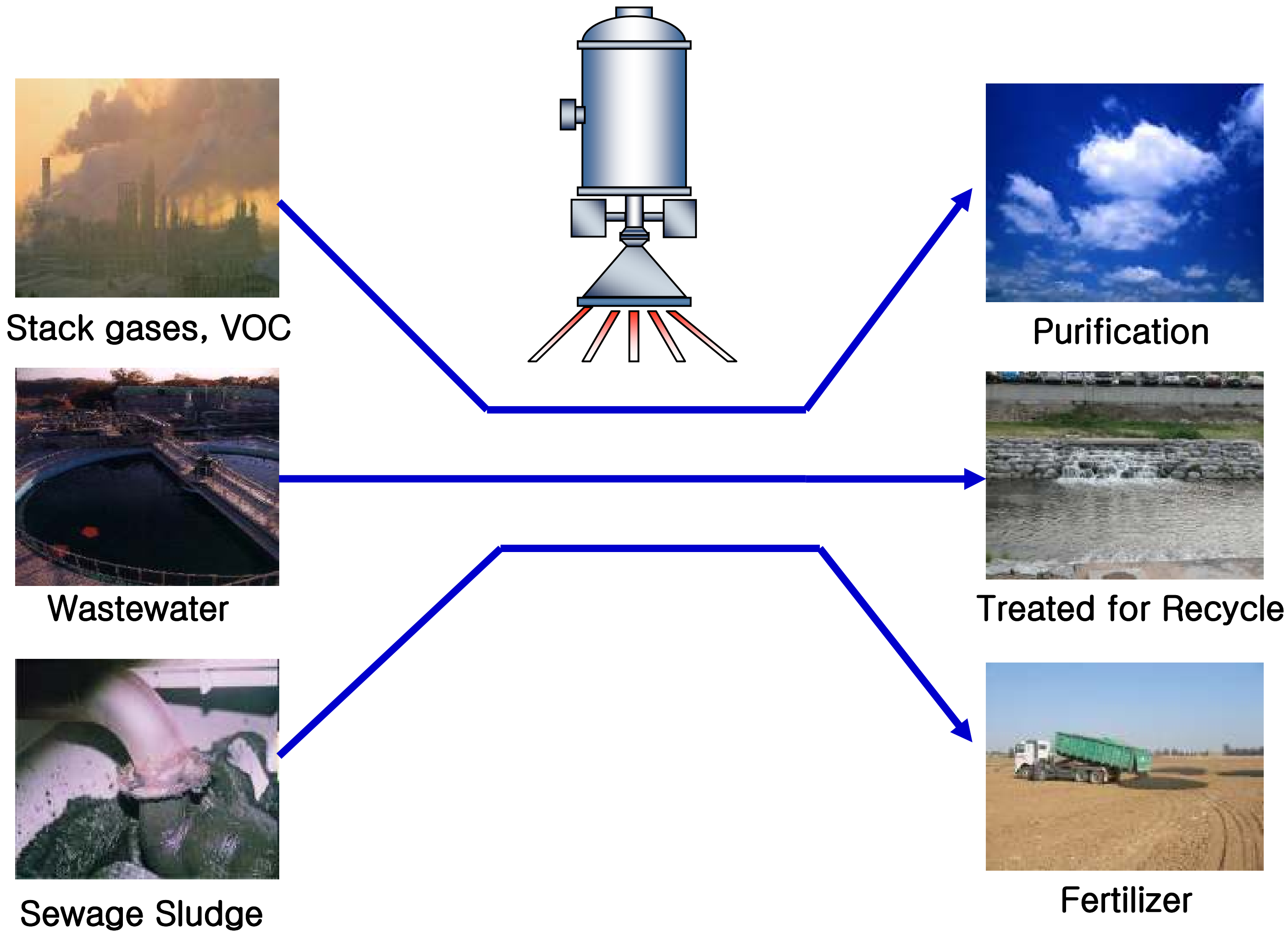
International Topical Meeting on Nuclear Research Applications and Utilization of Accelerators Vienna, Austria 4 - 8 May 2009.

Electron Beam for Environmental Conservation

Flue gas/VOC Purification

Wastewater treatment

Sludge treatment



Stack gases, VOC
Wastewater
Sewage Sludge
Purification
Treated for Recycle
Fertilizer

Technical Advantages of radiation process

*. Radiation Technology is Eco-friendly technology

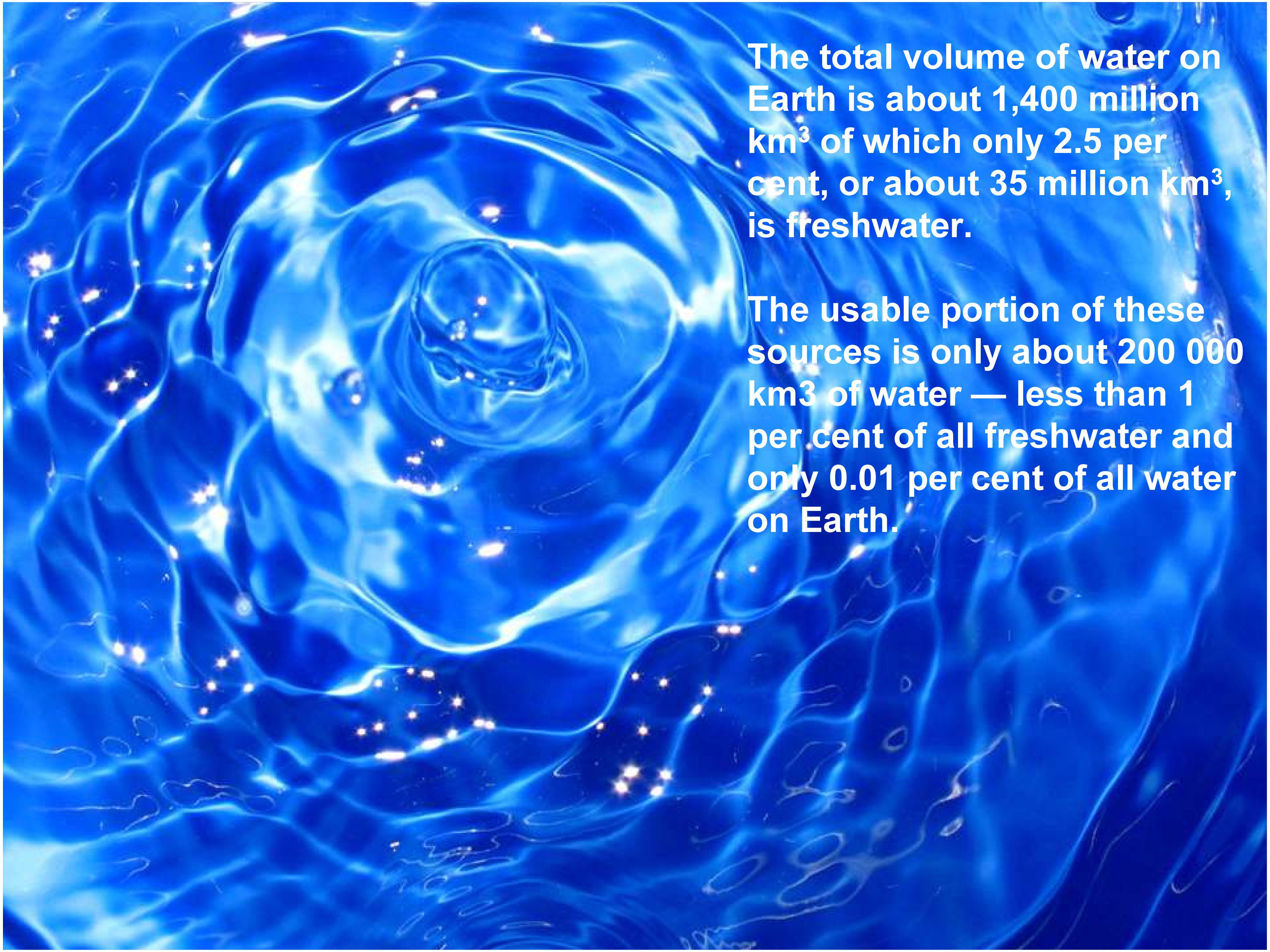
-. No secondary waste generation

-. No catalysts, no heating and easy for automation.

*. Experienced in pilot plant and several industrial plants

*. Economical Advantages in capital cost and O & M cost

*. For flue gas treatment and sludge treatment, by-products are useful for fertilizer.


The total volume of water on Earth is about 1,400 million km^3 of which only 2.5 per cent, or about 35 million km^3, is freshwater.
The usable portion of these sources is only about 200 000 km3 of water — less than 1 per cent of all freshwater and only 0.01 per cent of all water on Earth.

	Volume (1,000 km^3)	% of total water	% of total freshwater
Salt water			
Oceans	1,338,000	**96.54**	
Saline water/lakes	12,955	0.94	
Inland waters			
Glaciers,Snow covers	24,064	1.74	68.7
Fresh groundwater	10,530	**0.76**	30.1
Others	435	0.02	1.2
Total water	1,386,000	100	
Total freshwater	35,029		100

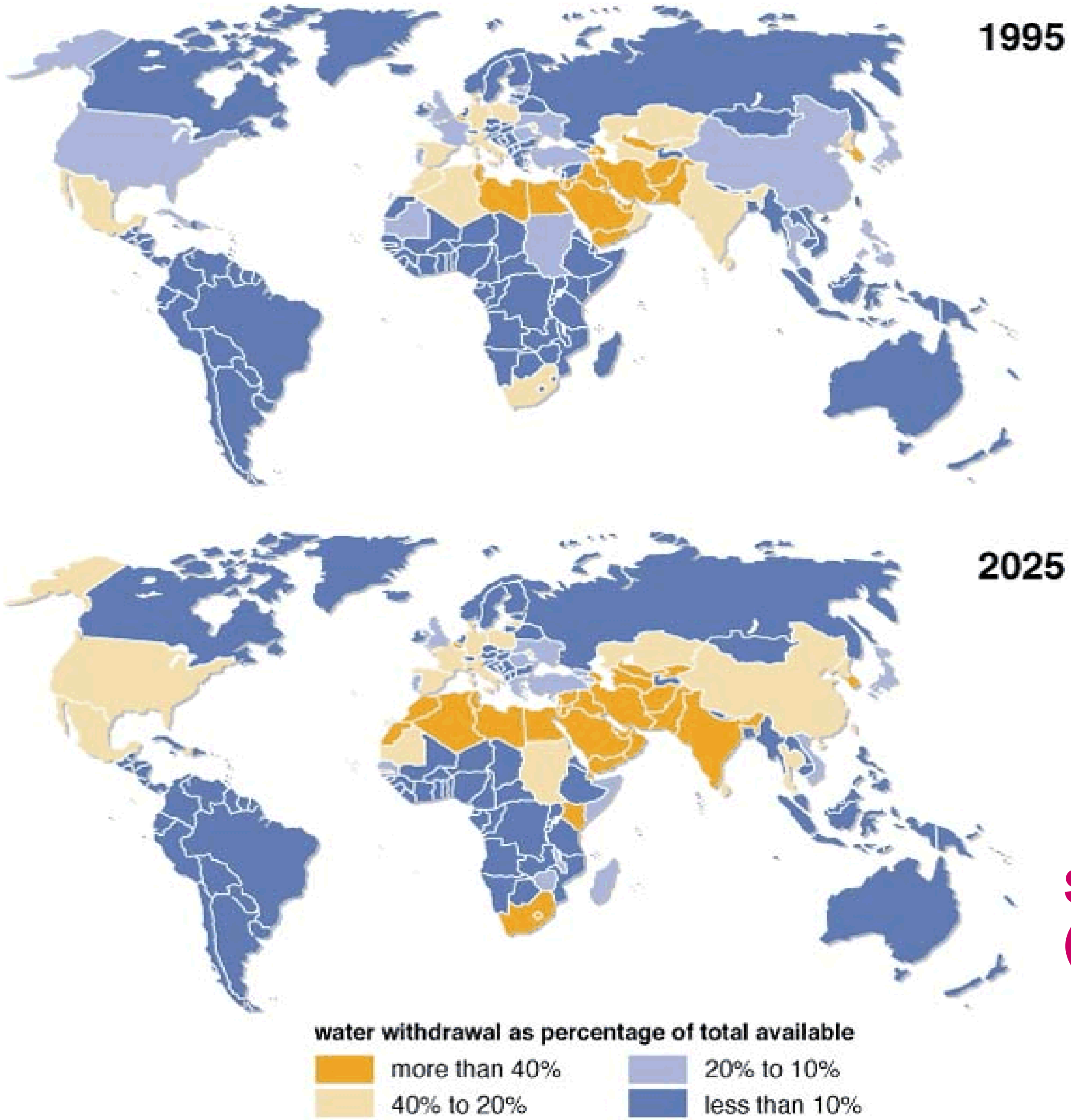
Major Stocks of Water

If the World were a village of 100 peoples,

75 people have some supply of food and a place to shelter them from the wind and the rain, but 25 do not.

17 have no clean, safe water to drink.

Adopted from " If the World were a village of 100 peoples," by Douglas Lummis



Severity of Water Stress
(Data from UN report)

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 endocrine disrupter (natural and synthetic chemicals such as Nonyl phenols and its derivatives)

Why e-beam water/wastewater treatment ?

1. Remove organic impurities with radiation chemical reaction

2. Remove colors by destruction of double bond

3. Remove odors by opening of rings in aromatic compound

4. Disinfection of microorganisms by destruction of DNA

5. Destruction of endocrine disrupter with radical reaction

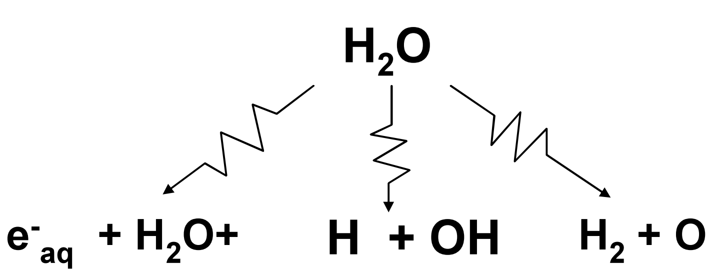
6. Recycle for irrigation, impoundment and individual uses

Characteristics of e-beam wastewater treatment

Water/Wastewater treatment by Radiation-Chemical reactions

Radiation (electron-beam) treatment consists in the formation of very reactive radical particles upon the water radiolysis. They are:

- hydrated electron e^{-}_{aq} (reducer);
- hydrogen atom ·H (reducer);
- hydroxyl radical ·OH (oxidizer).

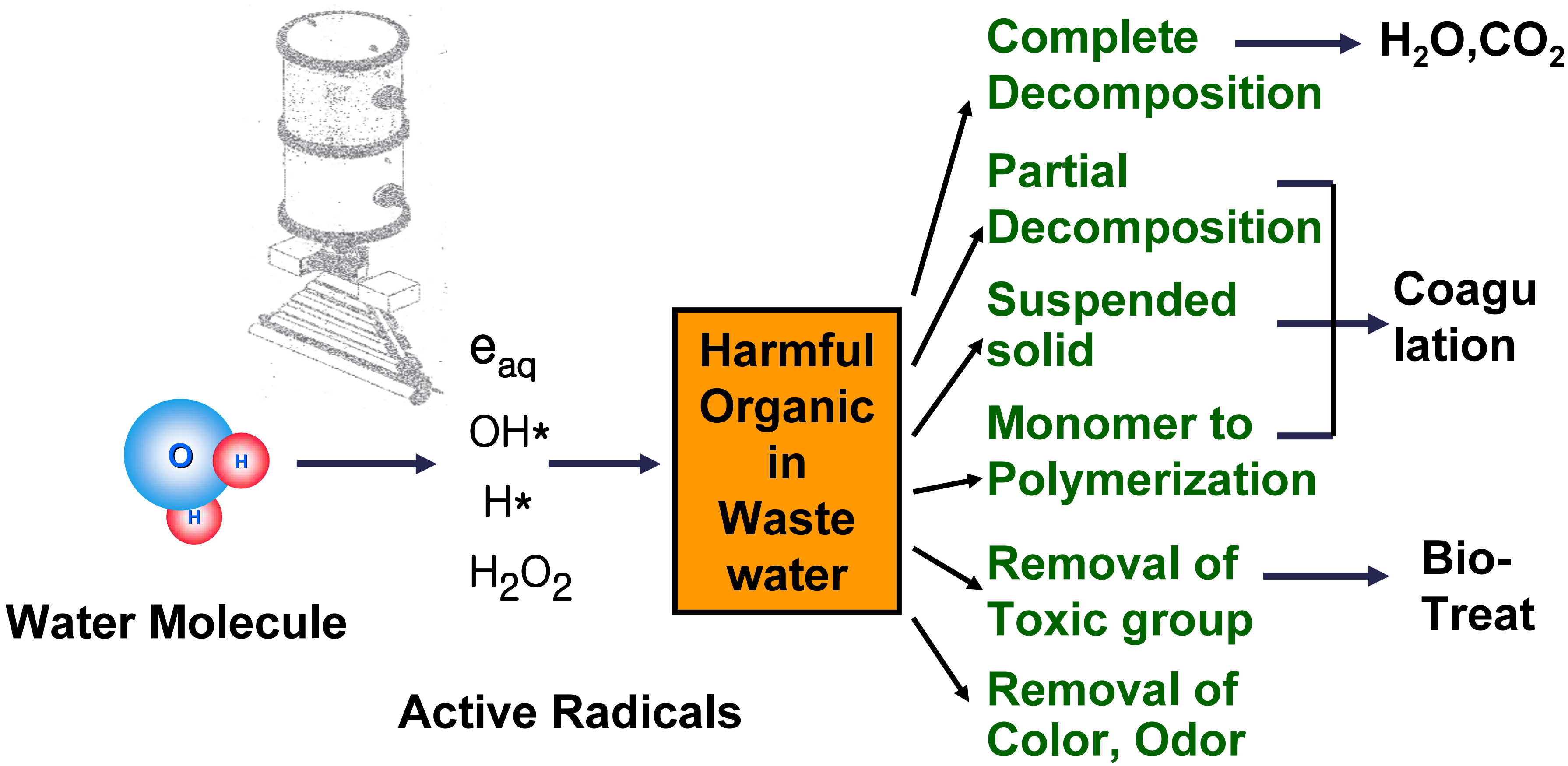


Ionization, decay of excited states $\leq 10^{-12}$ s

$$e^- \longrightarrow e^-_{therm} \longrightarrow e^-_{aq}$$
$$H_2O^+ + H_2O \longrightarrow H_3O^+ + OH$$
$$e^-_{aq} + H_3O^+ \longrightarrow H + H_2O$$
$$H + H \longrightarrow H_2$$
$$OH + OH \longrightarrow H_2O_2$$
$$e^-_{aq} + OH \longrightarrow OH^-$$

“Spur” reactions $\leq 10^{-8}$ s

Principles of Wastewater treatment with e- beam



Application on water/wastewater treatment

With high contamination

Textile dyeing wastewater
Leachate from Landfill area
from petrochemical plant
from Paper-Mill
from tanning industries
from slaughterhouse & fisheries

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

Low or less contamination

Underground water
Water from lake or marshes
Effluent of municipal plant

→ Disinfection
Removal of Color, Odor, residuals → Re-use

Application of e-beam on water/wastewater treatment

-. Wastewater from Textile Dyeing Companies

-. Wastewater from Papermill

-. Leachate from Sanitary Landfill

-. Wastewater containing Heavy metals (Cd,Hg,Pb,Cr^{+6})

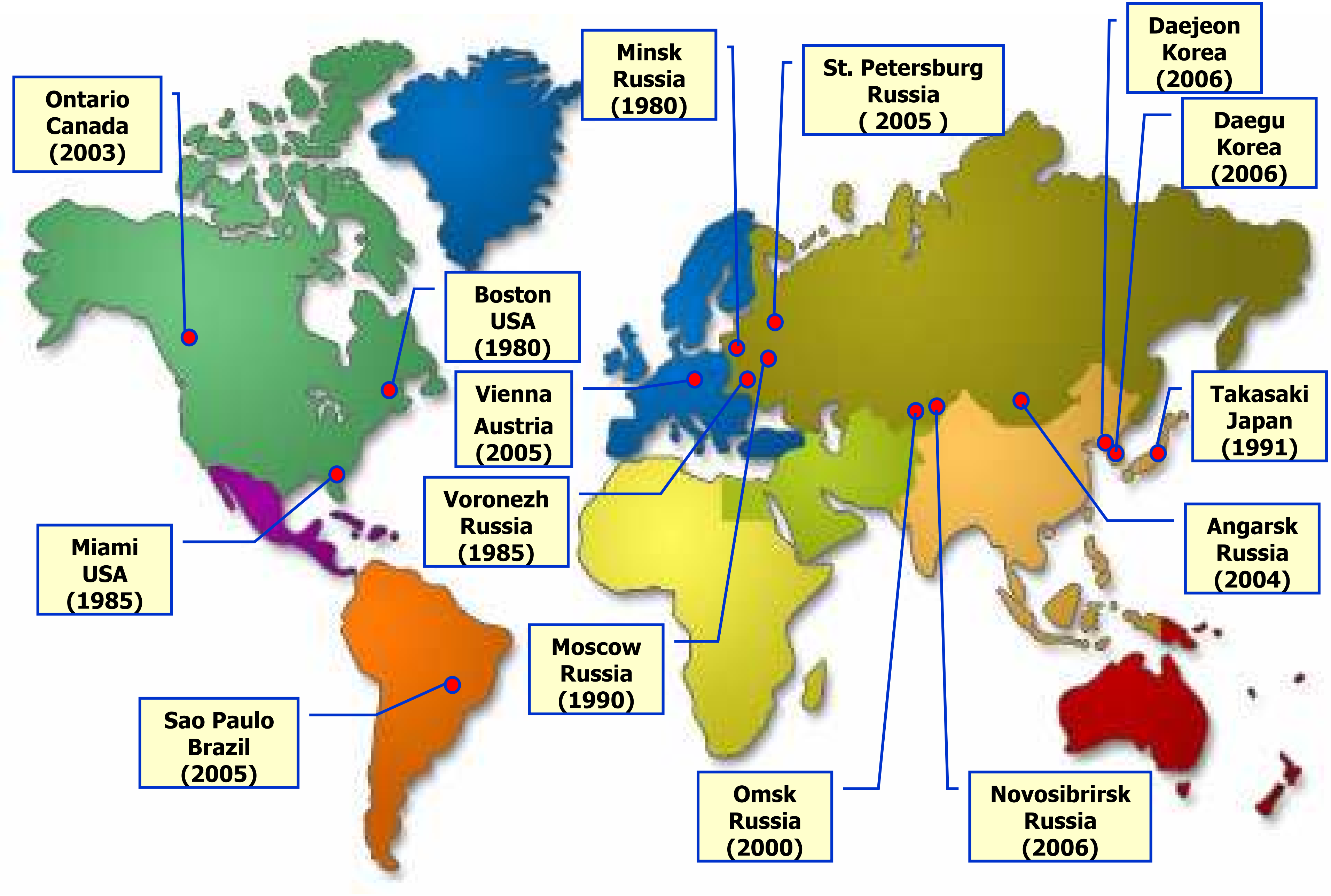
-. Re-use of effluent from municipal wastewater plant

-. Remediation of contaminated water (PCB,Explosives)

-. Contaminated Underground water

-. Drinking water

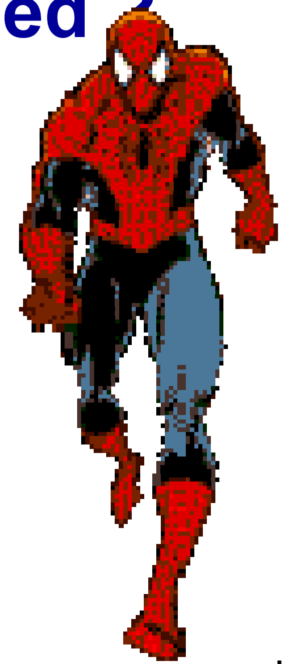
Water/Wastewater treatment plant



	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 chemical 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

Comparison of Flue Gas Purification, Wastewater & Sludge Treatment

Why e-beam processes are not widely used ?



Barriers for Industrial Application

-. Public Acceptances

Uneasy for the Radiation Safety

New Species by Radiation









Filament Wound/Tape Wound Composite Parts
High Temperature Wiring
Tire Components
Seals Gaskets And Hoses
Formed Polymer Components
Composite RTM Components
Composite Body Panels
Adhesive-bonded Composite Components



Why e-beam processes are not widely used ?

Barriers for Industrial Application

-. Public Acceptances	Uneasy for the Radiation Safety New Species by Radiation
-. Technical problems	Reliability for year-round operation Analysis of by-product, Toxicity

Why e-beam processes are not widely used ?

Barriers for Industrial Application

-. Public Acceptances
- Uneasy for the Radiation Safety
- New Species by Radiation

-. Technical problems
- Reliability for year-round operation
- Analysis of by-product, Toxicity

-. Regulation from Authorities

-. Competition with Other processes (Economics)

Difficult to beat the conventional processes
High investment cost and long returns
No Alternatives or by-passes for shut-down
Not universal for all environmental plant
Difficult to find BP

Ionizing radiation is an expensive form of energy.

If the e-beam process is the only and unique solution

- no restrictions on cost
- sterilization of some medical items, removal of toxic compound etc.

If not, severe competition with other process

- in cost, performance, safety, etc.
- especially in emerging technology Wastewater, Flue gas treatment, Sludge Hygienization
- even in well-known technologies, such as cross-linking of wires, heat-shrinkable materials and sterilization etc.

Performance

Raw material + radiation → added value

(improvement in physical/chemical properties, etc.)

Cost assessment

radiation + logistics + management > Before or to other process

When **Performance** > Cost — Acceptable in market

When Performance < **Cost** — **Kick-off from market**

Radiation process (e-beam, γ-ray etc.) can survive only when it has Technical & Economical advantages over existing processes.

Radiation processing should be

Better & Cheaper

to other processes.

1. Find the proper radiation source for products

-. Gamma-ray, X-ray, or e-beam

Steps of decision

-. Decide what you want to treat
(Polymer, Food, Medical items, Water, Gas, Sludge)
-. Decide what Kind of Radiation (e-beam, Gamma, X-ray)

-. E-beam ?

+. Limitation in penetration

-. Gamma ray ?

+. Low dose rate – slow productivity

-. How about X-ray ?

+. Less efficient for energy utilization

1. Find the proper radiation source for products

-. Gamma-ray, X-ray, or e-beam

2. Reduce doses

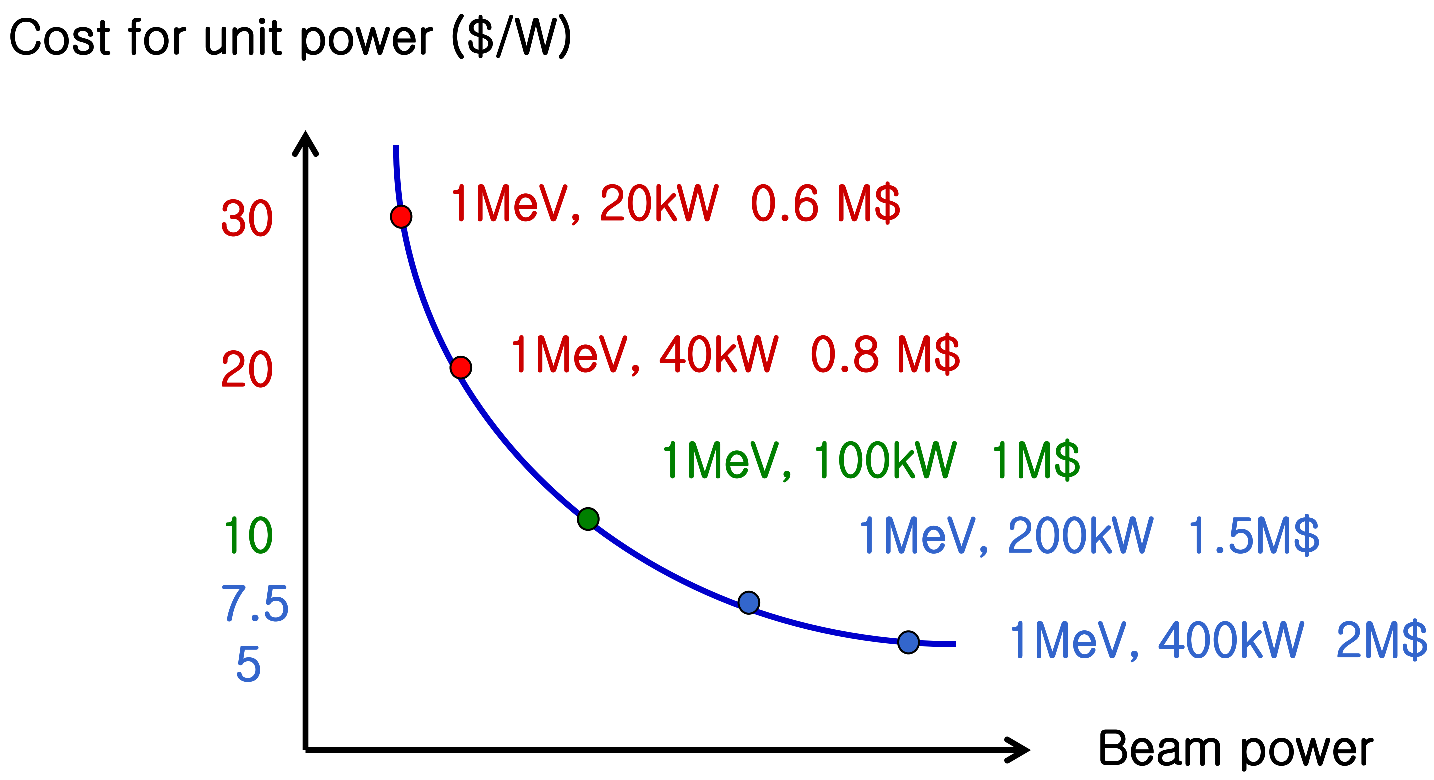
-. with combined methods (Bio-, Physical/chemical etc.)

3. Apply cost-effective accelerator (in case of e-beam)

ACCELERATORS FOR RADIATION PROCESSING
(recent achievements)

Accelerator type	Direct DC	UHF 100-200 MHz	Linear 1.3-5.8 GHz
Beam current	< 1.5 A	< 100 mA	< 100 mA
Energy range	0.1-5 MeV	0.3-10 MeV	2-10 MeV
Beam power	400 kW	700 kW	150 kW
Efficiency	80-90 %	25-50 %	10-20 %

Data from Dr. Z. Zimek of INCT, Poland



Beam Power	20kW	40kW	100kW	200kW	400kW	1MW
Total Cost (M$)	0.6	0.8	1.0	1.5	2	2.2*
Unit Cost ($/W)	30	20	10	7.5	5	2.2

1. Find the proper radiation source for products

-. Gamma-ray, X-ray, or e-beam

2. Reduce doses

-. with combined methods (Bio-, Physical/chemical etc.)

3. Apply cost-effective accelerator

4. Engineering Approaches

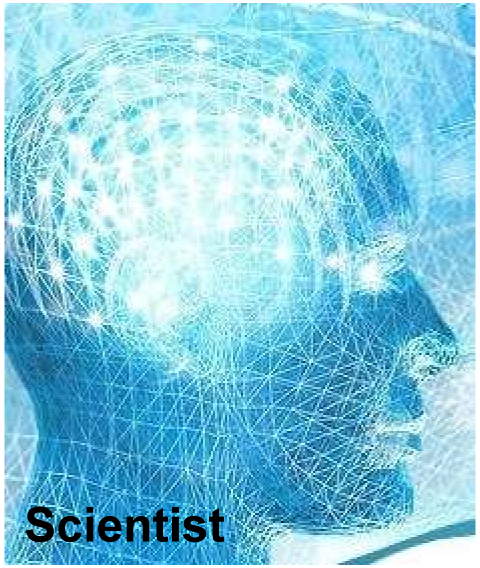
-. Analysis of existing process → Calculate the present cost

-. Economics of radiation → Max. allowable radiation doses

-. Find useful additives or combination for lowering doses

-. Laboratory test → Confirmation of process

-. Pilot plant → Industrial scale design → Commercial plants

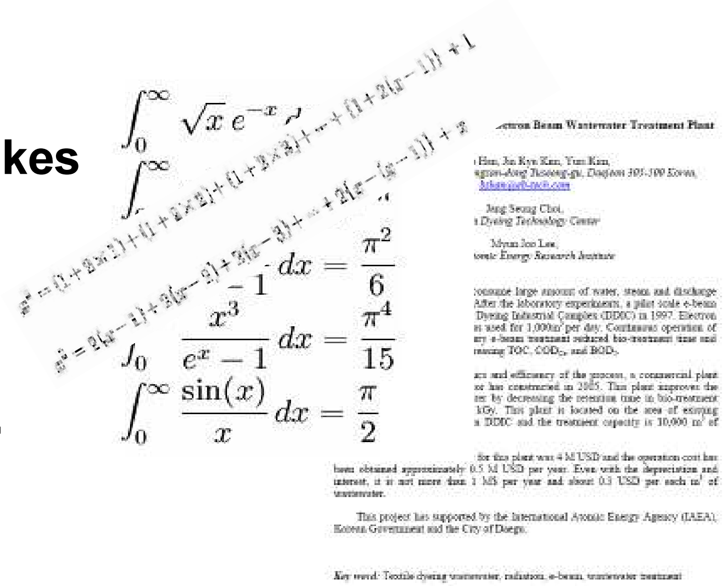


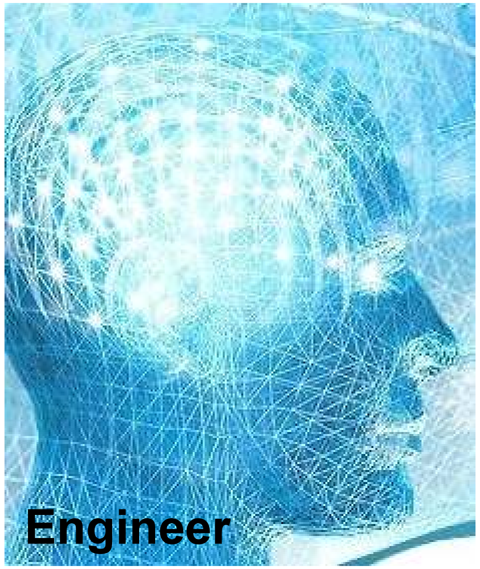
Scientists likes

Numbers,

Equations,

Papers etc.





Engineer (not all of them, a few …) cares

Economics !!!

- cost effective

What they do

-. Laboratory analysis → Find useful numbers

-. Analyze the meaning of those numbers → Some publications

-. Laboratory experiments → Basic design of plant

-. Estimation of plant → Calculation of necessary equipments

-. Comparison with existing process → ?

What we do

-. Analysis of existing process → Calculate the present cost

-. Economics of radiation → Max. allowable radiation doses

-. Find useful additives or combination for lowering doses

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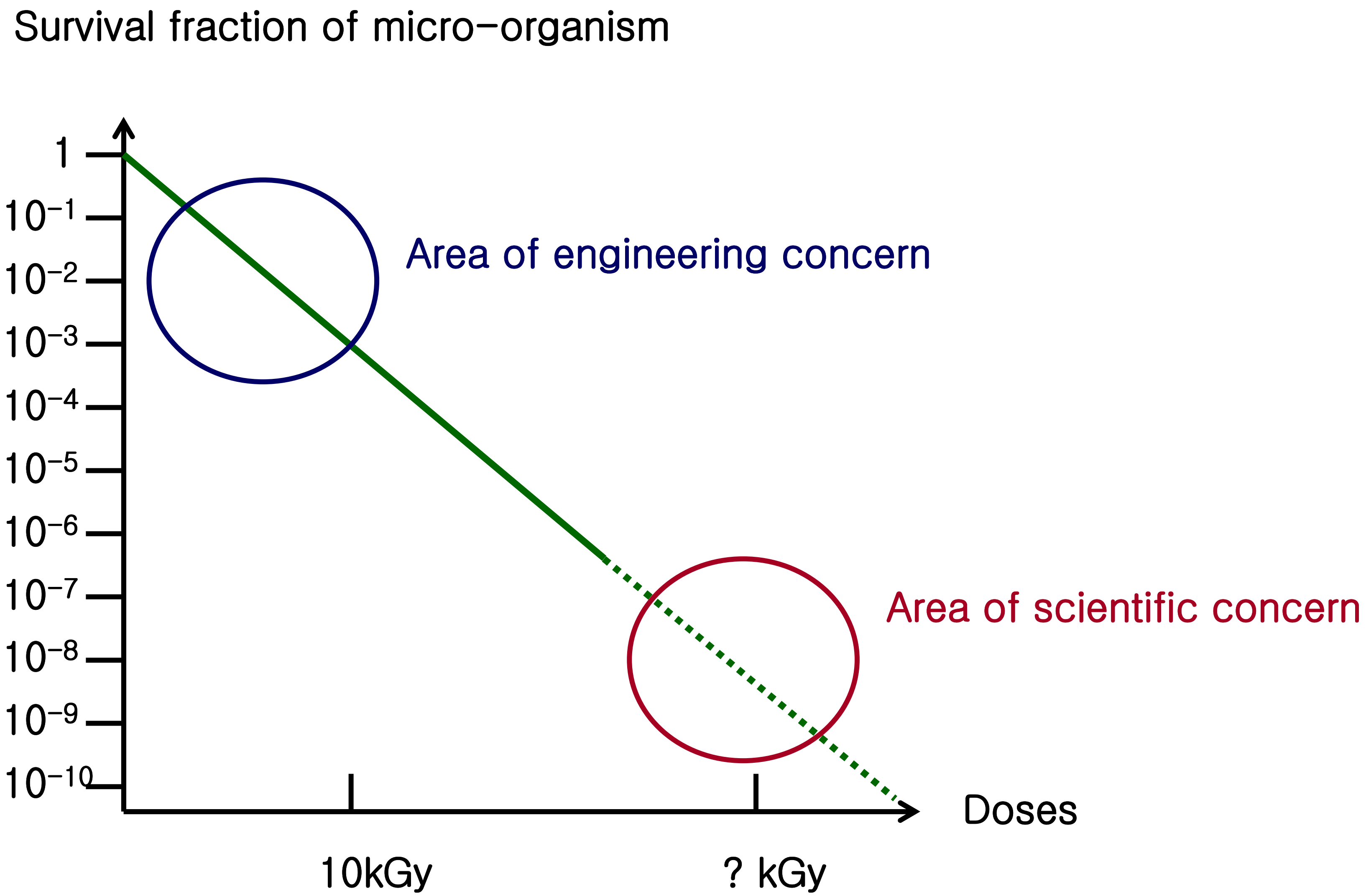
-. Pilot plant → Industrial scale design → Commercial plants


Survival fraction of micro-organism
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
Area of engineering concern
Area of scientific concern
Doses
10kGy
? kGy

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

Wastewater Treatment Facility in Daegu Dyeing Industrial Complex

Engineering Approaches

-. Analysis of existing process

→ Calculate the present cost : 1.1~1.2 USD per m^3 of wastewater

-. Economics of E-beam

→ Determine the target cost : below 1 USD including bio-treat

→ Cost for radiation processing : below 0.4 USD per m^3

→ Max. allowable radiation doses : less than 2 kGy

-. Find useful additives or combination for lowering doses

→ Combined with bio-system (Activated sludge system)

-. Laboratory test

→ Confirmation of process, engineering design (delivery etc.)

-. Pilot plant → Industrial scale design → Commercial plants

Calculation of Required E-beam power

P (kW, kJ/s) = D(kGy, kJ/kg) * M (kg/s) / F

Where P = delivered power of e-beam (kW = kJ/s)
M = mass productivity (kg/s)
D = absorbed dose (kGy = kJ/kg)
F = efficiency of beam energy transfer (0.6~0.7)

Required E-beam for 1,000m³/day

$$P\ (kW) = \frac{1{,}000 \times 10^3 kg/\ (24 \times 3600)\ sec \times D(kGy)}{0.6}$$

with 1kGy → 20kW,
10kGy → 200kW
100kGy → 2000kW

for treating 1,000m³/day, with 1~2kGy → 40kW

Researches on Wastewater Treatment

- 1994~1995 : Lab. scale feasibility Test with e-beam and Gamma ray
- 95.12~99.5 : Researches on Dyeing Wastewater Treatment with e-beam (Dyeing Technology Center/EB-TECH Co.)
- 96.2 ~97.2 : Treatment of Dyes and Dyeing Wastewater
- 97.2~98.10 : Construction of e-beam Pilot Plant (1000m^3/day)
- 98.10~ : Continuous operation of treatment facility
- 1998.9.16 : KT (Korea New Technology) Award
- 2000.7.19 : IR52 Industrial Research Award
- 2001~2006 : IAEA TC Project (Demo Plant Construction)
- 2001~2003 : Preparation for Plant Construction
- 2004 : Start up of Demo Plant Construction
- 2005.12 : Operation of Industrial scale plant (10,000m^3/day)

Required E-beam for 10,000m^3/day

$$P\ (kW) = \frac{10{,}000 \times 10^3 kg/(24 \times 3600)\ sec \times D(kGy)}{0.6}$$

with 1kGy → 200kW,
10kGy → 2,000kW
100kGy → 20,000kW

for treating 1,000m^3/day, with 1~2kGy → 400kW

How to make 400kW machine ?

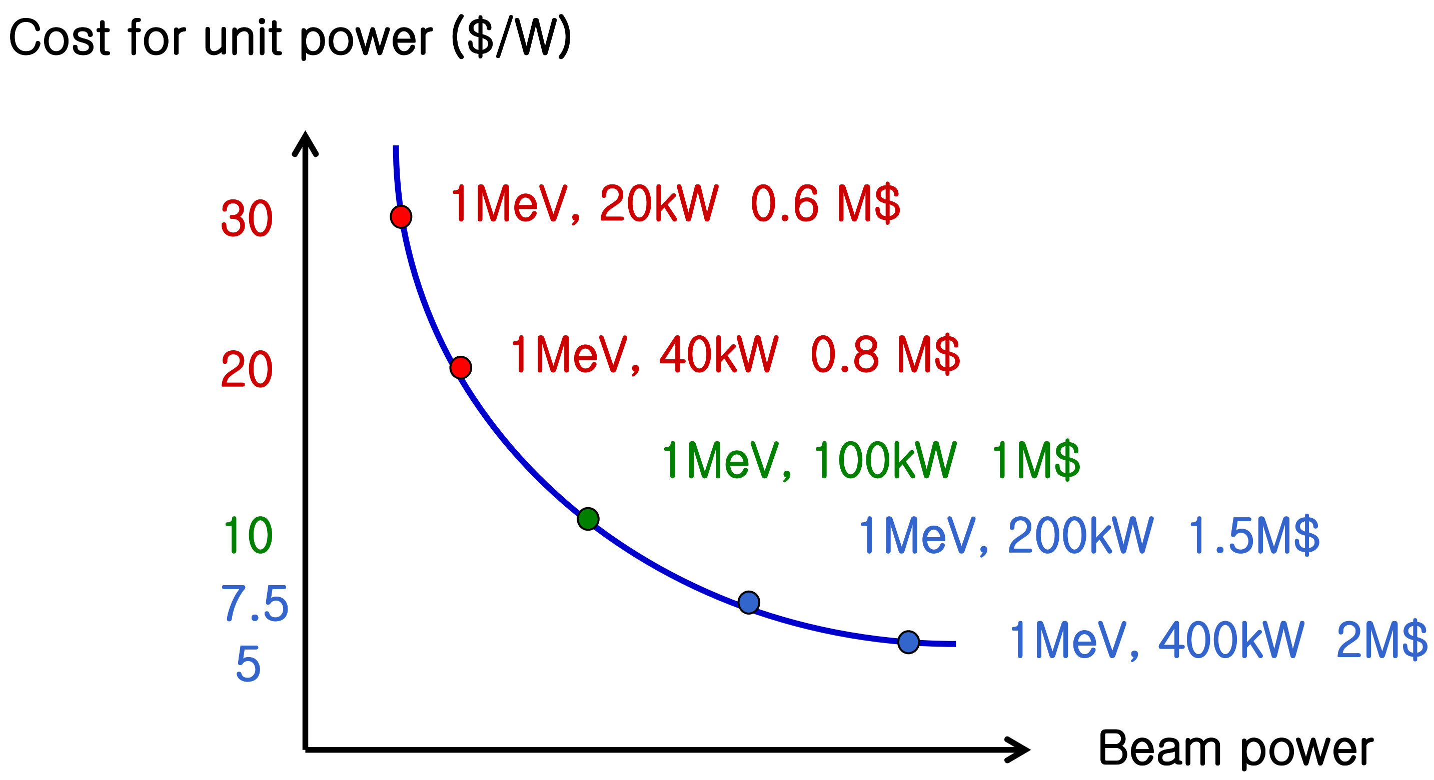
- -. Energy and power
- -. How many irradiators ?
- -. How to make uniform irradiation ?

Electron Energy (MeV)	Max. range in air (m) (20℃,1atm)	Maximum range in water (mm)	Maximum range in Al (mm)	Maximum range in lead (mm)
30	109	132	53.8	10.2
10	43.1	49.8	21.7	5.42
1	4.08	4.37	2.05	0.69
0.1	0.13	0.14	0.069	0.027
0.01	0.0024	0.025	0.0013	0.00073

Maximum range of accelerated electrons

Service Conditions of Accelerator for Environmental Uses

Flue gas/VOC Purification	Wastewater treatment	Sludge treatment
		
Ti foil between accelerator and reactor	Window is open to wastewater	Sufficient gap to Sludge



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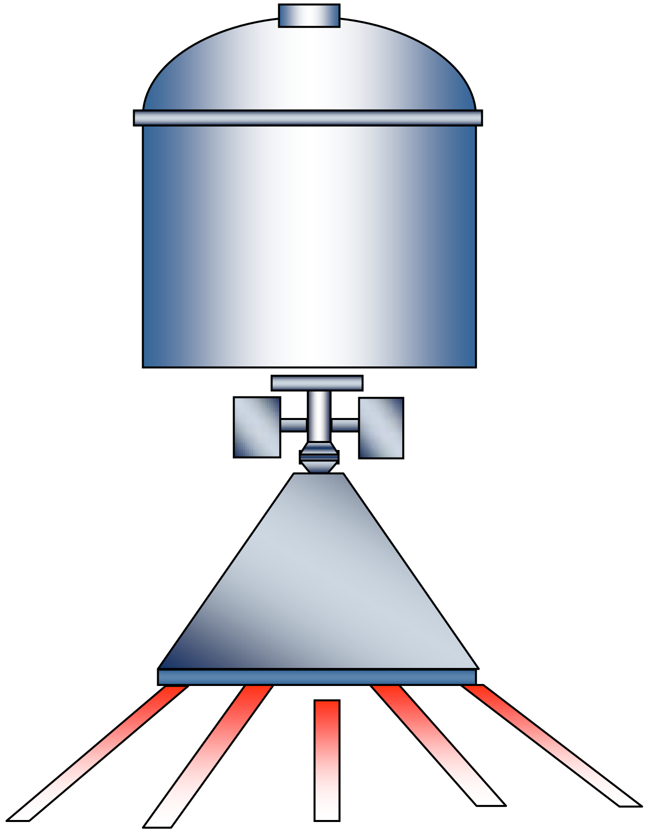
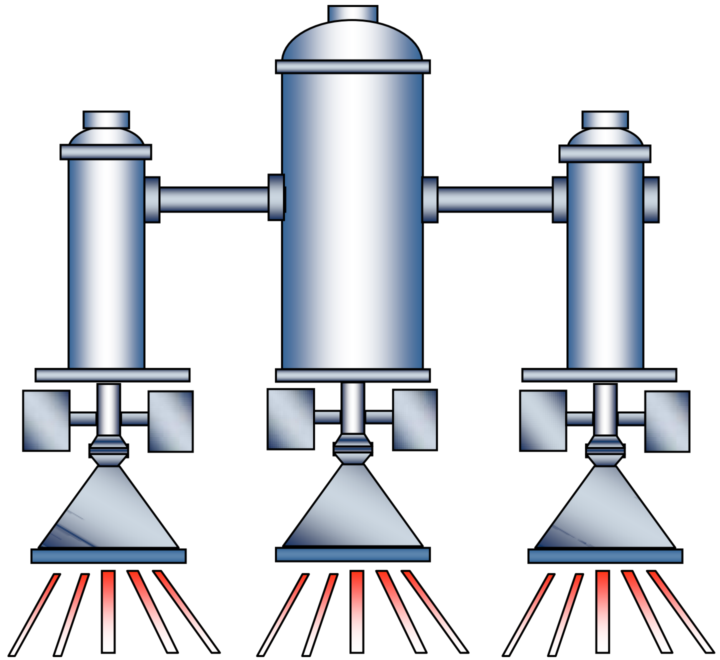


One- irradiator system



Multi-irradiator system

Experiences in Wastewater Treatment

- For treating 10,000m^3/day of water with one –irradiator

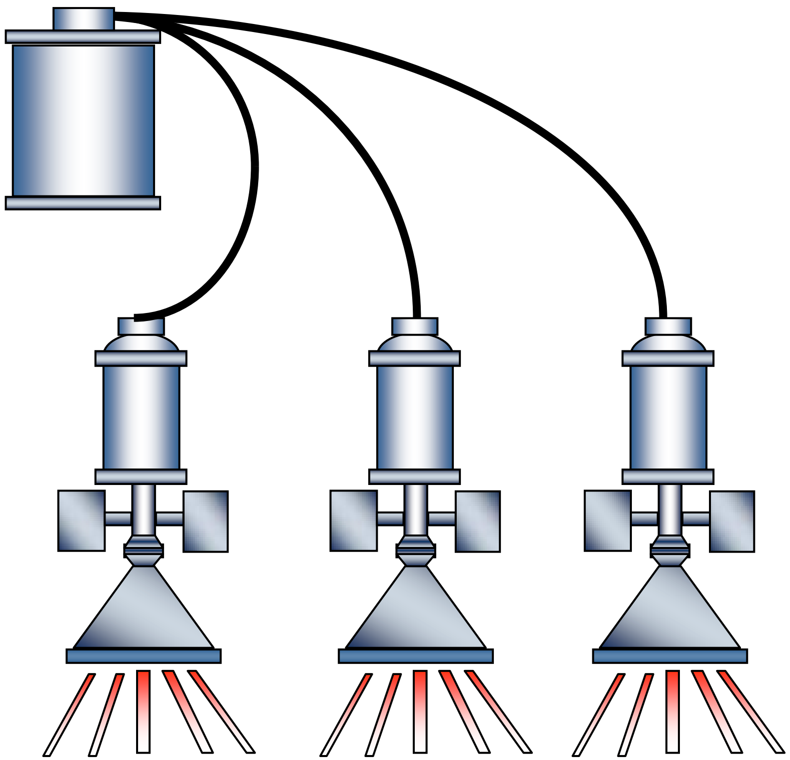
-. The injection speed of water

$$\frac{10{,}000\ m^3/day}{24 \times 3{,}600\ sec/day} = \frac{1}{0.004m \times 2m} = 14.5m/sec\ (52km/h)$$

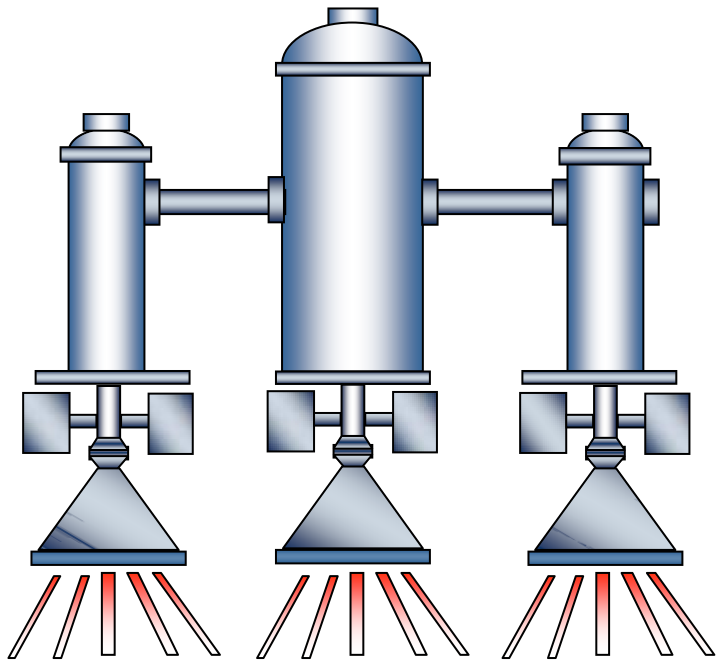
- For treating 10,000m^3/day of water with three –irradiators

-. The injection speed of water

$$\frac{10{,}000\ m^3/day}{24 \times 3{,}600\ sec/day} = \frac{1}{0.004m \times 1.5 \times 3} = 3.2m/sec$$

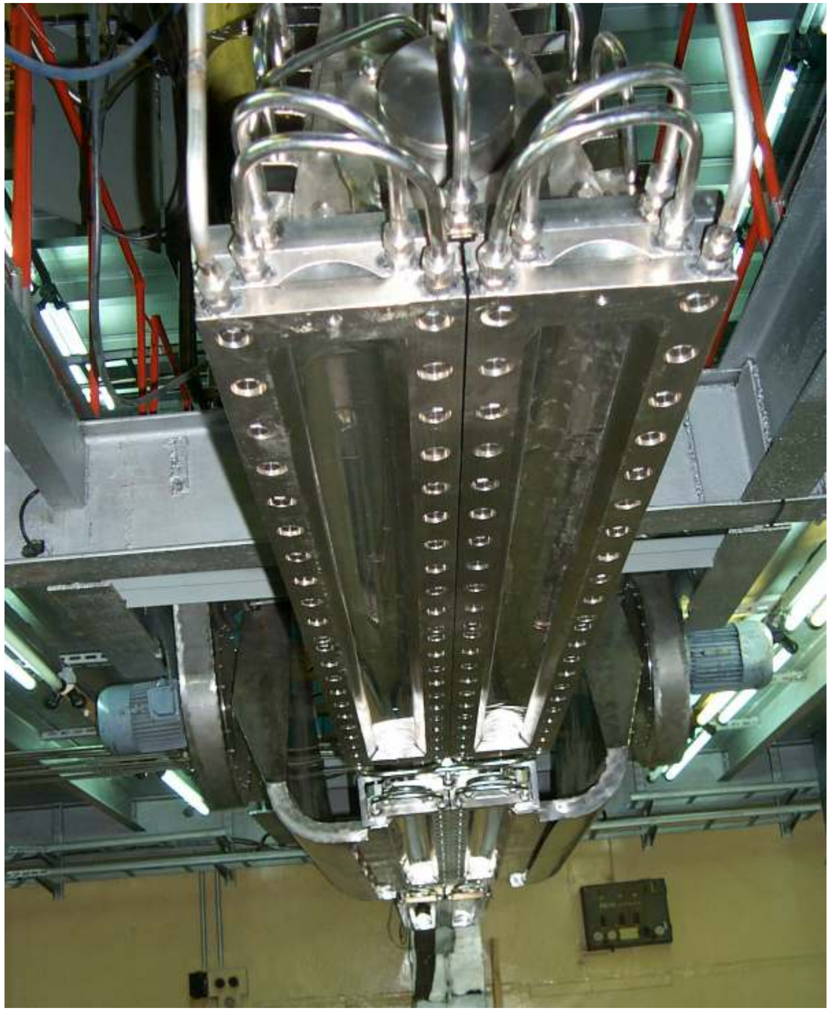


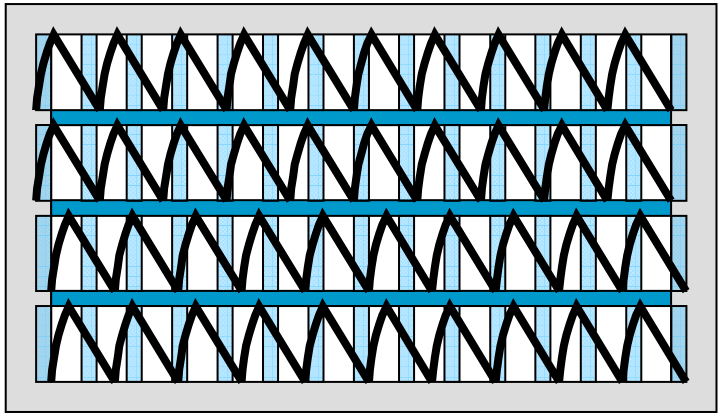
H.V. Cable Connection (<700kV)



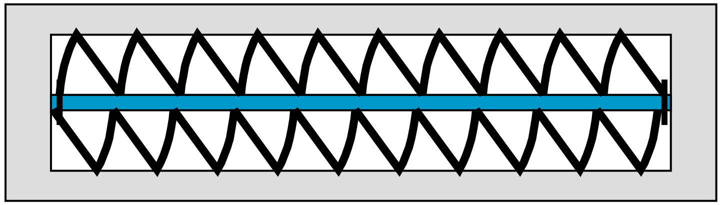
Solid Connection of H.V.

Double-window extraction device





-. Power loss
+. Theoretical 15%, 75kW for 500kW
+. Too much power loss, requires huge cooling system



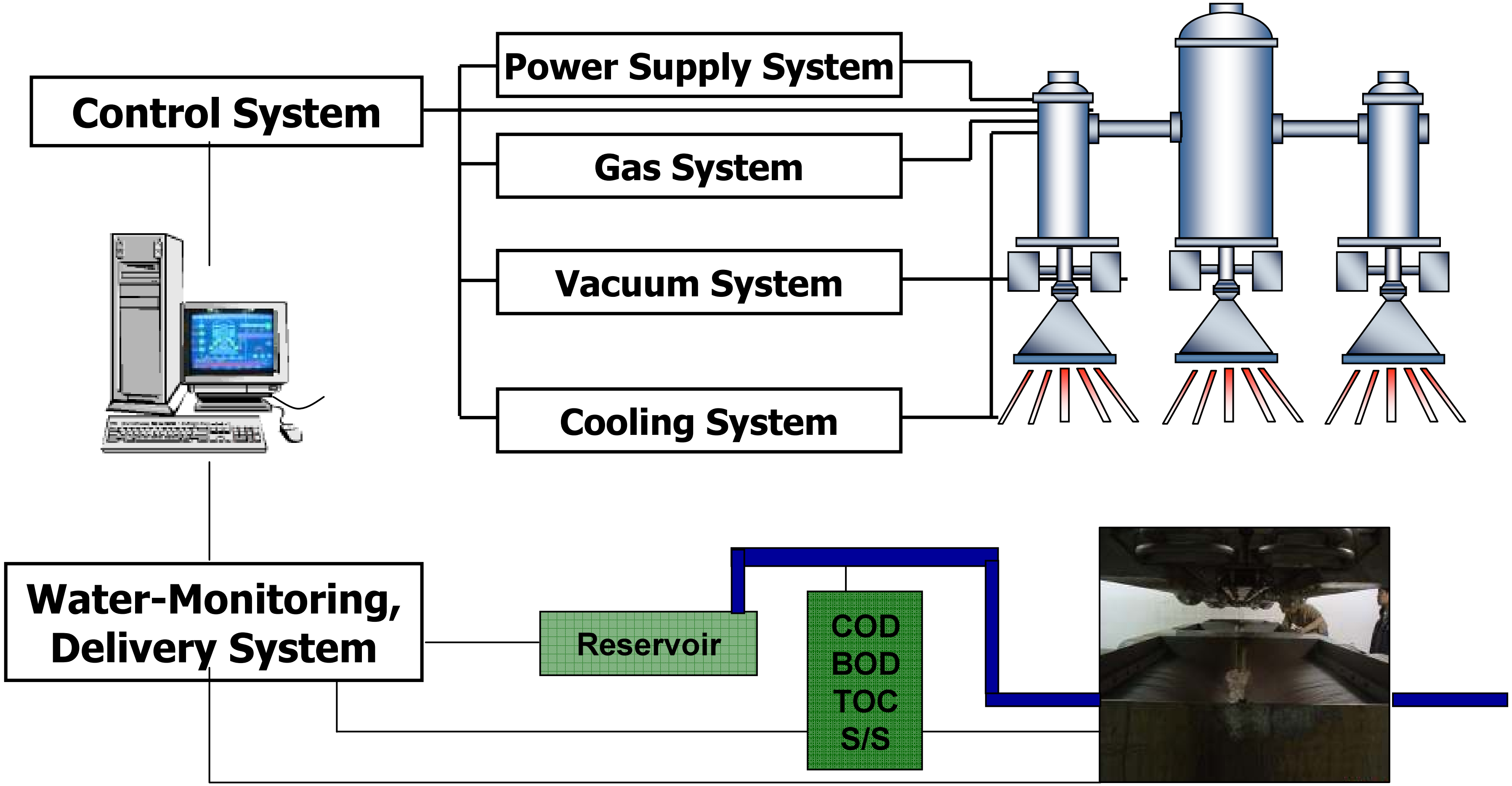
-. Power loss
+. Less than 1%, 4~5kW for 400kW
+. power loss concentrated on small area (jumping area)

High Power Accelerator (EB TECH & BINP)

ELV-12 Accelerator:
Energy : 0.6 - 1.0 MeV
Beam power: 400 kW
Beam current: 500 mA

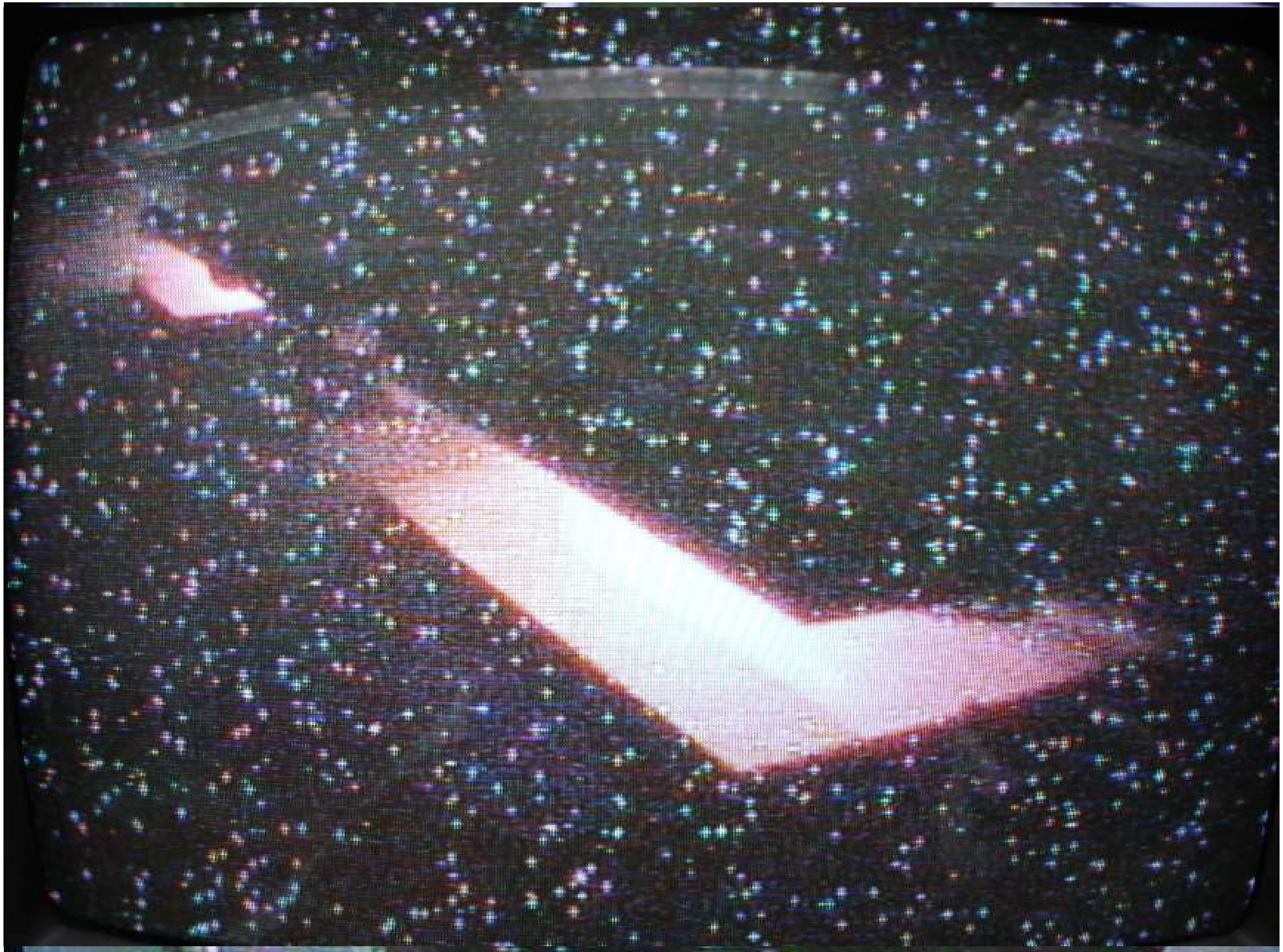
Irradiators : 3 (0~200mA)
Window width : up to 2m
Double extraction window
Discharge protection
High frequency scanning

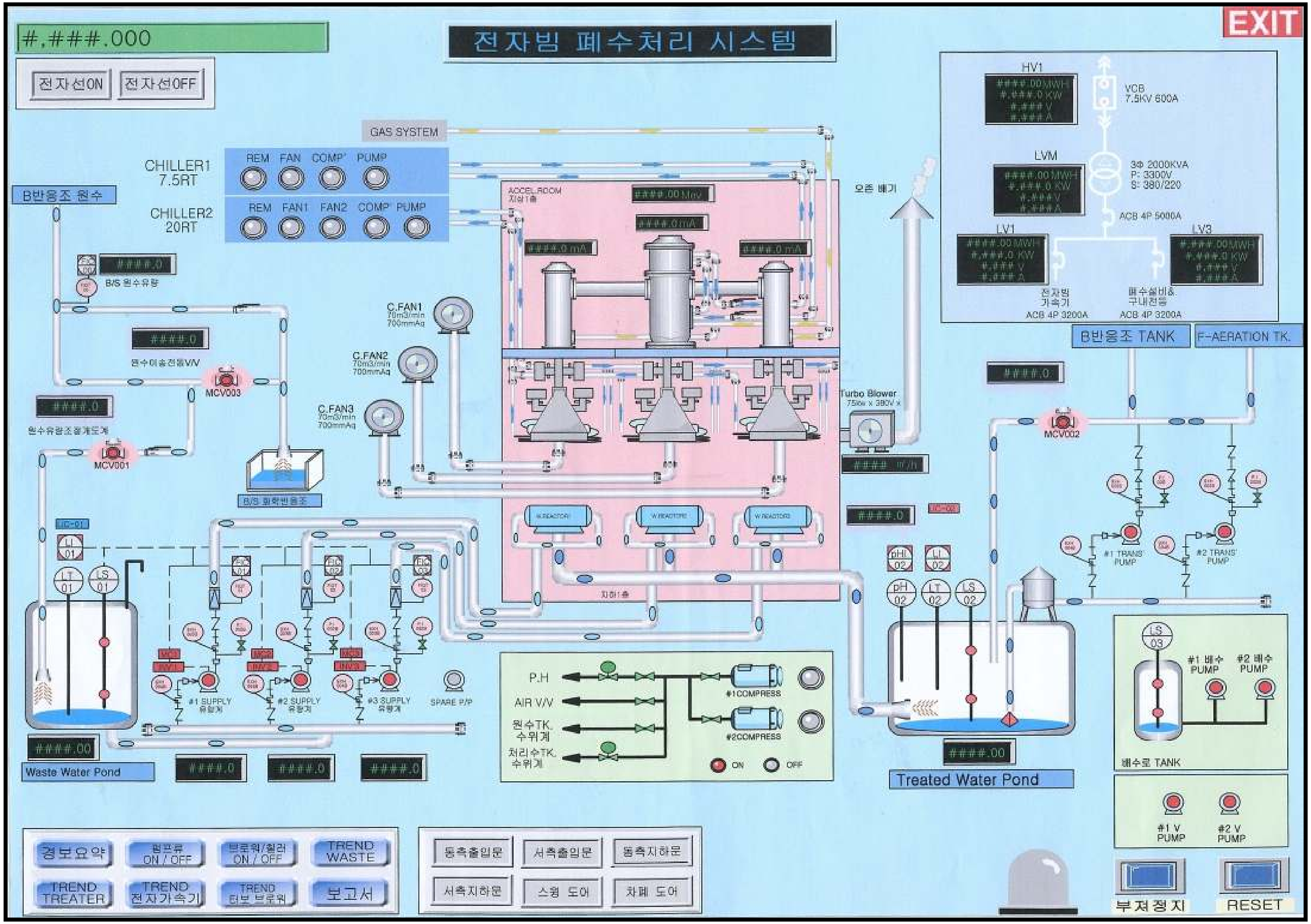
Configuration of e-beam Wastewater Treatment




Dec 17 14:07 14:07
Vacuum condition
F2- Edit a string and print
Program status
Normal mode of operation
Accelerator check disable
1.4 1.3 1.1
4.7 3.7 3.6
1.5 1.4 1.1
4.9 3.9 3.7
I - Enter current
Enter Energy
Print parameters
HF correction UP
HF correction DOWN
Calculate refdatas
LF 1 correction UP
LF 1 correction DOWN
Choose Scansystem
Energy MeV 0.91 0.91 ---
Full Beam Current mA 441.56 451.47 ---
Beam Current 1/2/3 mA 159.90 138.46 160.76
I HVR Up/Low/Total mA 230.14 219.91 450.04
U section Up/Low kV 26.00 25.07 ---
U Pr/Winding Up/Low V 820.44 834.55 ---
I Pr/Winding Up/Low A 1043.58 1033.27 ---
U FC SM2/SM1 +/2 V 485.82 503.28 ---
I FC SM2/SM1 total A 348.61 326.50 ---
I Tube Div-r 1/2/3 mkA 43.98 46.22 52.29
I Diaphragm 1/2/3 mkA 1.00 1.10 1.20
I Ext/Device 1/2/3 mA 23.19 28.17 28.96
U Heater 1/2/3 V 5.10 5.45 7.83
DAC energy V 7.24 7.23 ---

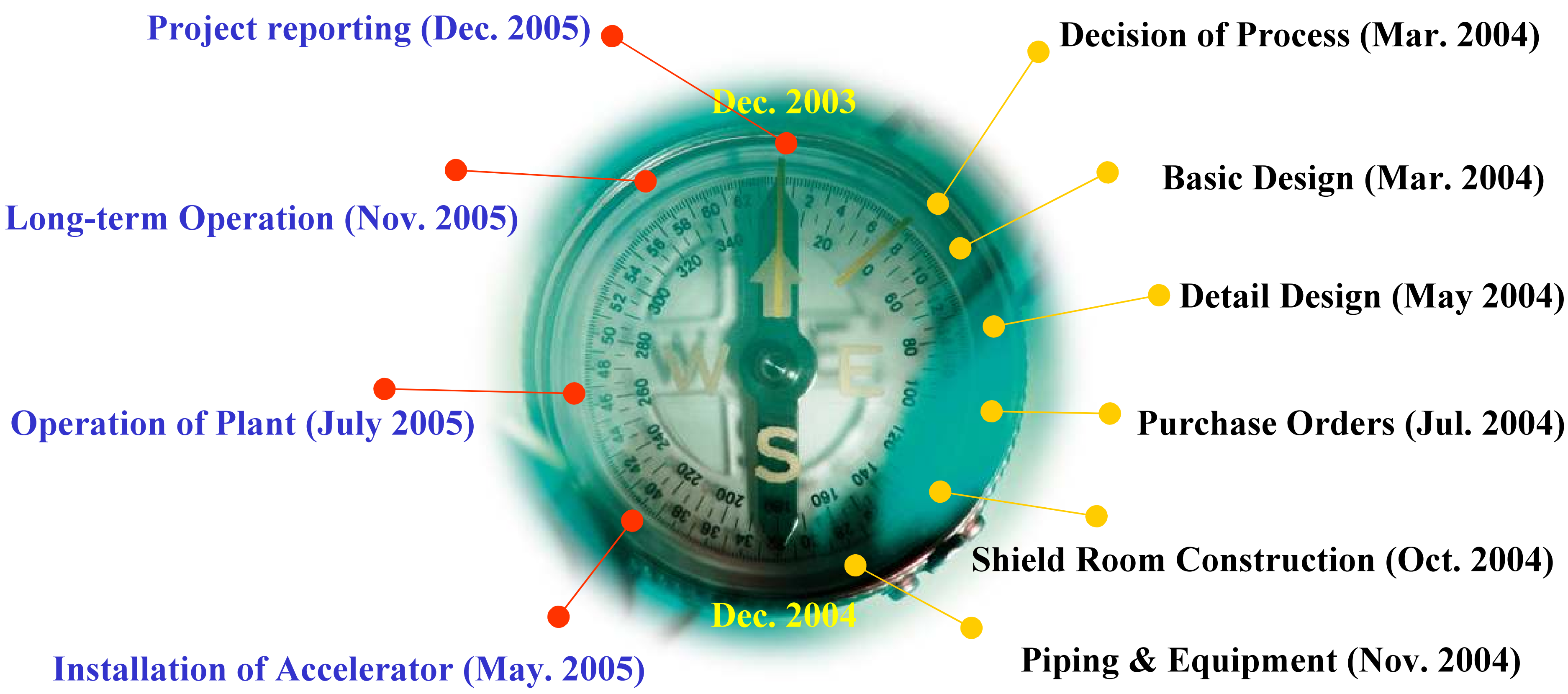

전자선조사실





#.###.000
전자빔 폐수처리 시스템
EXIT
전자선ON
전자선OFF
GAS SYSTEM
CHILLER1 7.5RT
CHILLER2 20RT
REM FAN COMP' PUMP
REM FAN1 FAN2 COMP' PUMP
B반응조 원수
B/S 원수유량
C.FAN1
C.FAN2
C.FAN3
MCV003
MCV001
MCV002
B/S 화학반응조
ACCEL.ROOM
오존 배기
Turbo Blower
HV1
VCB 7.5KV 600A
LVM
3Φ 2000KVA
ACB 4P 5000A
LV1
LV3
전자빔 가속기
ACB 4P 3200A
ACB 4P 3200A
B반응조 TANK
F-AERATION TK.
#1 SUPPLY
#2 SUPPLY
#3 SUPPLY
SPARE P/P
Waste Water Pond
P.H
AIR V/V
원수TK. 수위계
처리수TK. 수위계
#1COMPRESS
#2COMPRESS
ON
OFF
#1 TRANS' PUMP
#2 TRANS' PUMP
Treated Water Pond
#1 배수 PUMP
#2 배수 PUMP
배수로 TANK
#1 V PUMP
#2 V PUMP
경보요약
TREND WASTE
TREND TREATER
보고서
동측출입문
서측출입문
동측지하문
서측지하문
스윙 도어
차폐 도어
부저정지
RESET

Master Schedule



-. Fixed cost : interest of 8% and depreciation in 20 years
-. Variable cost (based on the year round operation : 8000hr/yr)
  +. Electricity consumption (700kW) :
   accelerator 500kW (80% efficiency) other equipment 200kW
  +. Labour cost (3-shift) : 100,000$/yr

Items		Cost Increase by Introducing E-beam	Remarks
Operation Cost	Invest (k$) Interest Depreciation	(3,000) 240 150	 8% 20yrs
	Electricity Labour Maintenance, etc.	312 100 80	700kW 3 shift 2%
Total cost		882	E-beam only

-. Operation cost for m^3 of effluent
  +. 882,000$ / 10,000 m^3/day /300 ≈ 0.3$ per m^3 = 30 ¢ per m^3

		Existing Facility	E-beam plant *	Remarks
Capital cost	Investment Interest Depreciation	- - -	(3,000) 240 150	 8% 20 years
Operating cost	Chemicals Sludge treatment Electricity	1,367 1,712 497	580 1,005 809	
	Total	3,576	2,784	EB + bio

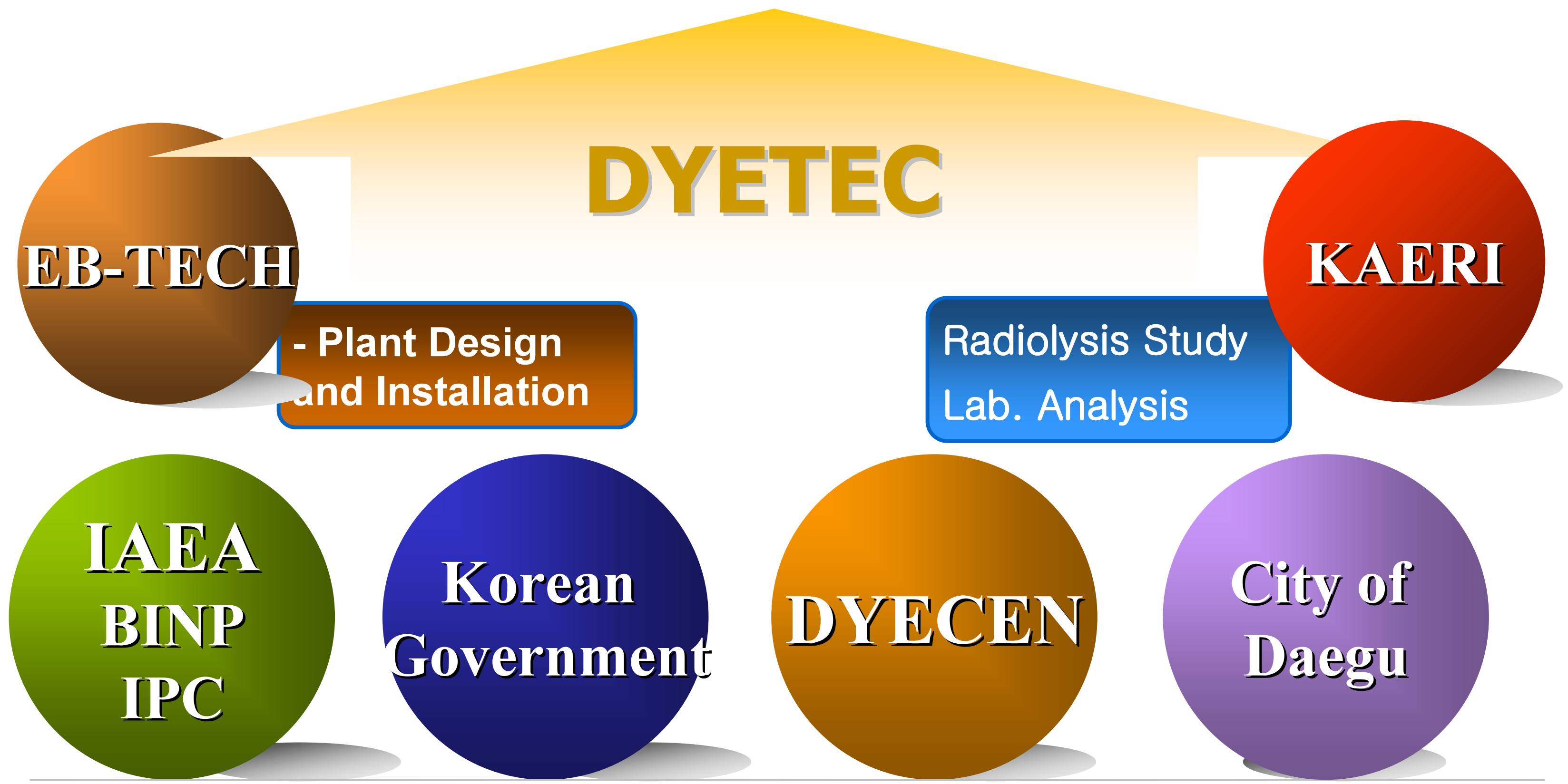
-. Comparison with existing facility

+. Savings by reduction of Chemicals in pre-treatment

+. Savings of sludge treatment costs by reduction in chemicals and also the reduction in retention time in bio-treatment

+. Increase in electricity consumption

-. Moreover, the quality of treated water has improved



-Technical Support -Consulting	- Research Project - Peaceful use of Radiation Technology	- Analysis of Economy - Electric Power - Bio-treatment	- Funding from Local Gov. Budget

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**

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

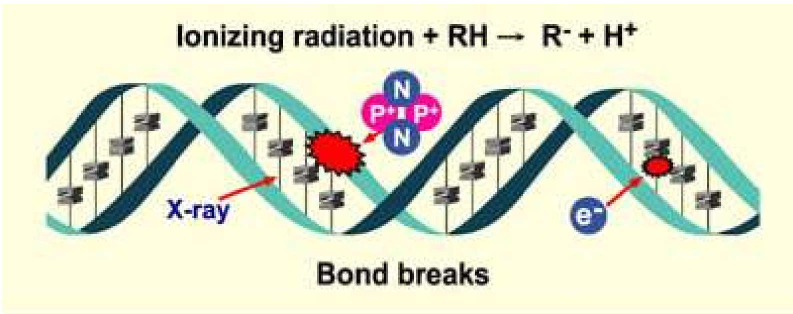
To discharge to river, or to re-use in industries or irrigation

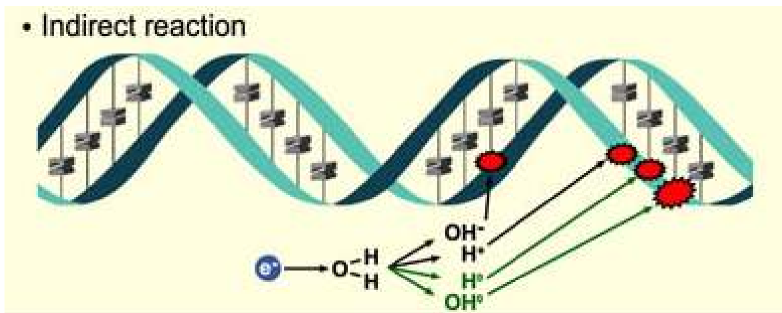
-. Disinfection of microorganisms
(Coli-form & pathogenic organisms)

-. Destruction of endocrine disrupter (natural and synthetic chemicals such as Nonyl phenols and its derivatives)

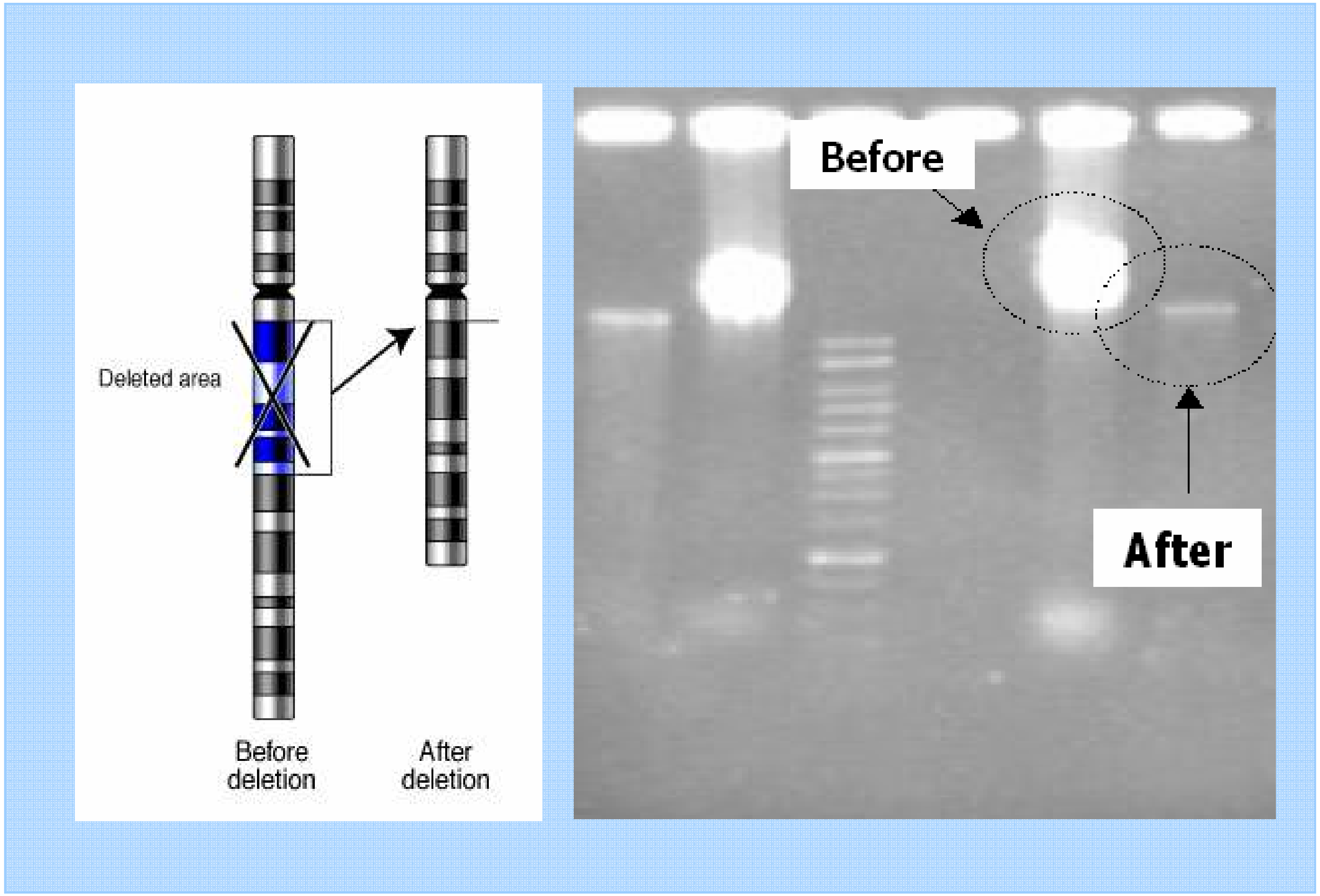
$$H_2O \xrightarrow{\text{E-Beam}} \bullet OH,\ H\bullet,\ e^-_{aq},\ H_2,\ H_2O_2$$

$\bullet OH$, $H\bullet$, e^-_{aq}, + DNA (in microorganism) $\rightarrow$ Damage to DNA,
(Inactivation of bacteria)





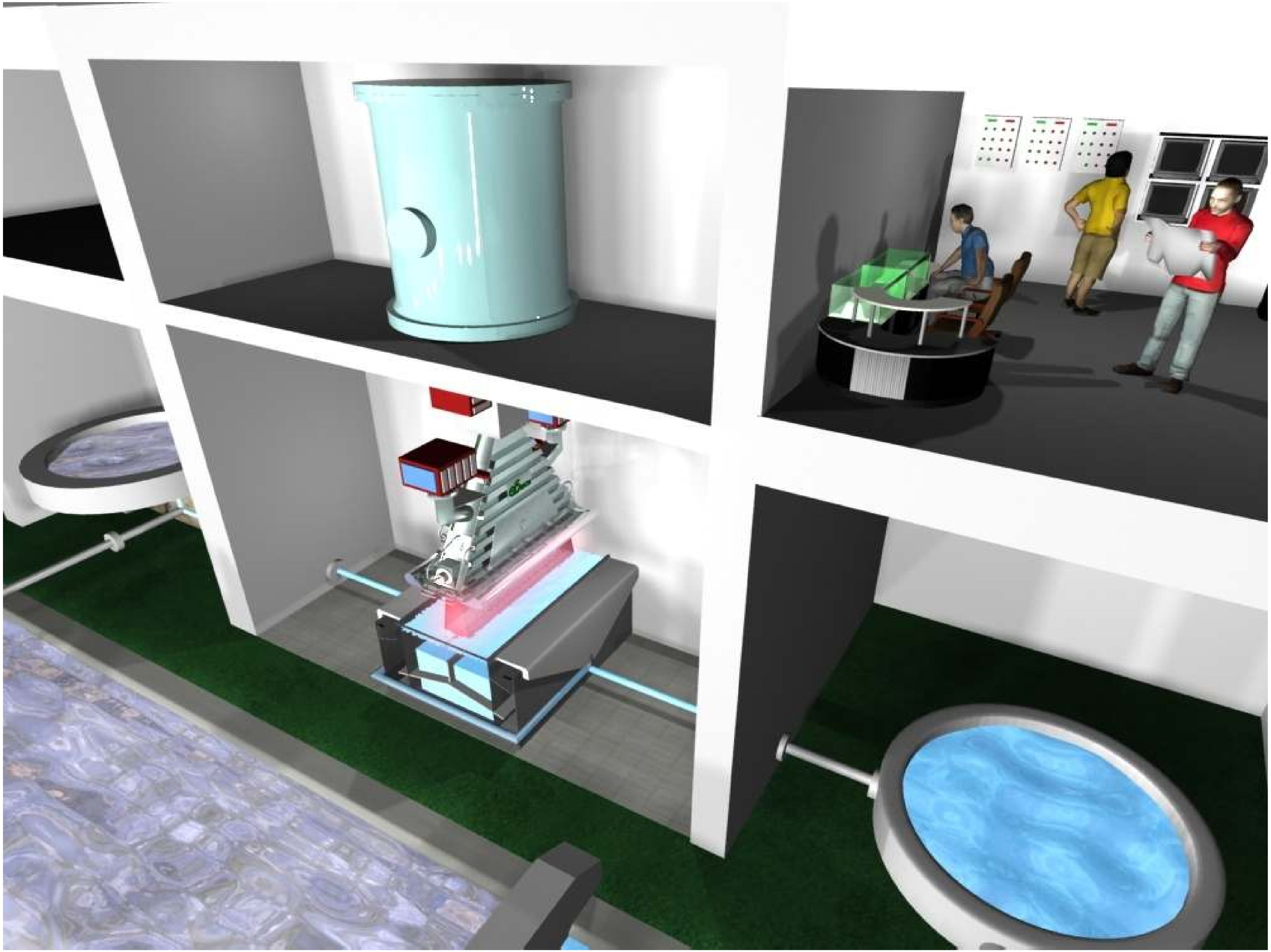
Sterilization Mechanism



Variation of DNA at E. Coli before and after electron beam (Electrophoresis)

Comparison in Disinfection Technology

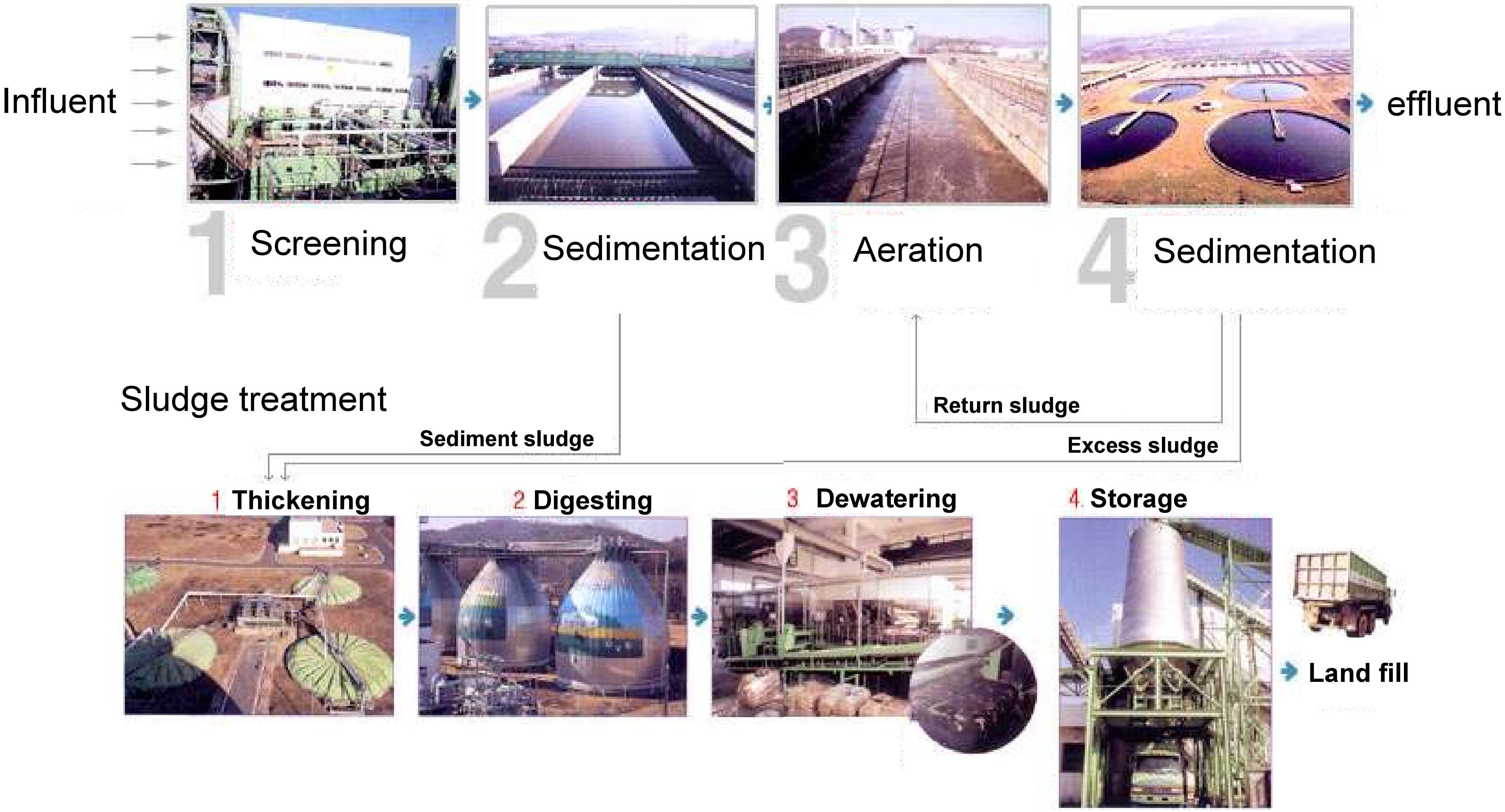
CHLORINATION	UV RADIATION	OZONE	ELECTRON BEAM
Enhances color removal. Least expensive disinfection.	Effective against bacteria & viruses at low dosages. Not efficient in large scale	More effective than chlorine for inactivation of viruses. Biocidal activity is not influenced by pH. Not efficient in large scale	Very effective against bacteria & viruses at low dose. Simple design and feasible to large scale.
Forms THMs. Chlorine gas is a hazardous corrosive gas.	Water with high calcium, turbidity & phenols may not be applicable Maintenance cost of UV lamp is high.	Byproducts are formed (bromide, aldehydes, ketones). Initial cost of ozonation equipment is high.	Needs Shielding (X-ray)



Municipal Wastewater Treatment Plant in Daejeon

Capacity : 900,000m³/day
Influent : 664,000m³/day

Municipal wastewater treatment



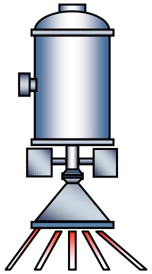
Existing System

Discharge after Bio treatment

Coli–forms etc.

Residual odor, colors

Proposed System



Radiation

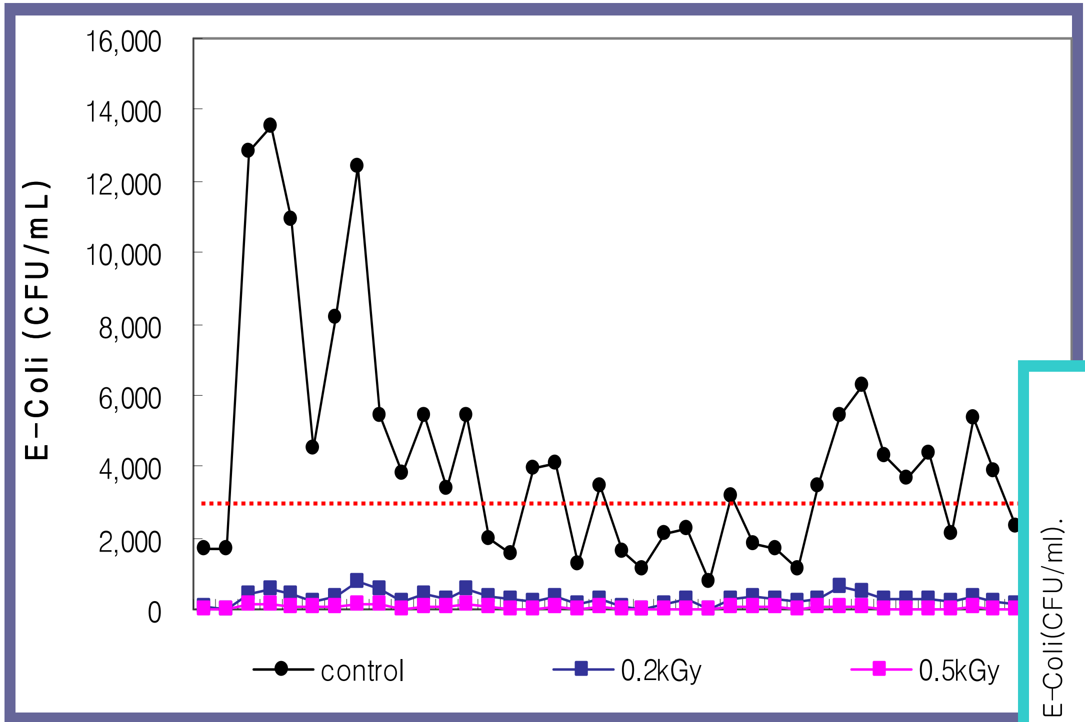
Disinfection, Removal of odor, colors

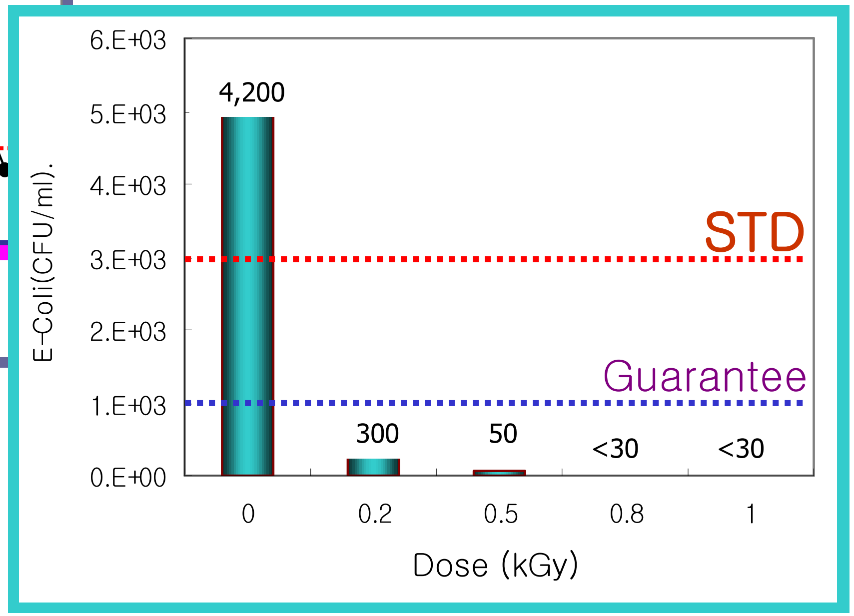
Irrigation

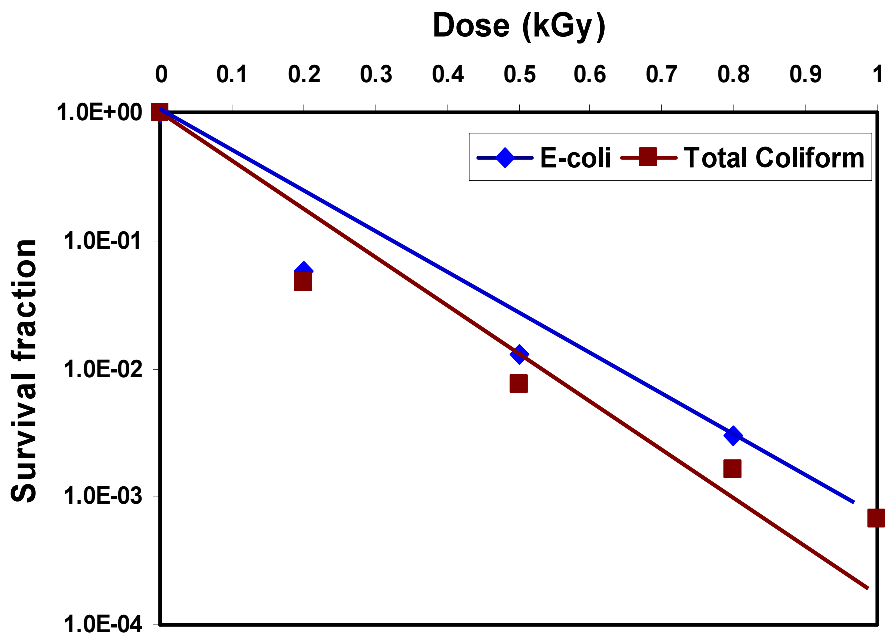
Industries

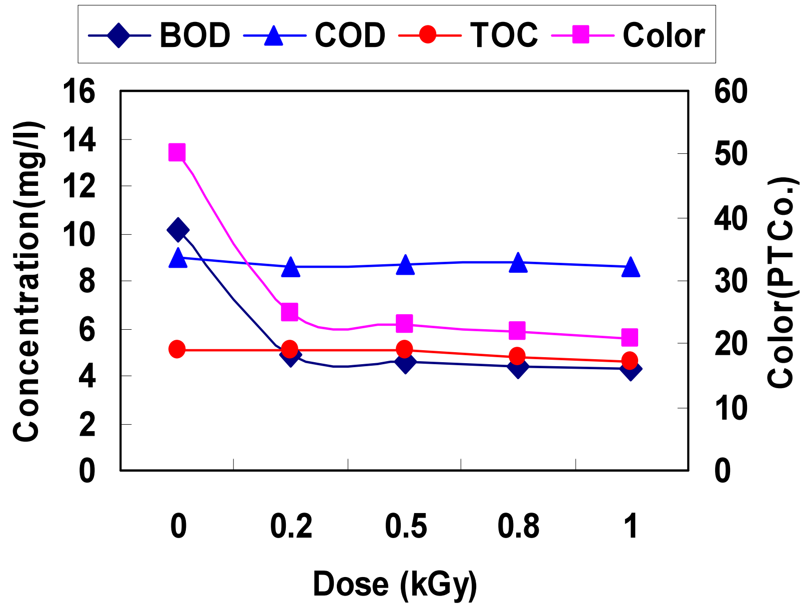
Re–use

E-Coli


16,000
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
E-Coli (CFU/mL)
control
0.2kGy
0.5kGy


6.E+03
5.E+03
4.E+03
3.E+03
2.E+03
1.E+03
0.E+00
E-Coli(CFU/ml).
4,200
300
50
<30
<30
STD
Guarantee
0
0.2
0.5
0.8
1
Dose (kGy)





Effect of electron beam on the effluent from municipal wastewater plant:
a – radiation induced inactivation of some coliforms in the effluent;
b – variation of BOD, COD, TOC and Color with absorbed doses.

Design and Estimation of E-beam plant

-. For Treating Effluent from Municipal Wastewater Plant
or from the Contaminated Ground water

-. To re-use in Irrigation or Industrial purposes

-. Design Basis

+. Capacity : 100,000 m^3/day

+. Dose : around 0.2 kGy

+. Expectation : Remove microorganisms over 99%
Reduction in Color, Odor etc.

+. Operates year-round

Investment

items		Investment	Remark
Construction	Accelerator	2,000k$	400kW
	Facilities	1,000k$	Shield room
	Others	1,000k$	
Sub-total		4,000k$	
Area		150m^2	

Operation

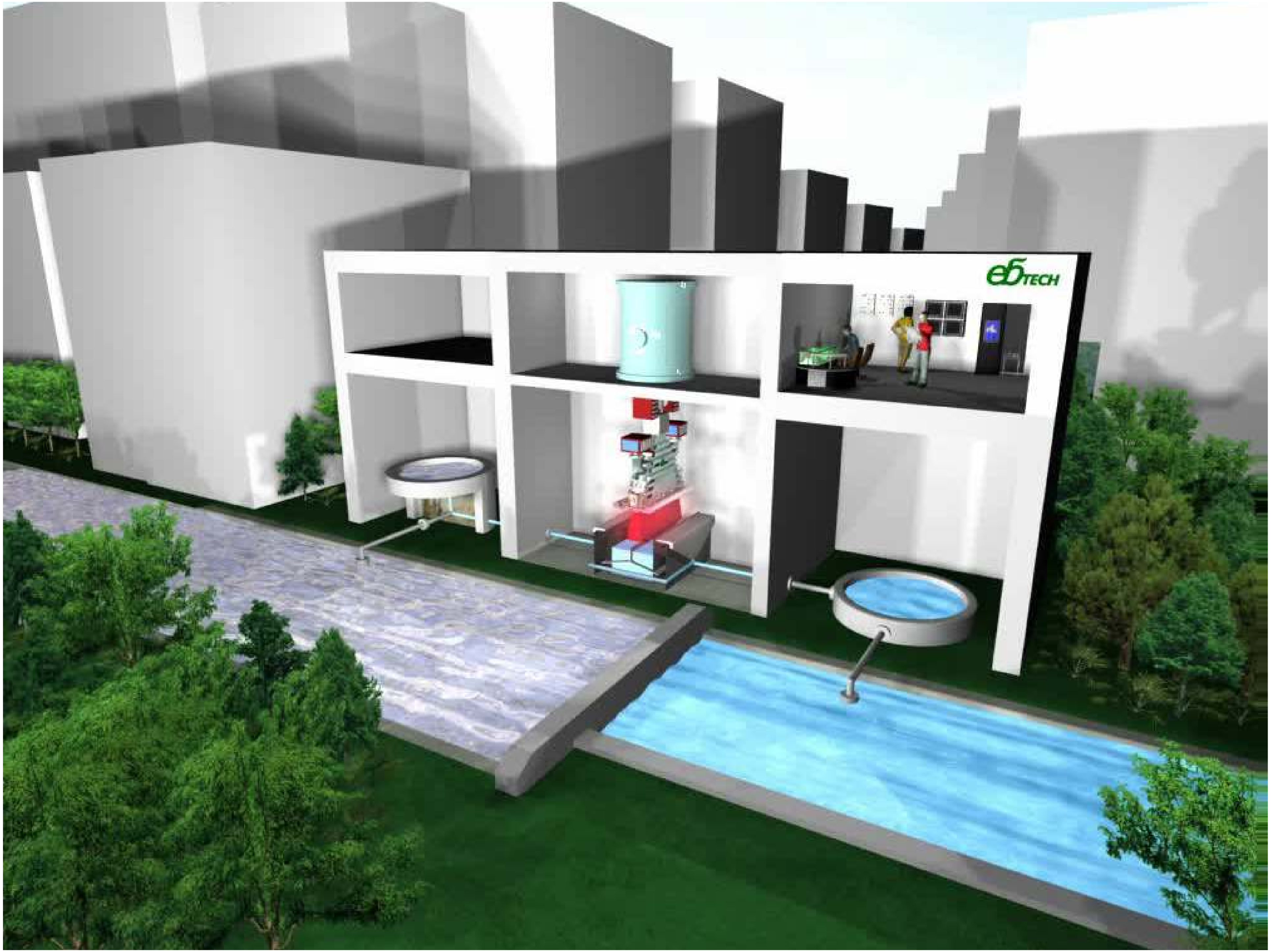
Items	Annual Cost	Remark
1. Labor	100k$	
2. Electricity	320k$	800kW*0.05$/kWh*8000hr
3. Maintenance	80k$	
4. Interest	(240k$)	6%
5. Depreciation	(200k$)	20yrs
Total	500k$(440k$)	

Operation cost→ 940k$/[(100,000ton/day)*330day] = 0.028$/ton

Cost analysis of EB & other processes

Technology	Ozone	Electron Beam(EB)	Ultraviolet (UV)
Flow		100,000m³/day	
Capital Cost	7.4M$	4.0M$	2.4M$
Annual O&M Cost	1.2M$	0.5M$	1.0M$
Etc.			Lamp life : 1year Lamp p/u : $550

1. *Combined Sewer Overflow Technology Fact Sheet, Alternative Disinfection Methods [EPA 832-F-99-033] September 1999*
2. *Wastewater Technology Fact Sheet, Ultraviolet Disinfection [EPA 832-F-99-064] September 1999*
3. *1999 Drinking Water Infrastructure Needs Survey, Modeling the Cost of Infrastructure [EPA 816-R-01-005] February 2001*
4. *EB-TECH Report[2001]*



		Amount of wastewater (m^3/day)		
		1,000 or less	*1,000~10,000*	*over 10,000*
A/S	**Invest**	**H**	**M**	**L**
	Operation	**M**	**L**	**L**
Ozone	**Invest**	**M**	**MH**	**H**
	Operation	**M**	**MH**	**H**
Membrane	**Invest**	**M**	**H**	**H**
	Operation	**M**	**H**	**H**
E-beam	**Invest**	**H**	**M**	**L**
	Operation	**LM**	**L**	**L**

Relative cost for treating less-polluted industrial wastewater

1. Find the proper radiation source for products

-. Gamma-ray, X-ray, or e-beam

2. Reduce doses

-. with combined methods (Bio-, Physical/chemical etc.)

3. Apply cost-effective accelerator

4. Engineering Approaches

-. Analysis of existing process → Calculate the present cost

-. Economics of radiation → Max. allowable radiation doses

-. Find useful additives or combination for lowering doses

-. Laboratory test → Confirmation of process

-. Pilot plant → Industrial scale design → Commercial plants

5. Show and Prove the feasibility by pilot operation

-. Laboratory experiments → Pilot scale test with Mobile machine

Lab. Scale Experiments ($1 \sim 50 m^3$/day)

Lab. Scale Experiments ($1 \sim 10,000 Nm^3$/h)

Pilot scale Experiments ($500 \sim 1,000 m^3$/day)

-. Cost
-. Space
-. O & M etc.

Industrial scale Wastewater Plant ($10,000 m^3$/day)

Industrial scale EBFGT Plant ($\sim 600,000 Nm^3$/h)

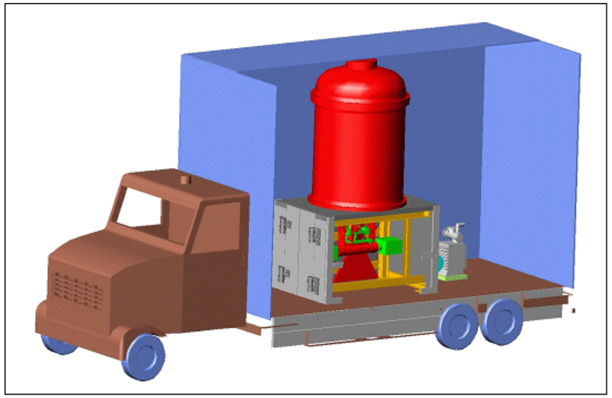
Construction Cost for Pilot Plant

Type	Capacity	Main facility	Others	Total
Liquid	500~1,000m^3/d with 1~5kGy	accelerator (50kW) 0.7M$ shieldroom and Civil 0.4M$ reactor/piping etc. 0.2M$	reservoir 0.3M$ etc. 0.1M$	1.7M$
Gas	~20,000Nm^3/h with 4~8kGy	accelerator (50kW) 0.7M$ shieldroom and Civil 0.4M$ reactor/piping etc. 0.2M$	cooler 0.2M$ ESP 0.4M$ etc. 0.1M$	2.0M$
Sludge	10~20m^3/h with 10kGy	accelerator (50kW) 0.7M$ shieldroom and Civil 0.4M$	conveyor 0.1M$ feeder 0.3M$ piping etc. 0.2M$	1.7M$

Lab. Scale Experiments (1~50m^3/day)

Lab. Scale Experiments (1~10,000Nm^3/h)

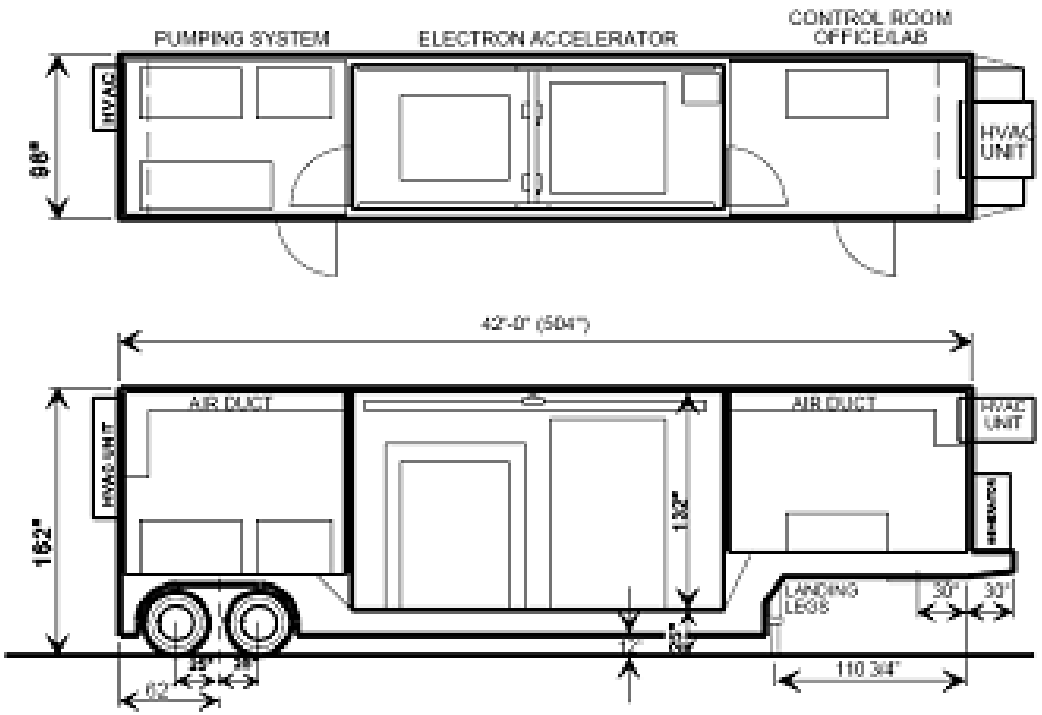
Pilot scale Experiments (500~1,000m^3/day)



Industrial scale Wastewater Plant (10,000m^3/day)

Industrial scale EBFGT Plant (~600,000Nm^3/h)

Previous Mobile Accelerator (HVEA, U.S.A. 1990)



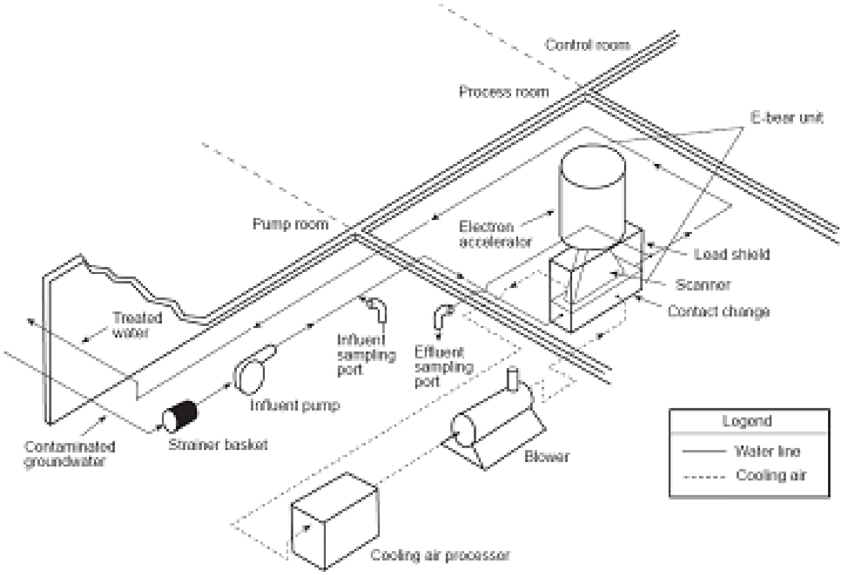
ICT accelerator

500 keV

0~40 mA

Max. 20kGy

for watsewater

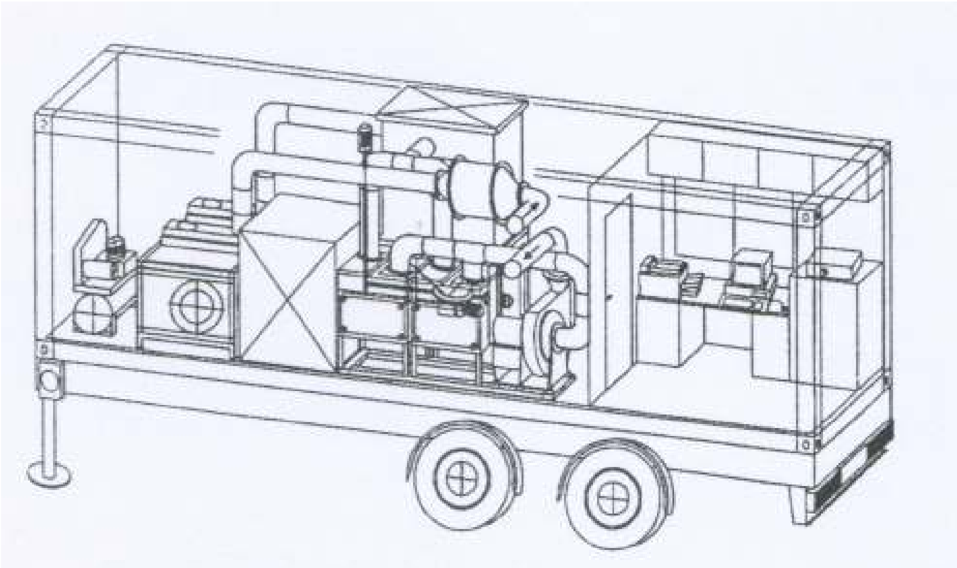


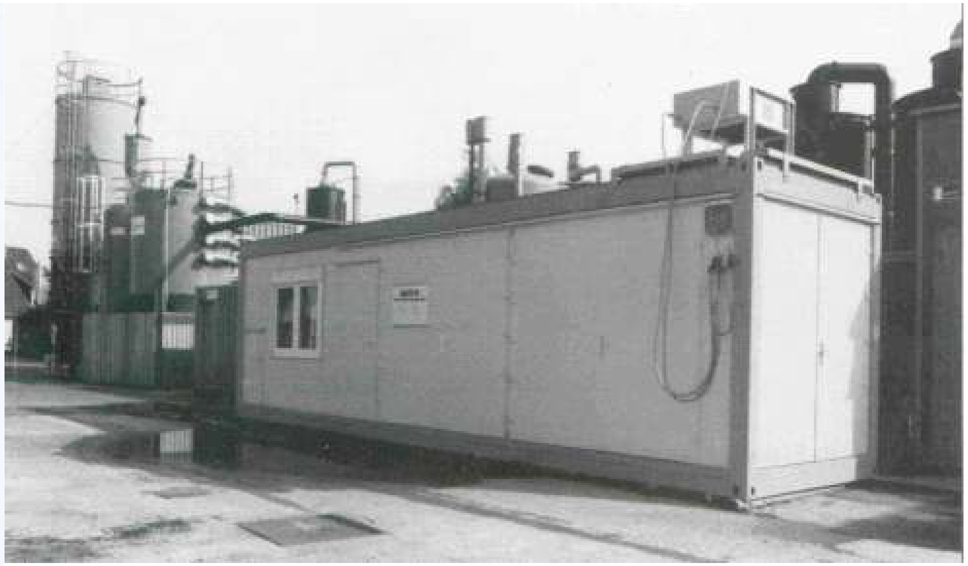
Ref.) Environmental Applications of Ionizing Radiation, Edited by william J. Cooper, Randy D. curry, and Kevin E. Oshea, "Field Application of a mobile 20-kW electron beam treatment system on contaminated groundwater and industrial wastes", p.451-466, ISBN 0-471-17086-0, 1998 John Wily & Sons, Inc.

Previous Mobile Accelerator (FZK, Germany 1984)

ESI Electrocurtain 200 keV, 0~150 mA

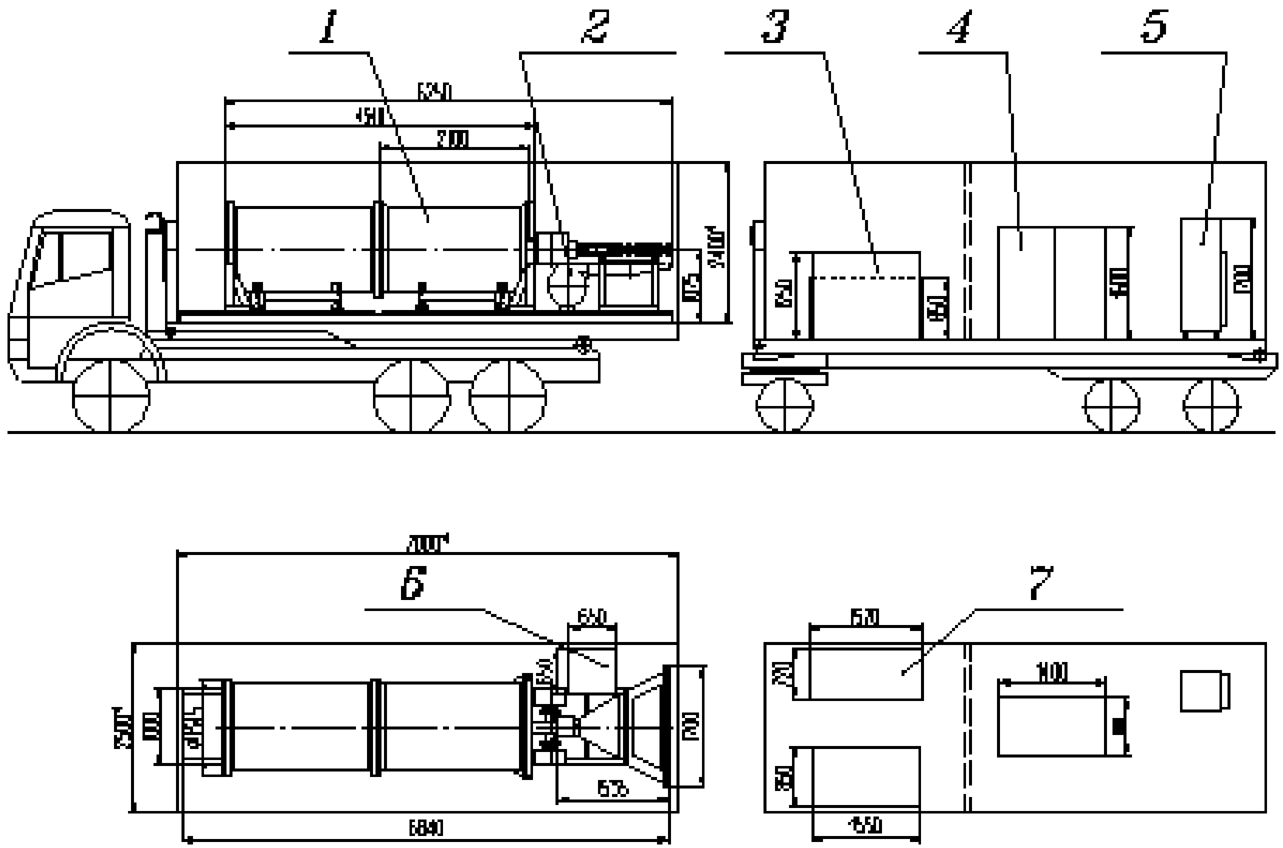
Flow rate : 1,000Nm^3/h for gas treatment



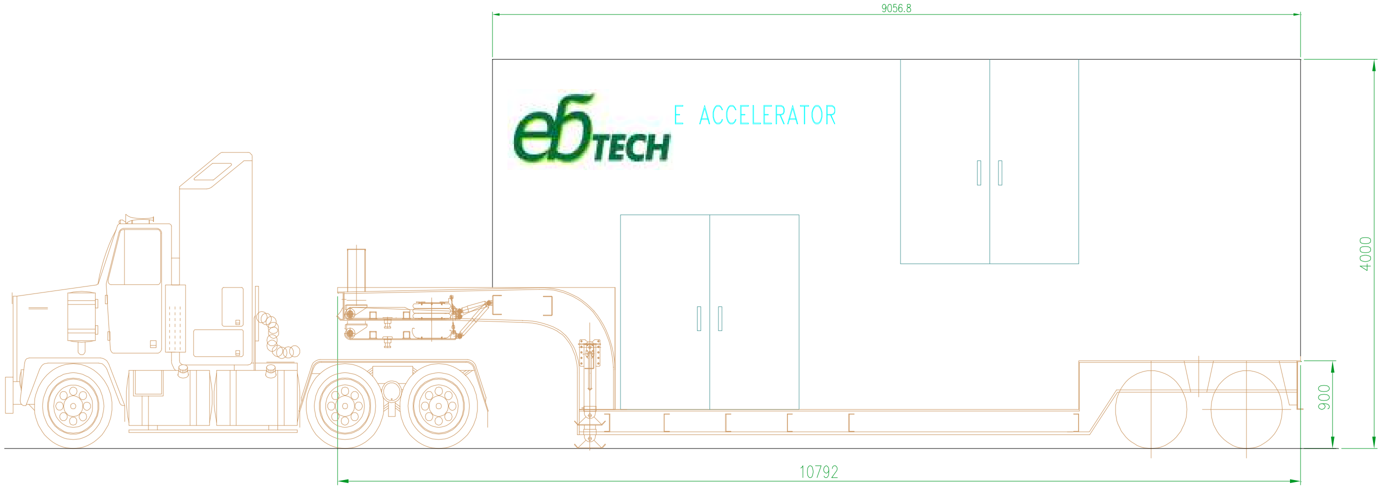


Ref.) FUCH, P.; ROTH B.; SCHWING, U.; ANGELE, H.; GOTTSTEIN, J. Removal of NOx and SO2 by the electron beam Process. Radiation Physics and Chemistry, 31, No. 1-3,(1988) 45-56

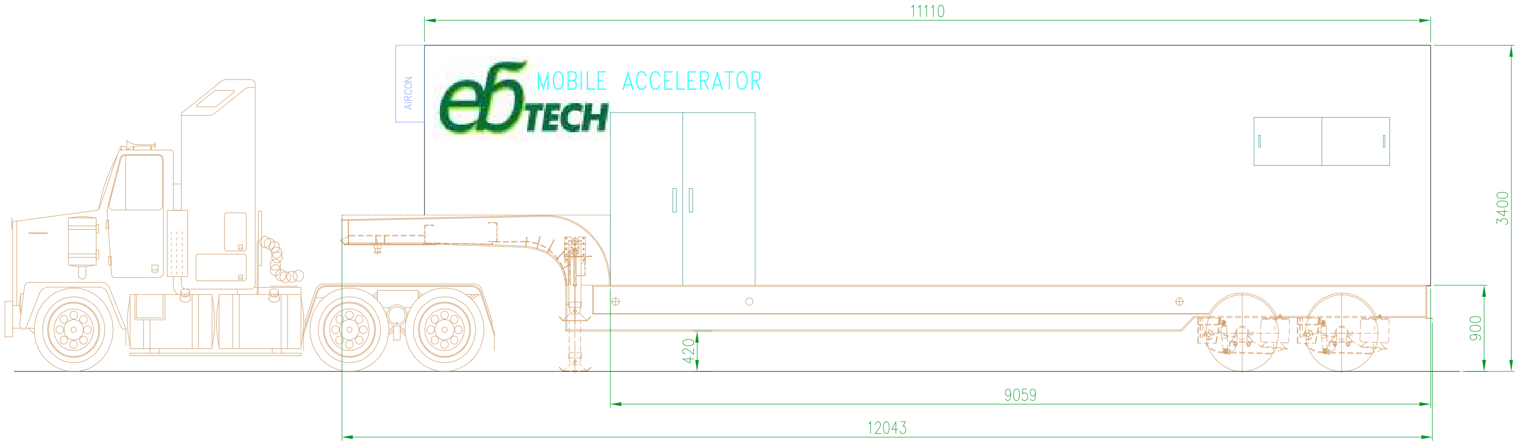
Previous Mobile Accelerator (BINP, Russia design)



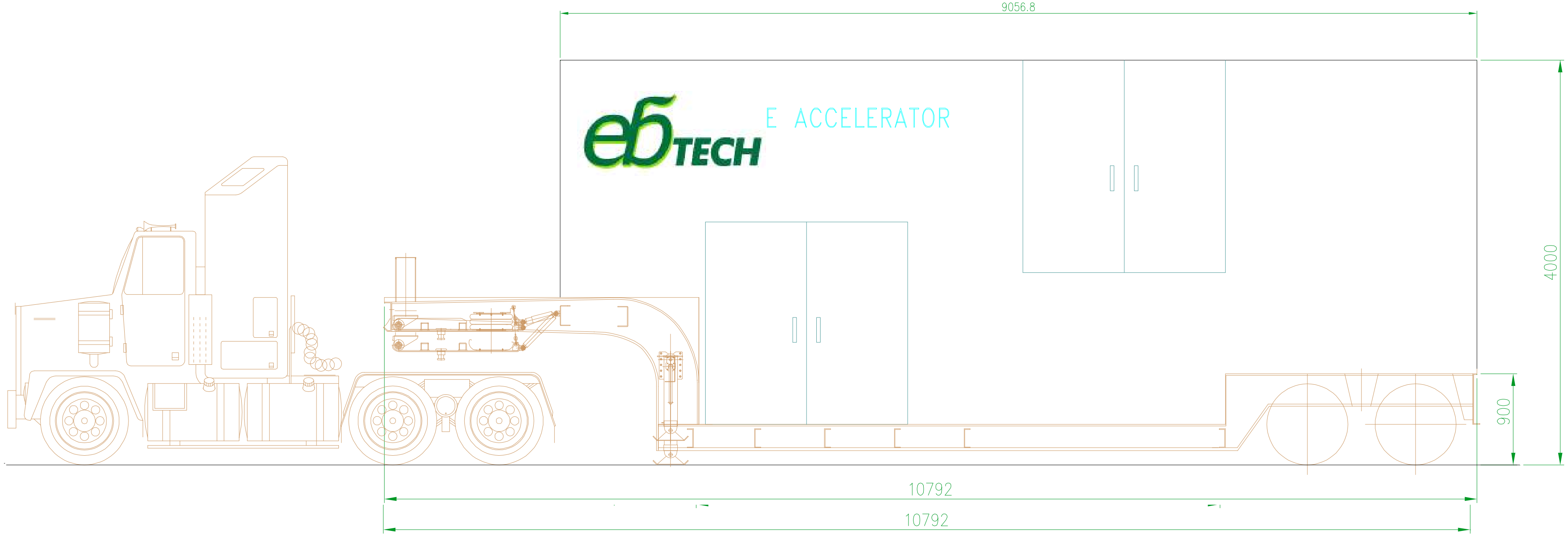
Ref.) VESTNIK "RADTECH-EUROASIA", Edited by S.I.Suminov "Accelerators of ELV type : Status, Development, Applications" pp6~15 Novosibirsk, 1999



Electron Accelerator



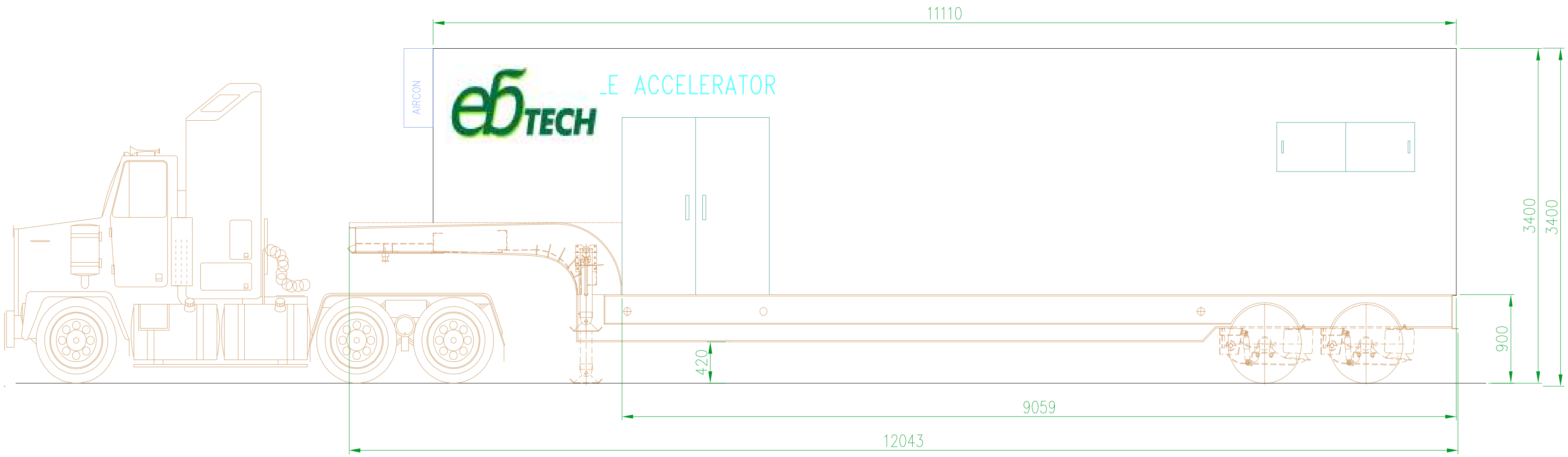
Experimental and analysis systems



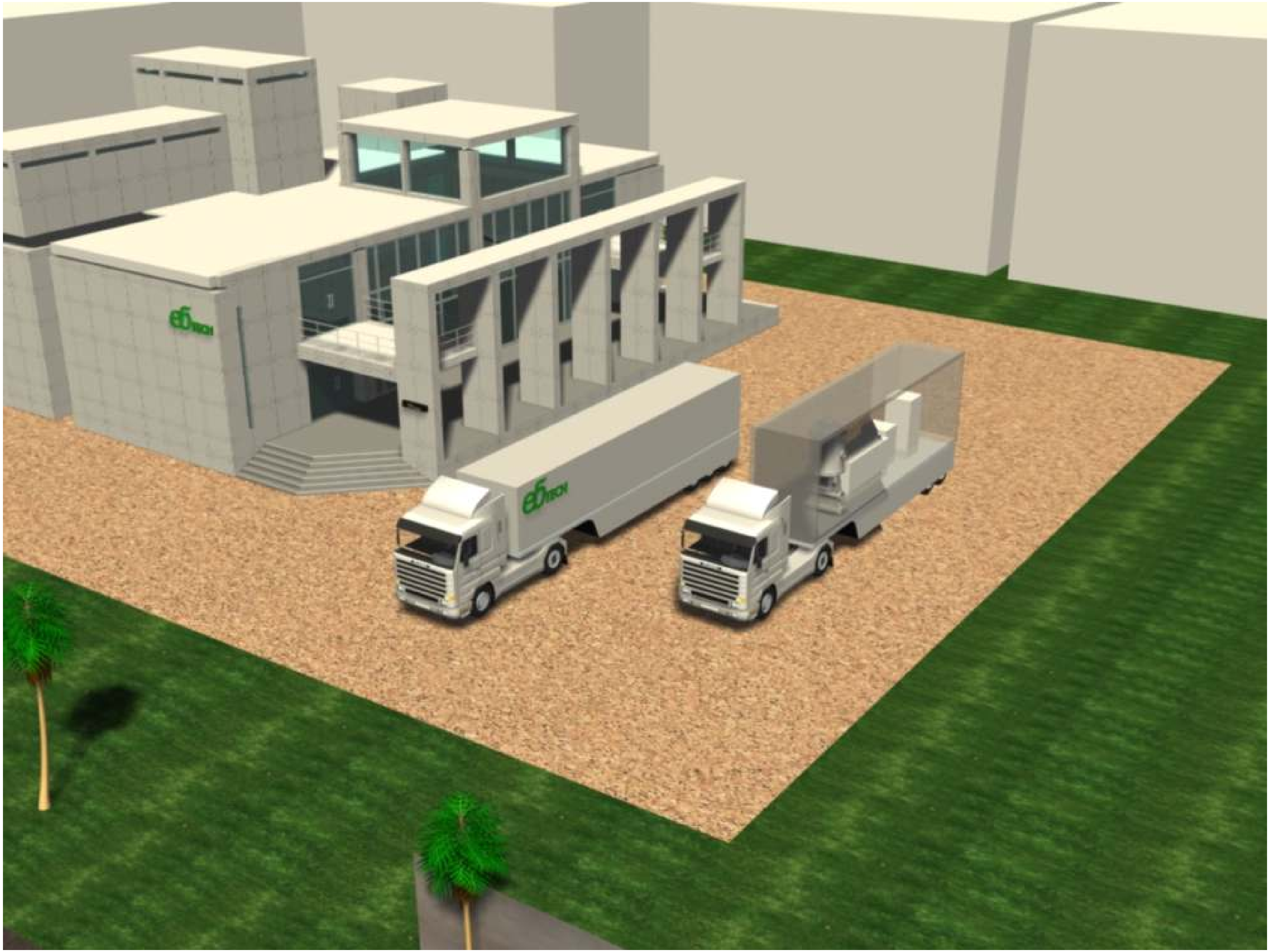
Beam Energy : 0.4~0.7MeV,   Beam Power : 20kW

Self-sustaining system : Diesel electricity generator

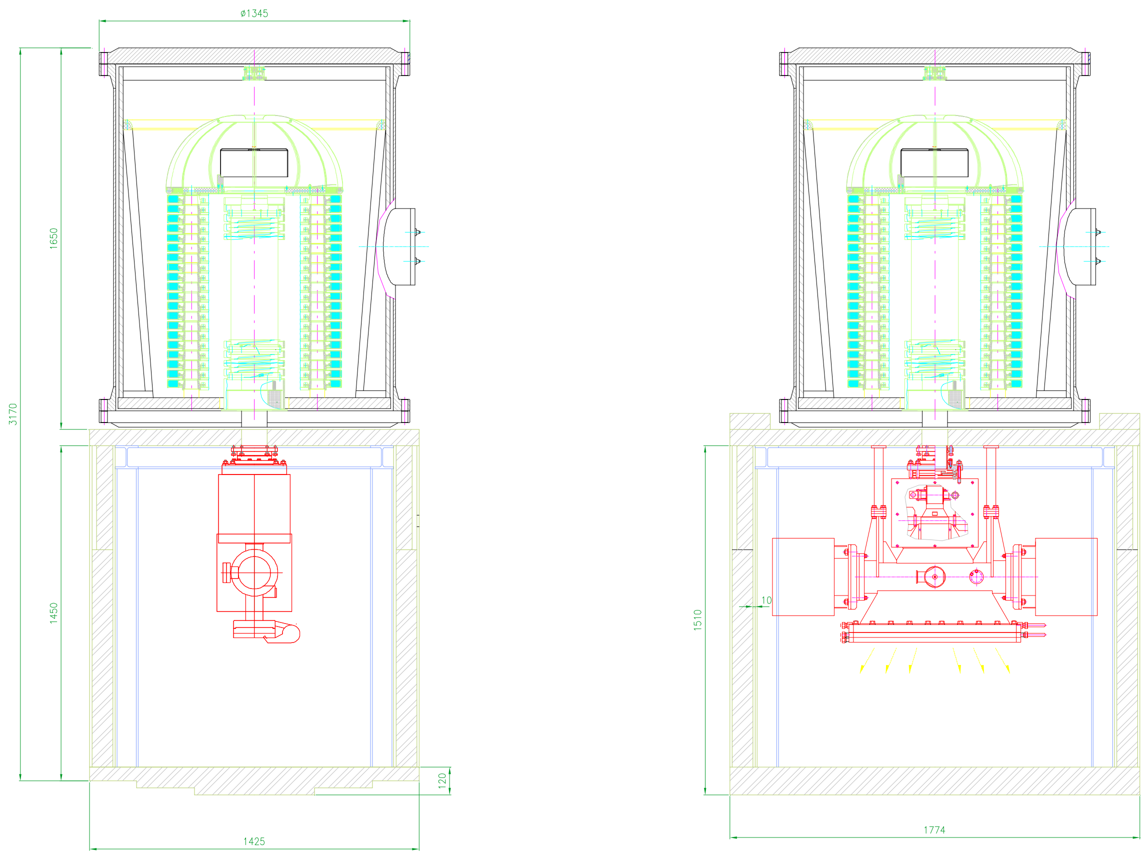
Total weight : 40 tons



Treatment Capacity	**Liquid waste**	**: 500m³/day**	**(at 2kGy)**
	Gaseous waste	**: 10,000Nm³/h**	**(at 4kGy)**
	Sludge	**: 10m³/h**	**(at 10kGy)**




TECH



Window size : 640mm, Height from bottom to window : 560mm

Reactors for water, gas and sludge can be located upon the experiments

us

Application of mobile accelerator

-. Reduction of SO_X /NO_X, Dioxin from power plant

-. Removal of VOCs, stench stink etc.

-. Treatment of contaminated underground water

-. Treatment of Industrial wastewater

-. Reclaimanation of effluent from municipal plant

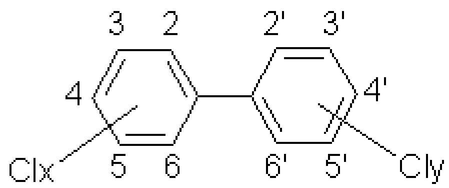
-. Sludge hygienization

Current Application of e-beam wastewater

-. Treatment of Textile Dyeing Wastewater
(Korea, Sri Lanka, Brazil etc.)
-. Removal of Toxic Chemicals from Pharmaceutical and Petrochemical Companies.
(Pesticide, Explosives, Dyes etc.)
-. Removal of PCBs from the Transformer Oils

Removal of PCBs in Transformer Oil

PCB (PolyChlorinatedBiphenyl) :



Current Application of e-beam wastewater

-. Treatment of Textile Dyeing Wastewater
(Korea, Sri Lanka, Brazil etc.)

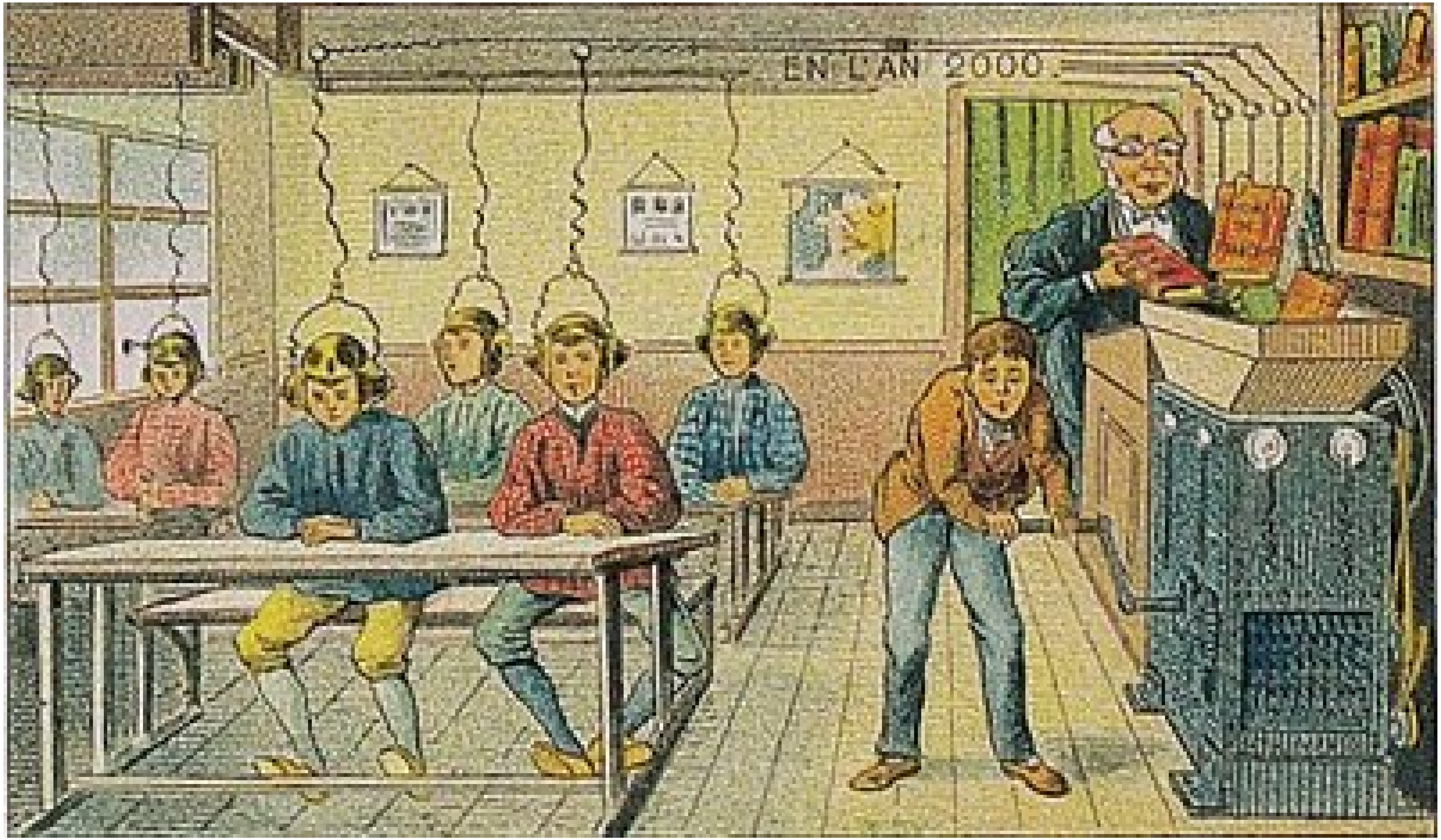
-. Removal of Toxic Chemicals from Pharmaceutical and Petrochemical Companies.
(Pesticide, Explosives, Dyes etc.)

-. Removal of PCBs from the Transformer Oils

-. Reclamation of Municipal Wastewater
(Disinfection, Removal of endocrine disruptors)

-. Treatment of Contaminated Underground Water
(MTBE, PCBs, Oils, etc.)

-. Drinking Water (?)



Drawing by Villemard (1910) – Which will be possible in year 2000
(National Library of France)

Summary

1. Radiation processing has been one of the promising process for environmental treatment, such as Flue gas/VOC, Water/ Wastewater, and Sludge from 1970s. However, implementation of large scale plant has still several barriers. (both in technical and economical)

2. Accelerators of several hundreds kilowatt power is already available in the market, and some of them have proved their reliability in long term operation in Flue gas treatment or Wastewater treatment.

3. In spite of tough competitions, radiation processes are promising as long as we keep in economic advantages. And in some cases, the radiation treatment is the only and unique solution for treatment (niche application) .

Radiation process (e-beam, ɣ-ray etc.) can survive only when it has Technical & Economical advantages over existing processes.

Thank You for your attention

Electron Beam Technology

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