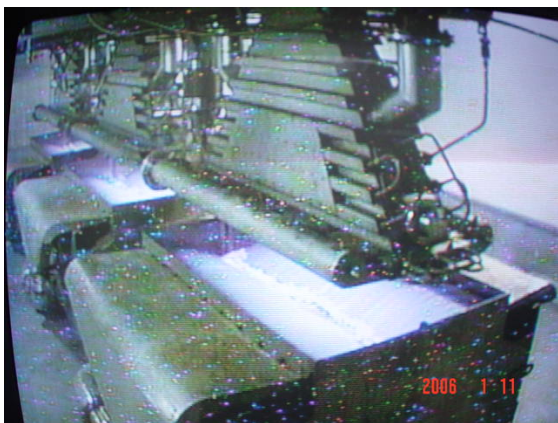


Figure 5 : Wastewater treated with e-beam

## CONCLUSIONS

A pilot plant for treating 1,000m<sup>3</sup> of textile dyeing wastewater per day with electron beam has constructed and operated continuously since October 1998. This plant is combined with biological treatment system and it shows the reduction of chemical reagent consumption, and also the reduction in retention time with the increase in removal efficiencies of COD<sub>Cr</sub> and BOD<sub>5</sub> up to 30~40%. Increase in biodegradability after radiation treatment of aqueous-organic systems is due to radiolytical conversions of non-biodegradable compounds. In present experiments the improvement of biological treatment of wastewater after preliminary electron-beam treatment was found to be caused by radiolytical transformations of biodegradable compound.

On the basis of data obtained from pilot plant operation, construction of actual industrial scale plant has started in 2003, and finished December 2005. This plant is located on the area of existing wastewater treatment facility in DDIC and to have treatment capacity 10,000m<sup>3</sup> of wastewater per day using one 1MeV, 400kW accelerator, and combined with existing bio- treatment facility.

## ACKNOWLEDGEMENT

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