TREATMENT OF WASTEWATER FOR REUSE WITH MOBILE ELECTRON BEAM PLANT

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Abstract

The use of alternative disinfectants to chlorine for the wastewater treatment has received increasing attention in recent years to treat either liquid or solids streams within wastewater treatment plants for pathogens and trace organics (TOrCs). Although several technologies have come to the forefront as an alternative to chlorine (e.g., ultraviolet [UV] and hydrogen peroxide), the majority of these technologies are chemically based, with the exception of UV. An attractive physical disinfection approach is by electron beam (EB) irradiation. EB 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 [Pikaev (1986)]. Sometimes methods such as EB with biological treatment, adsorption and others improve the effect of EB treatment of the wastewater purification. In the process of EB 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 [Woods and Pikaev (1994)].

1. Introduction

One of the important environmental problems is the reuse of wastewater to industrial and agricultural applications. on-site pilot scale treatment of wastewater from municipal plant will be applied to optimize the operation parameters by a skid mounted Mobile Electron Beam Plant (MEB) mounted in a 40’ box metal cargo shipping container.To compare EB technology with other advanced oxidation processes (AOP) such as UV and Ozone technology, in regard to costs and effects for different application cases and local situations.The objectives of this study are optimization of the EB process for minimizing energy loss and absorbed dose upon the water thickness optimization of pre-treatment and post-treatment design parameters and development of design criteria to construct commercial scale re-use plant. Also the evaluation of alternatives to address unforeseen problems resulting from the actual use of proposed treatment processes and characterization and quantification of the raw water and finished water will be conducted.

2. Objective of the research

The treatment of industrial wastewater with EB is one of the actively studied subjects for the environmental application in Korea. The use of alternative disinfectants to chlorine for the liquid stream has garnered increasing attention in recent years. Besides the production of disinfection by-products (DBPs), chlorine poses safety hazards for operational staff and shipping hazards. In addition to health and public welfare risks, chlorine has a minimal attenuation on TOrCs. Although several technologies have come to the forefront as an alternative to chlorine (e.g., ultraviolet [UV] and hydrogen peroxide), the majority of these technologies are chemically based, with the exception of UV. An attractive physical disinfection approach is by EB irradiation.

One of the important environmental problems is the reuse of wastewater to industrial and agricultural applications. The objective of this research evaluates the efficiency of electron-beam disinfection to treat either liquid or solids streams within wastewater treatment plants for pathogens and trace organics (TOrCs). TOrCs refer to endocrine disrupting compounds (EDCs), pharmaceuticals and personal care products (PPCPs), and other trace constituents. The rationale behind targeting both streams relates to the notion that EB lends itself toward either medium. In this proposal, on-site pilot scale treatment of wastewater from municipal plant will be applied to optimize the operation parameters by a skid mounted Mobile Electron Beam Plant (MEB) mounted in a 40’ box metal cargo shipping container.

3. Previous works

When wastewater is irradiated with high energy electron, the energy absorbed is deposited in water molecules, and the ionization and excitation of water molecules result in formation of free radical and molecular species. The use of such free radicals as disinfectant for effluents from municipal wastewater treatment plants could be state-of-the-art and eco-friendly disinfection processes. EB has the following advantages over chemically based and UV approaches: operates at ambient temperatures and pressure; requires no additional chemicals that could further pollute downstream; has the capacity to mineralize persistent compounds; and its performance is not affected by solids since the EB easily penetrate particles/solids.

The treatment of industrial wastewater with EB is one of the actively studied subjects for the environmental application in EB TECH Co., Ltd (EB TECH). The wastewaters investigated are from textile dyeing companies, petrochemical processes, papermill, leachates from sanitary landfill areas, explosive productions and so on. Those are summarized in Table 1.

TABLE 1 WASTEWATER INVESTIGATED AT EB TECH CO., LTD

Wastewater(from)	Purpose of investigation	Results
Textile dyeing companies[a]	Removal of color and organic impurities	Industrial plant constructed Improved removal efficiency
Papermill[b]	Decrease in COD, color Increase in re-use rate	Reduction in COD, color Commercial plant designed
Leachate from landfill[c]	Removal of organic pollutants	Bio-treatment efficiency improved
Heavy metals[d]	Decrease in the contents in water	Removal of Cd(II), Pb(II), Hg(II), Cr(VI)
Power plant clean-up[e]	Decrease in the contents of organic acid in water	Decrease in the contents of organic pollutants
Explosive production[f]	Decrease in COD, T-N Re-use for production	

a Han et al. (2002, 2005)
b Shin et al. (2002)
c Pikaev et al. (1997a)
d Kartasheva et al. (1997, 1998), Pikaev et al. (1997b), Ponomarev et al. (1997), Yurik and Pikaev (1997)
e Kim et al. (1999)
f unpublished results

4. Materials and Methods

To confirm the use of EB as an alternative disinfectant to chlorine for the liquid stream, a bench scale experiments were conducted in EB TECH with samples from the Municipal Wastewater Treantment Plant in Daejeon City which has the capacity of 900,000m^3/day equipped with the conventional physical and biological treatment system. This plant has been in operation, but to face the control of TOrCs. Typical operation data of influent and effluent of this plant is in Table 2.

TABLE 2 WASTEWATER IN MUNICIPAL WASTEWATER TREATMENT IN DAEJEON CITY

	BOD (mg/l)	COD (mg/l)	SS (mg/l)	T-N (mg/l)	T-P (mg/l)	E-coli [(a)] (#/ml)
Influent (avg.)	15.1	127.4	201.8	34.2	4.5	N/A
Regulation	<20	<40	<20	<60	<8	<3,000
Designed	<14	<14	<15	<25	<1.5	<1.5
Actual	8.9	11.2	7.2	16.2	4.3	28,000

(a) effective from 2003 in Korea

In this experiments, electron accelerator of 1 MeV, 40kW with the dose rate of 40kGy/s is used with the laboratory unit, schematically shown in FIG. 1, was constructed for irradiation under continuous flow conditions. The initial samples are placed in storage vessel, which serves as an equalizing basin. Wastewater from the vessel is delivered to injection nozzle by pump. Thickness of injected was equal to 4 mm; 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. The wastewater injected along horizontal part of their flight was treated by EB, then irradiated wastewater was collected into the special container. The experiments were conducted with the doses up to 1kGy at atmospheric temperature (20~25℃).

The number of microorganisms decreases 10^2 times with 0.2 ~ 0.5 kGy and 10^4 times with 1kGy without any changes in other water quality indices. From the obtained results, it is clear that 0.2 ~ 0.5 kGy is enough to control the number of E-coli below 1,000CFU/ml. It is observed at low doses (below 0.2kGy), most of the microorganisms have decreased, but there still exist a large amount of microorganisms, however the numbers are not increased after the irradiation since they were inactivated.

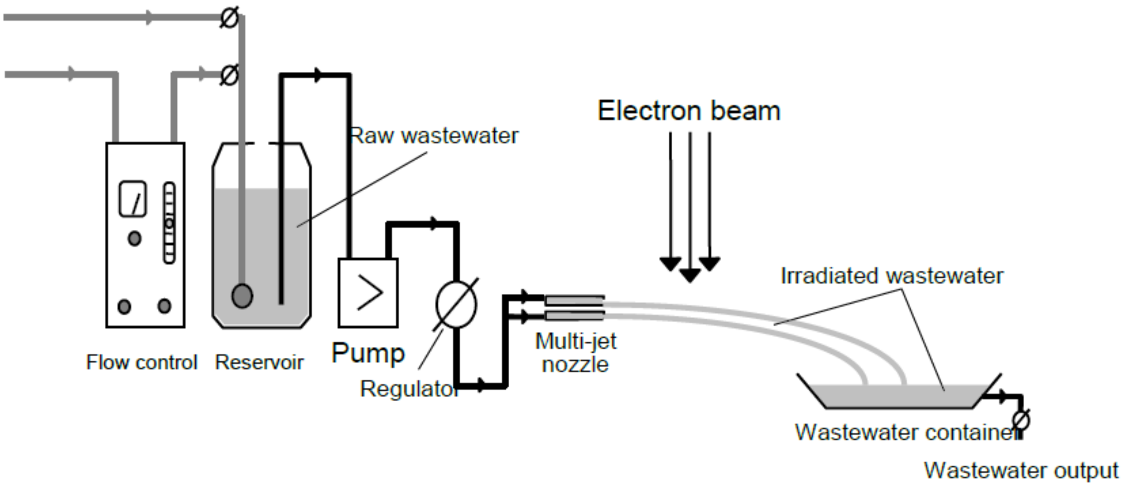

Fig. 1. Laboratory electron beam unit; 50m3/day up to 2kGy at continuous operation mode.

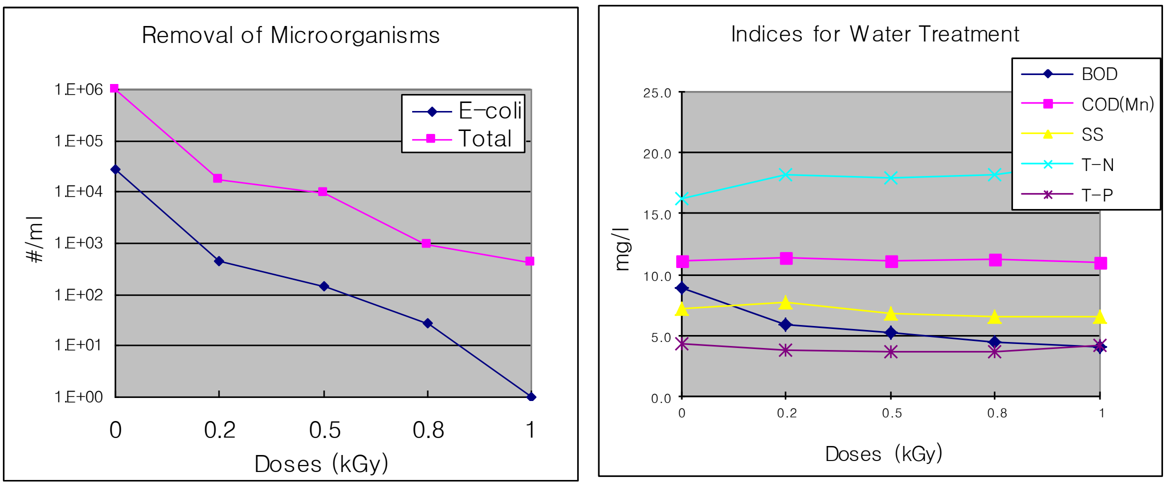

FIG. 2. Removal of indicator microorganisms and variation of other indices with doses up to 1kGy.

4.1. Mobile Electron Beam Plant (MEB)

On-site pilot scale treatment of wastewater from municipal plant will be applied to optimize the operation parameters by a skid mounted Mobile Electron Beam Plant (MEB) mounted in a 40' box metal cargo shipping container as shown in below figure.

with water/air cooling system are the main constituents of the plant. Also the wastewater treatment facilities (pumps, gauges, reservoirs etc.) are included. This plant can treat up to 500m^3/day with 2kGy at continuous operation mode.

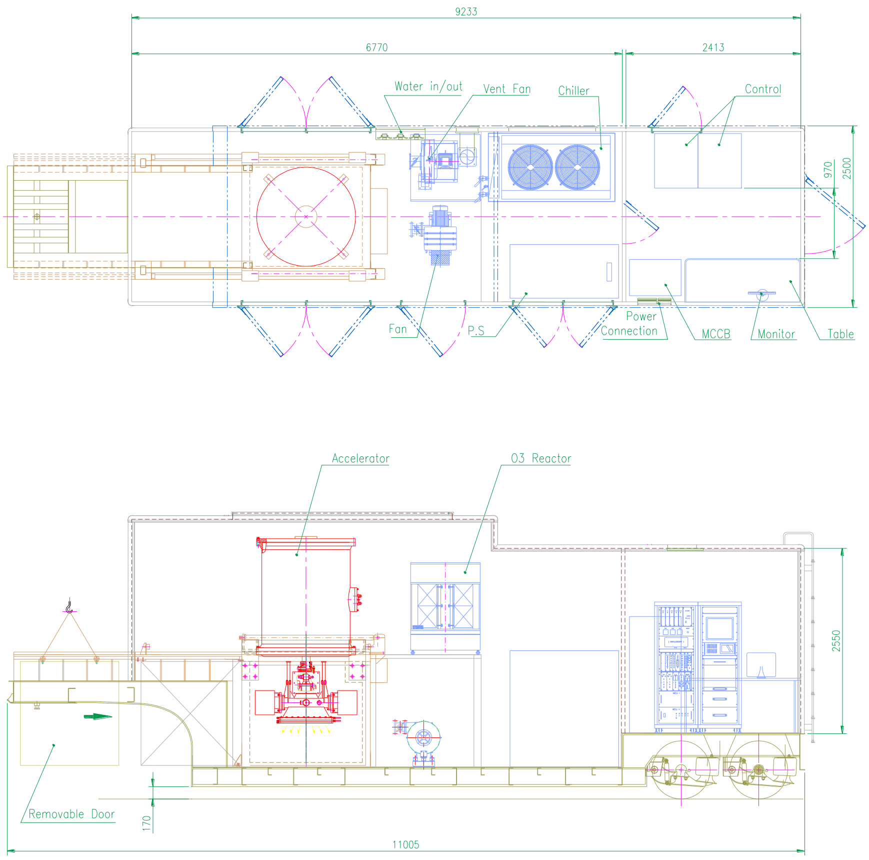

Fig. 3. Mobile Electron Beam Plant (MEB); 500m3/day with 2kGy at continuous operation mode.

This Mobile Electron Beam Plant (MEB) has proved its on-site daptability as operating for a pilot scale demo plant for flue gas treatment from power plant in Jeddah, Saudi Arabia.

Fig. 4. Mobile Electron Beam Plant (MEB) in flue gas treatment in Jeddah, Saudi Arabia.

4.2. Analytical Aproaches

The approach addresses the fate of not just conventional indicator organisms (*E. coli*, *Enterococcus*, coliforms, and total coliforms), but also provides a framework to track and monitor the fate of alternate indicator organisms like the *Bacteroidales*, which are anaerobic and hence decay faster in ambient waters. Unlike traditional indicators, because they are hostassociated, a given *Bacteroidales* genetic marker can be used in the differentiation between human and nonhuman pollution and in the identification of specific animal sources – important information for source control and treatment programs. Both *Enterococcous* and *Bacteroidales* are currently being considered by U.S. EPA in their epidemiological studies to update existing ambient water quality criteria using quantitative PCR (qPCR) methodology.

For technologies entering the market place, it is crucial to have results for the inactivation of both conventional and alternate indicators since alternate indicators are beginning to enter the permitting arena. Although not currently permitted, TOrC removal is gaining momentum as a concern for many municipalities. Our approach investigates the efficacy of e-beam technology to remove TOrCs at doses used for indicators removal, as well as at environmentally relevant TOrC levels.

As describe above, with the on-site operation of mobile electron beam plant, the basic parameters to implement commercial scale disinfection plant for municipal wastewater treatment plant could be achieved. And the optimization of pre-treatment and post-treatment design parameters and evaluation of alternatives to address unforeseen problems resulting from the actual use of proposed treatment processes could be also expected.

4.3. On-site operation of mobile electron beam plant

The mobile plant will be operated continuously to obtain parameters for collecting data with various conditions to secure consistency and reliability of EB process despite fluctuating external environmental variables like day versus night operation, weather and seasonality. Evaluation of obtained data for optimization of the EB process for municipal treatment and alsd the evaluation of energy loss and absorbed dose upon the water thickness will be conducted to optimize the pre-treatment and post-treatment design parameter. In order to develop the design criteria to construct commercial scale re-use plant, evaluation of alternatives to address unforeseen problems resulting from the actual use of proposed treatment processes will also be conducted.

5. Anticipated Results

Anticipated outcomes are:

1. Guidelines of design parameters for constructing commercial scale re-use plant.

2. Achievement of the necessary data to claim the disinfection standards (for example in U.S. as stipulated by California Department of Health Services' Title 22')

3. Effectiveness of EB processing, i.e., consistency and reliability despite fluctuating external environmental variables like day versus night operation, weather and seasonality

References

1. Pikaev, A. K. Modern Radiation Chemistry. Radiolysis Of Gases And Liquids, Nauka, Moscow, (1986) (In Russian) Pp.440.

2. Woods, R.J. And Pikaev, A. K., Applied Radiation Chemistry : Radiation Processing, Wiely, New York (1994)

3. Han, B. Et Al. “Combined Electron Beam And Biological Treatment Of Dyeing Complex Wastewater : Pilot Plant Experiments”, Radiation Physics And Chemistry **64**(1) (2002) 53–59.

4. Han, B. Et Al. “Electron Beam Treatment Of Textile Dyeing Wastewater : Operation Of Pilot Plant And Construction Of Industrial Plant’ Water Science And Technology **52**(10,11) 317-324 (2005)

5. Kartasheva, L.I. Et Al. “Purification Of Water From Cadmium In The Presence Of An Oh Radiacl Scavengers”, High Energy Chemistry **31**(5) (2002) 349–352.

6. Kartasheva, L.I. Et Al. “Combined Electron Beam And Adsorption Method Of Removal Of Cadmium From Water”, High Energy Chemistry **32**(2) (2002) 152–153.

7. Kim, J.Ch. Et Al. “Deep Degradation Of Formic Acid In Aqueous Solutions Under Electron Beam Treatment”, High Energy Chemistry **33**(6) (1999) 413–417.

8. Pikaev, A.K., Dosimetry In Radiation Chemistry, Nauka, Moscow (1975)

9. Pikaev, A.K. Et Al. “New Developments In Electron Beam Technology For Purification Of Industrial Wastewater’ Report At Iaea Consultants’ Meeting On Radiation Degradation Of Industrial Wastes, 8-11 December, Miami, U.S.A.

10. Pikaev, A.K. Et Al. “ Removal Of Heavy Metals By Electron Beam Method In The Presence Of An Hydroxyl Scavengers”, Mendeleev Communications **7**(2), 52-53

11. Ponomarev, A.V. Et Al, “ Combined Electron Beam And Adsorption Purification Of Water From Cadmium And Mercury Using Materials From Vegetable Origin As Sorbents” Radiation Physics And Chemistry **494**(4) (1997) 473–479

12. Yurik, T.K. And Pikaev, A.K. “Radiolysis O Weekly Acidic And Neutral Aqueous Solutions Of Hexavalent Chromium Ions” High Energy Chemistry **33**(4) (1999) 248–252

13. Zhestakova, T.P. Et Al., “Removal Of Lead From Aqueous Solutions By Electron Beam Treatment In The Presence Of Oh Radical Scavengers” High Energy Chemistry 31(4) (1997) 252–255