

Waste Water Treatment : Application of Nuclear Techniques (Electron Beam)

Dr. Siti Aiasah Hashim
Accelerator Development Centre
Nuclear Malaysia



Outline

- Introduction
 - Issues on pollution in Malaysia
 - Electron beam accelerator
 - EB facilities in Nuclear Malaysia
- EB for pollution control
- Basic Radiation chemistry for EB treatment of water/ wastewater
- EB for waste water treatment
- Conclusion

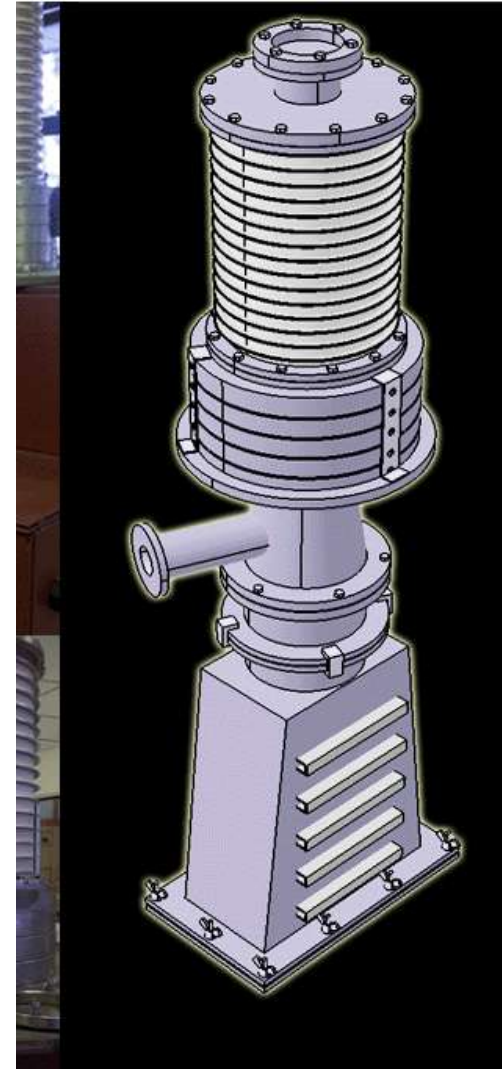
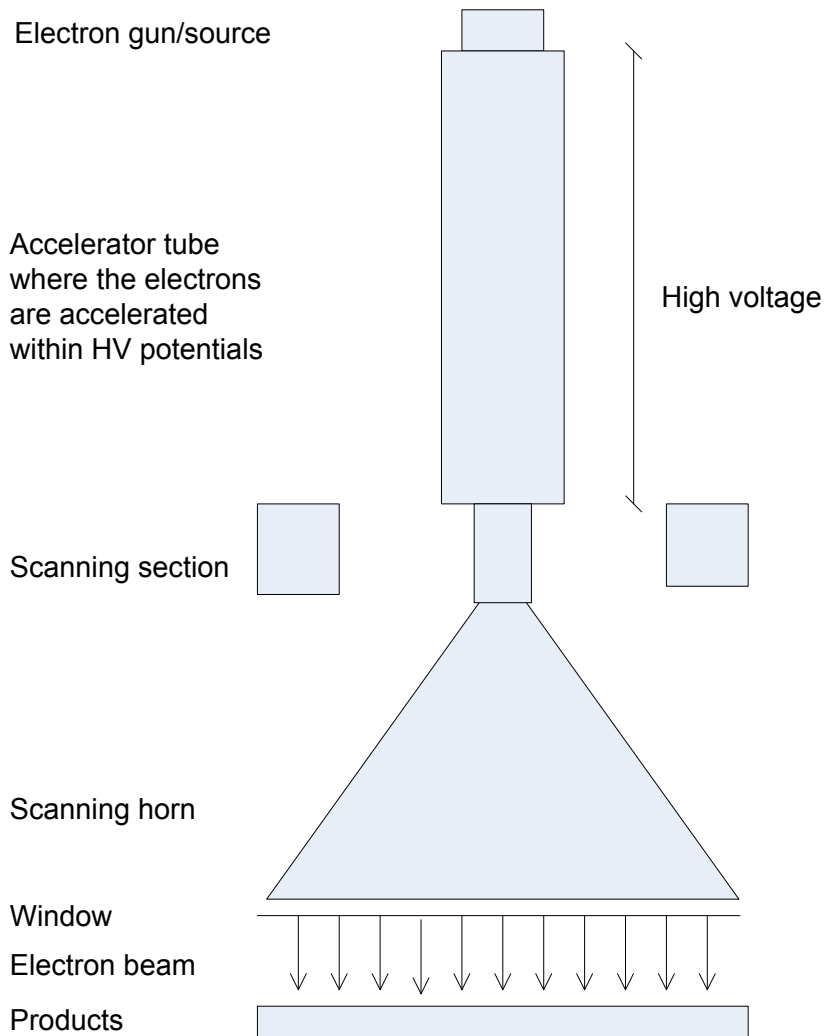
Issues on pollution in Malaysia

Let's talk about it!

Solutions

Problems

Electron Beam Accelerator



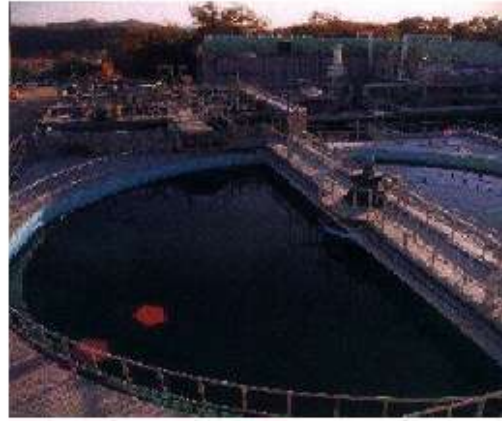
EB in MALAYSIA

- EB facilities at Nuclear Malaysia
 - 3 MeV, 90 kWatt EPS
 - 1 MeV, 50 kWatt ELV-4
 - 200 keV, 4kWatt CURETRON
- Research areas
 - Polymer
 - Surface treatment
 - Environmental preservation
 - Food preservation

How the electron beam work for Pollution Control



Flue gas Purification



Wastewater Treatment



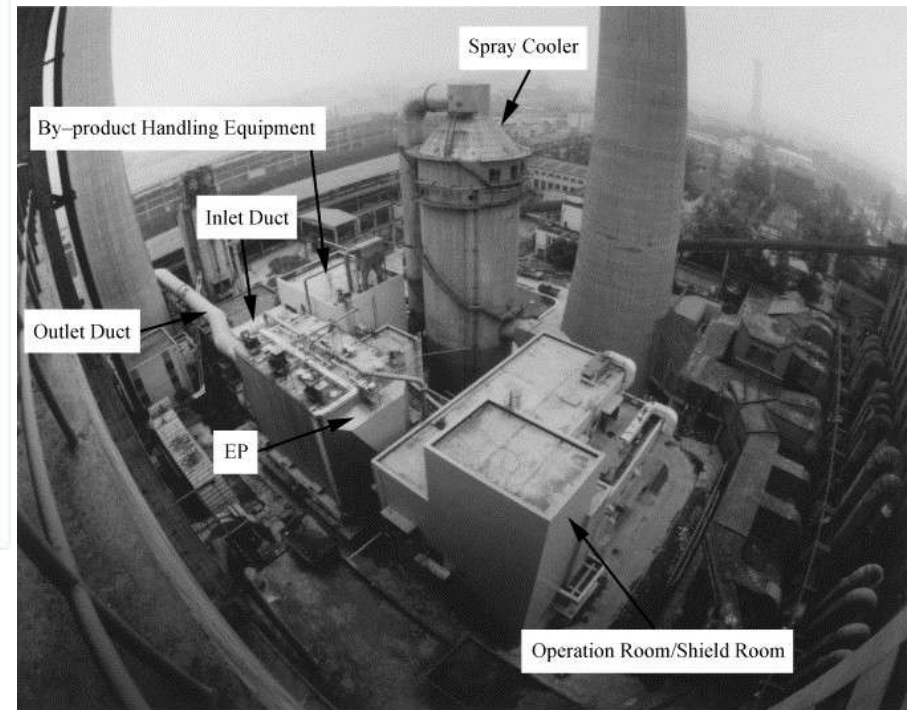
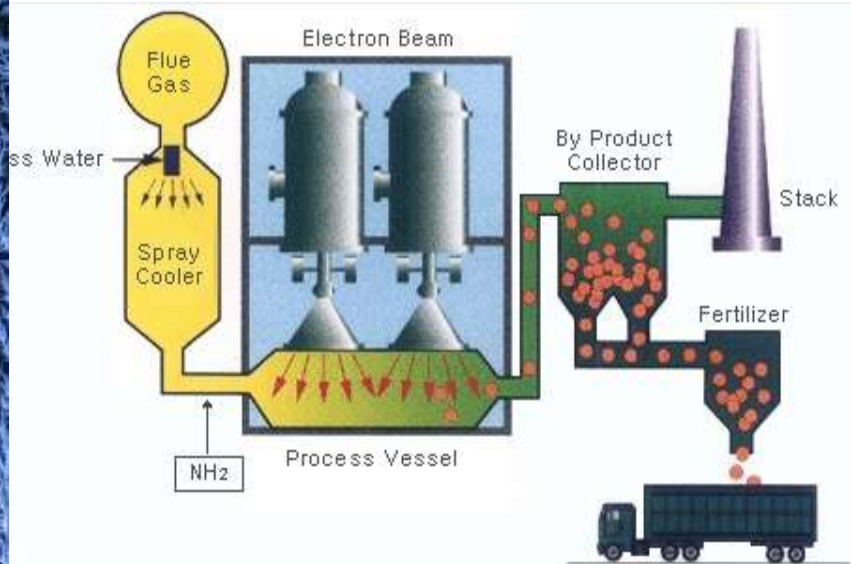
Sludge Hygienization



	Flue Gas Purification	Wastewater Treatment	Sludge Hygenization
Contaminants to clear	SO ₂ , NO _x , (Dioxin)	Complex COD, BOD, S/S etc.	Disinfection of Microorganism
Cleaning Process	Simple	Limitation in depth Combined with others	Limitation in depth Handling system
Competition with other processes	Superiority proved in commercial plant	Complicate to analyze	Many advantages over other processes
Technology	Fully Developed	Lab. to Pilot scale	Lab. to Pilot scale
Economies	Proved through Pilot & Commercial plant	Complicate to analyze	Complicate to analyze
By-product	Useful for fertilizer	Wastewater (less toxic)	Useful for fertilizer or soil treatment

New Generation of Pollution Control ELECTRON BEAM

Electron beam flue gas system (EBFGD)

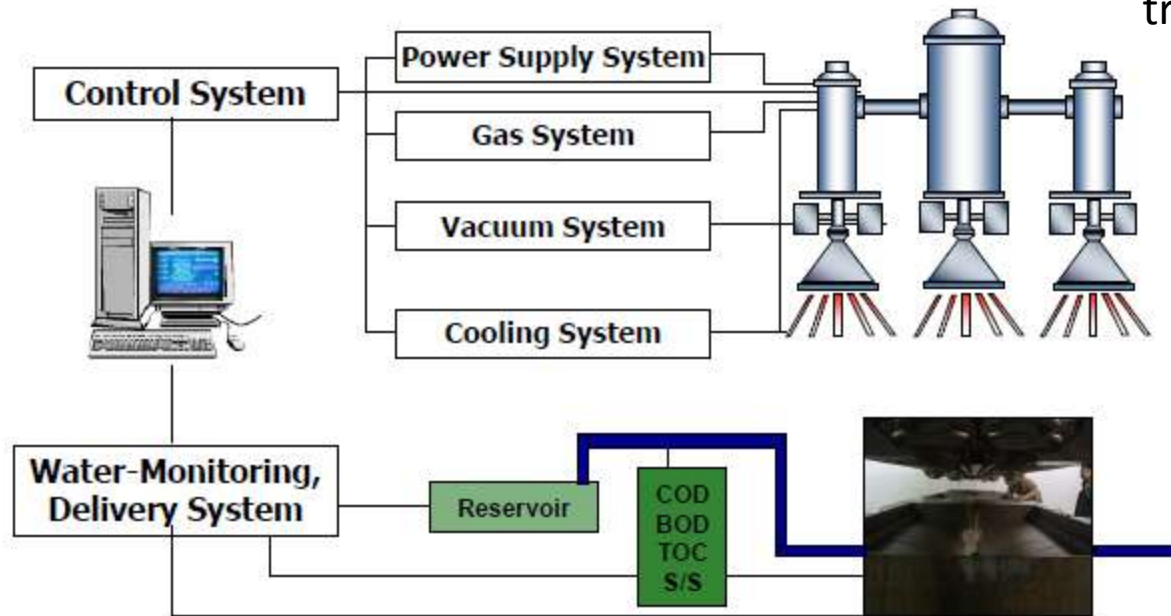


ELECTRON BEAM DESULFURIZATION PROJECT IN CHINA

New Generation of Pollution Control ELECTRON BEAM

Configuration of E-Beam Wastewater Treatment

10,000m³/day
1 MeV, 400kW EB
In line with bio
treatment



Basic radiation chemistry for water / wastewater treatment

- Radiation (e-beam) treatment involves production of very reactive radical particles in the form of:
 - Hydrated electron e^-_{aq} (reducer)
 - Hydrogen atom $\cdot\text{H}$ (reducer)
 - Hydroxyl radical $\cdot\text{OH}$ (oxidizer)

Reactions of these particles with the solute give rise to its chemical and physical transformations. Main results of the transformation being:

- complete decomposition of organic compounds;
- partial decomposition of organic compounds:
 - loss of characteristic features (color, odor, toxicity),
 - changes in structure;
- polymerization of monomers;
- redox-reactions of inorganic compounds:
 - changes in valence state of metal cations.
 - conversion of complex anions;
- changes in stability of colloids.

On the base of these, e-beam treatment may be applied in two ways: for direct destruction of the substance (or elimination of any unwanted property of contaminated water), as well as for stimulating or improving other purification processes, like filtration, sorption, flotation, co-precipitation, biological treatment, etc.

Hydrated electron e^-_{aq}

(reduction reactions)

Inorganic

1. All the metal Cations
(exceptions :cations of alkaline and alkali-earth metals)
2. Majority of Oxygen containing and other complex anions, like NO_2^- , NO_3^- , CrO_4^{2-} , $\text{Cr}_2\text{O}_7^{2-}$, MnO_4^- , $\text{Fe}(\text{CN})_6^{3-}$, etc.
(low reactivity to SO_4^{2-} , ClO_4^- , CO_3^{2-} , and some others)

Organics

1. Benzene ring and aromatic compounds
2. Hetero-atomic double or triple bonds (carbonyl, nitro, nitril)
3. Thiol, disulfide, halide, nitro functional groups in both saturated and unsaturated (including aromatic) hydrocarbons

Hydrogen atom H

(reduction reactions)

I. Reduction reactions (one electron transfer)

1. Majority of metal cations

(low reactivity to Cd^{2+} , Zn^{2+} , some rare-earth metal cations, et al.).

2. Some strong oxidizing inorganic anions, like CrO_4^{2-} , $\text{Cr}_2\text{O}_7^{2-}$, MnO_4^- .

3. Disulfide, iodo, bromo, nitro functional groups and benzene ring in organic compounds.

II. Addition reactions to a double bond in unsaturated hydrocarbons, aromatic compounds.

III. Reaction of H-atom abstraction from saturated carbon in any organic compounds

Hydroxyl radical OH

(Oxidizing reactions)

I. Oxidation reactions (one electron transfer)

1. Majority of inorganic cations and anions

2. Benzene ring in aromatic compounds.

II. Addition reactions to a double bond in unsaturated hydrocarbons, aromatic compounds.

III. Reactions of H-atom abstraction from saturated carbon in any organic compounds.

For basic form of OH- radical (O-)

- i. Oxidation reactions – some lower rate constants
- ii. Additional reaction to a double bond
- iii. Reactions of H-atom abstraction from saturated carbon
 - Almost the same efficiency

What is wastewater ?

Characteristics of wastewater

- No pure chemicals, no pure solution
- Mixture of many inorganic and organic compounds
- Represented as COD, BOD etc.

additionally

- Microorganisms (Coli-form & Pathogenic organisms)
- Chemicals (Endocrine disrupter :natural and synthetic chemicals such as Nonyl phenols and its derivatives, Pharmaceutical residues etc.)
- Heavy Metals etc.

What is water/wastewater treatment ?

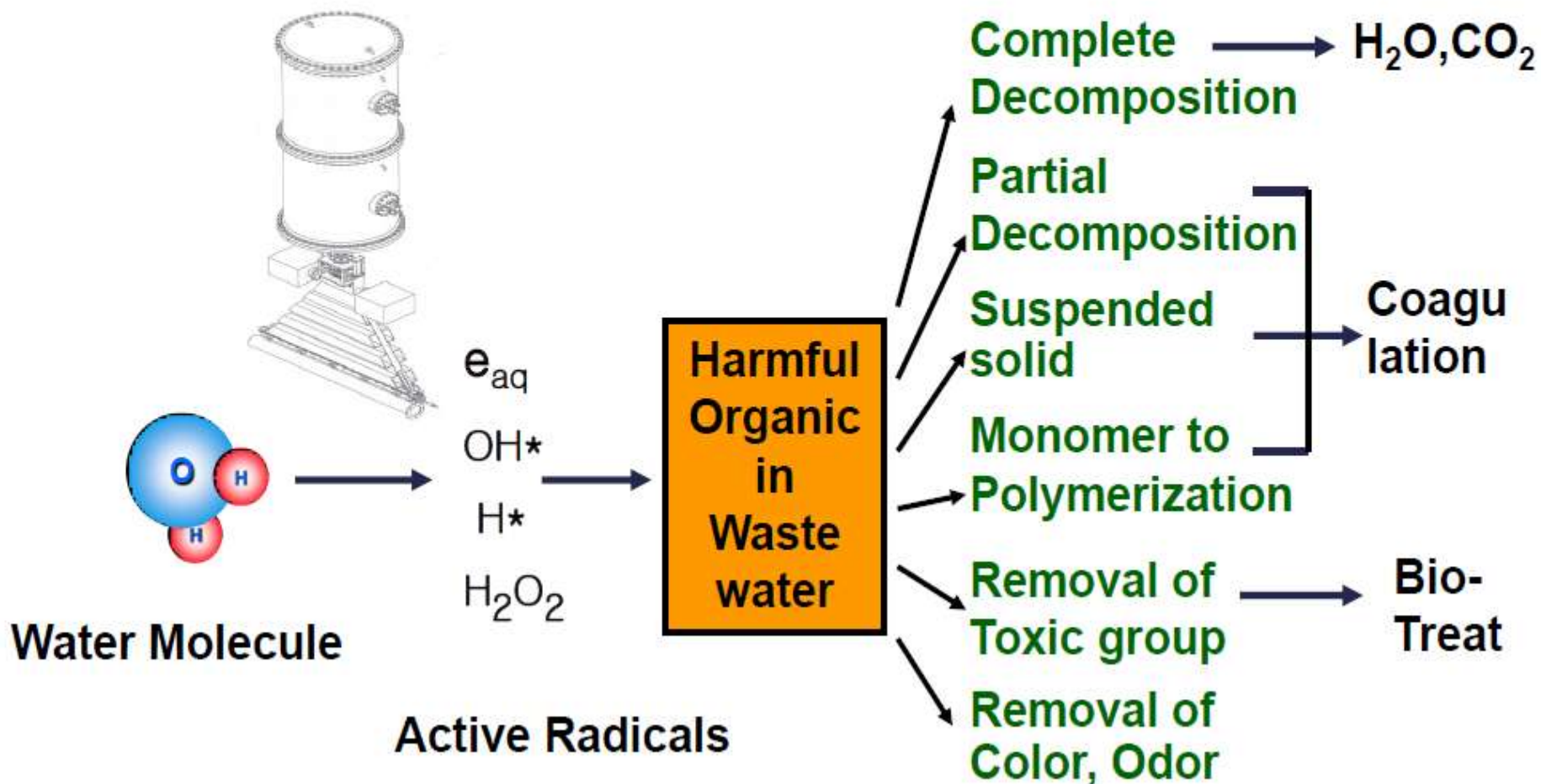
Main purpose of wastewater treatment

- Removal of harmful impurities (COD, BOD, S/S etc.)
- Removal of color, odor etc.
- Removal of T-N, T-P

To discharge to river, or to re-use in industries or irrigation

- Disinfection of microorganisms
(Coli-form & pathogenic organisms)
- Destruction of chemical residues (endocrine disrupter, pharmaceuticals etc.)

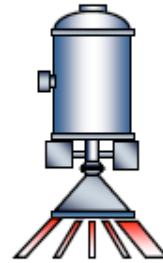
Principles of Wastewater treatment with e- beam



Types of Water/Wastewater Treatment

High contamination

Textile dyeing wastewater
Leachate from landfill area
from petrochemical plant
from paper mills
from mines (coal, metals)
from chemical plants



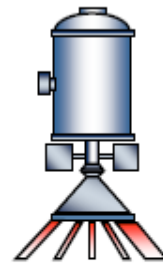
**Removal of impurities
(COD, BOD, S/S etc.)**



Discharge

Low or less contamination

Underground water
Water from lakes or marshes
Effluent of municipal plants



**Disinfection
Removal of Color,
Odor, Residuals**

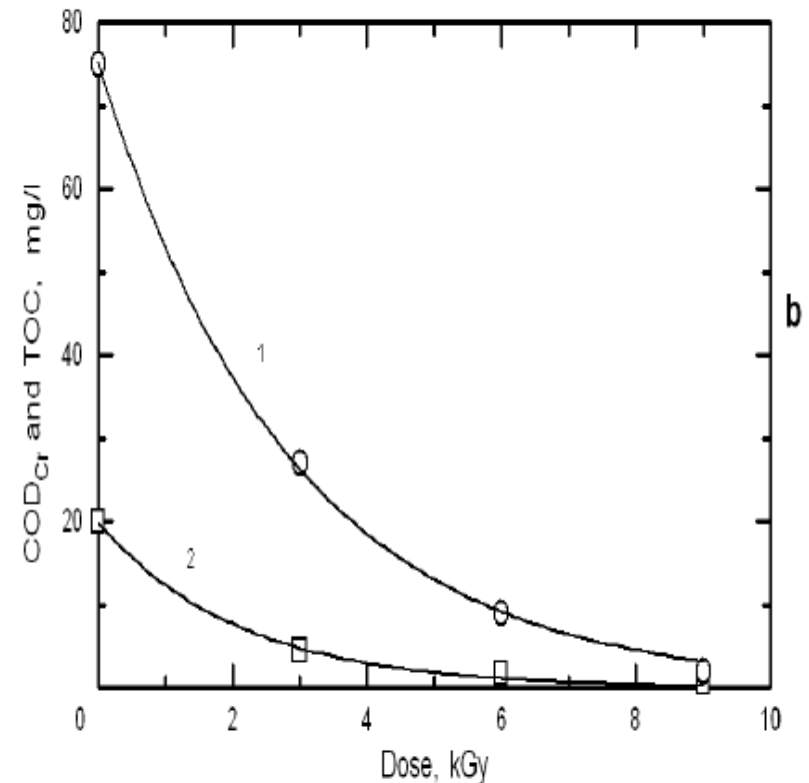
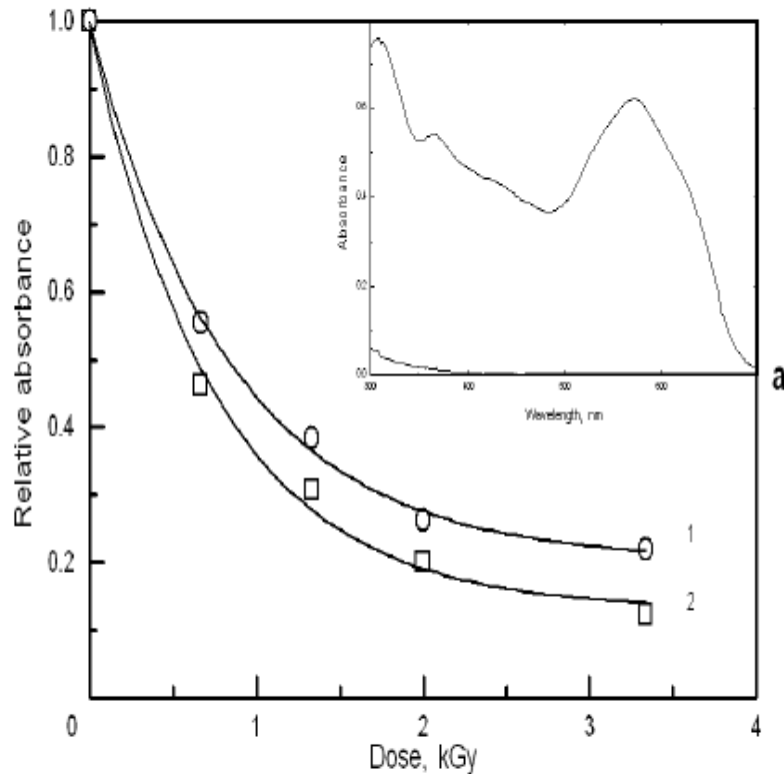


Re-use

Examples of Engineering Approaches

- Example 1. Industrial e-beam Plant for Treating Textile Dyeing Wastewater.**
- Example 2. Disinfection of Effluent from the Municipal Wastewater Treatment Plant for Reclamation**

Lab. Scale E-Beam Treatment of Wastewater



Degradation of acid red dye AB LDN in aqueous solutions (50 mg/l) upon electron-beam treatment:

a - decrease in relative absorbance at 570 nm with dose in deaerated (1) and aerated (2) solutions; b - decrease in COD_{Cr} (1) and TOC (2) with dose in aerated solutions. Insert in a - optical absorption spectra of the dye solution before and after irradiation at 9 kGy.

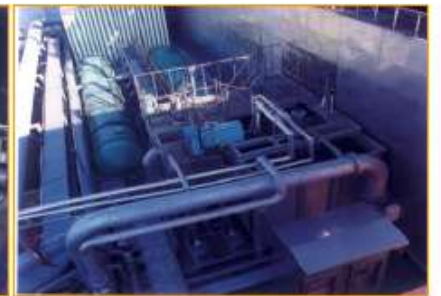
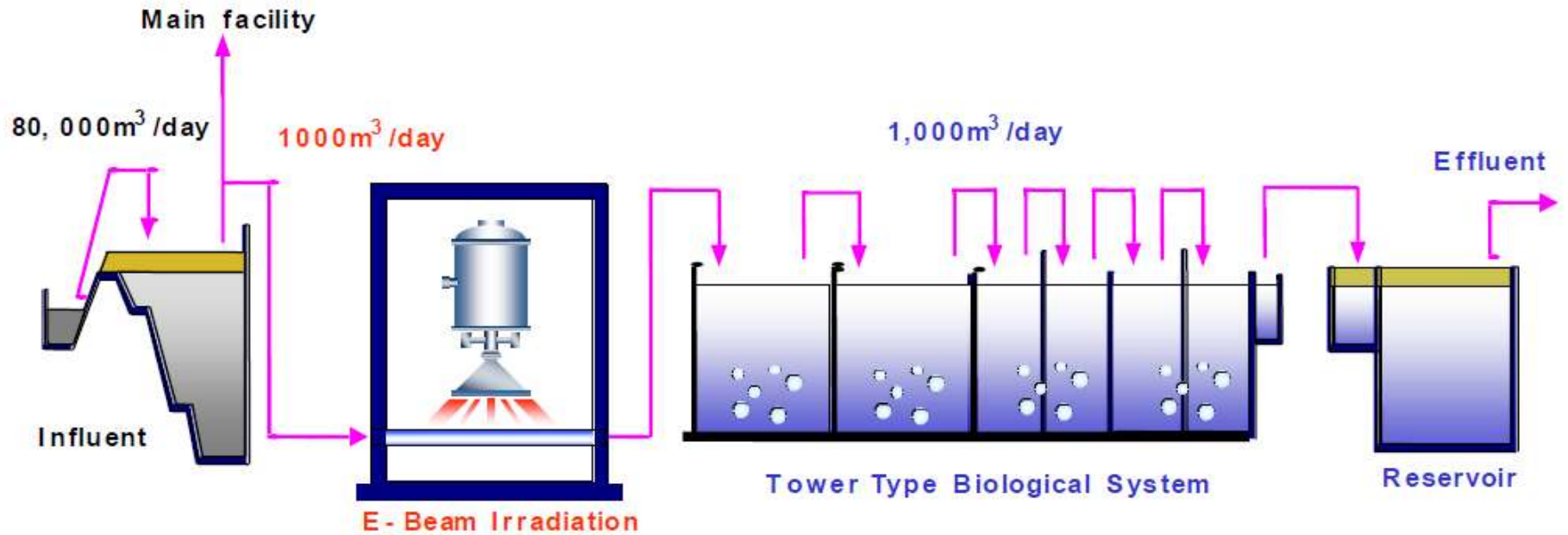
Why Textile Dyeing Wastewater ?

(1000m³/day)

	Number of Companies (%)	Amount of waste-water generated (%)	Amount of waste-water discharged (%)
Textile co.	1,423 (5.6)	473 (5.4)	457 (19.2)
Paperrmill	268 (1.1)	711 (8.1)	364 (15.3)
Light ind.	511 (2.0)	390 (4.5)	243 (10.2)
Processing ind.	3,376 (13.3)	439 (5.0)	200 (8.4)
Metal Fabrication	437 (1.7)	5,346 (61.1)	169 (7.1)
Others	19,284 (76.2)	1,382 (15.8)	942 (39.7)
Total	25,299 (100)	8,741 (100)	2,375 (100)

The amount of waste water generated and discharged in Korea, as of 1995

Schematic Diagram of Pilot Plant



Waste water treatment using combined biological & EB methods

Samples	COD(mg/l)	BOD(mg/l)	Colour (ADMI)
Textiles wastewater	900-3000	100-150	Above1000
Food wastewater.	530-1000	200-400	50 - 100

Characteristics of textile and food industry wastewater

Waste water treatment using combined biological & EB methods



Biological treatment (activated sludge system) used in this project.

Waste water treatment using combined biological & EB methods

Textile effluent	COD (mg/l)	BOD₅ (mg/l)	Colour (ADMI)
Non irradiated	428.0	36.0	899.5
Irradiated 1MeV, 100kGy	302.0	28.0	379.3

*Work carried out by Khomsaton Abu Bakar

Acknowledgement

- Dr. Bam Soo Han from EB Tech, Korea whose slides on Radiation Chemistry of water/wastewater I borrowed
- Madam Khomsaton Abu Bakar of Nuclear Malaysia – work on wastewater treatment using EB.



THANK YOU