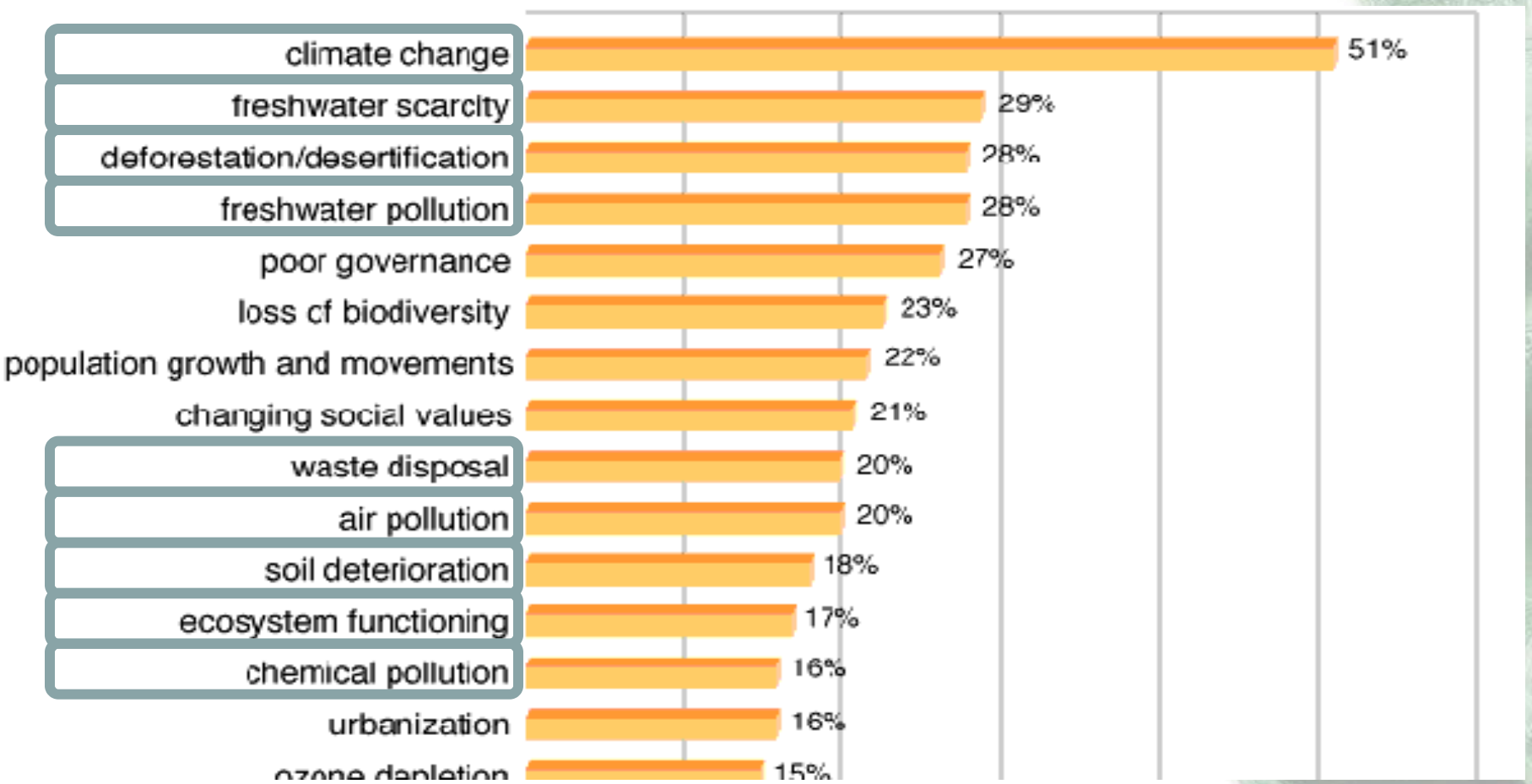
Electron beams for wastewater and sludge treatment

2013. 04. 11

BUMSOO HAN, EB TECH Co. Korea

Consultants' Meeting on "Networking of Users of EB facilities and the Role of the IAEA Collaborating Centers" 8~12 April 2013 INCT, Warsaw, Poland

Major emerging issues identified in the survey (beginning of 2000)



Human Development and Pollution

Human Development

Impressive gains in human development, particularly in the developing world: incomes and income poverty have improved, people are living longer, are healthier, more literate and better educated than ever before.

Average annual incomes in developing countries have mostly risen during 1972- 99 by 13 per cent in Africa, by 72 per cent in Asia and the Pacific and by 35 per cent in Latin America and the Caribbean

World population increased from 3.85 billion people in 1972 to 6.1 billion in mid-2000, and is currently growing by 77 million people a year

Most of the growth is concentrated in developing regions, with nearly two-thirds in Asia and the Pacific, Latin America and the Caribbean .

The Problems

By rapid economic growth, fast urbanization and enhanced industrial activities all of which add to the degradation of the environmental quality.

The environmental pollution caused by industrial discharges and urbanization, among others, has becoming an acute problem in developing cities in the world. In the current prospect, the problem is projected to be amplified in the future if suitable mitigation measures would not be taken.

The efficient treatment of pollutants discharged in various form and contents from the human activities could be an important contribution to the mitigation of the environmental quality management in the world.

The UN Millennium Development Goals

The UN Millennium Development Goals

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Radiation Technology for Pollution Control

Flue gas Purification

Wastewater Treatment

Sludge Hygienization

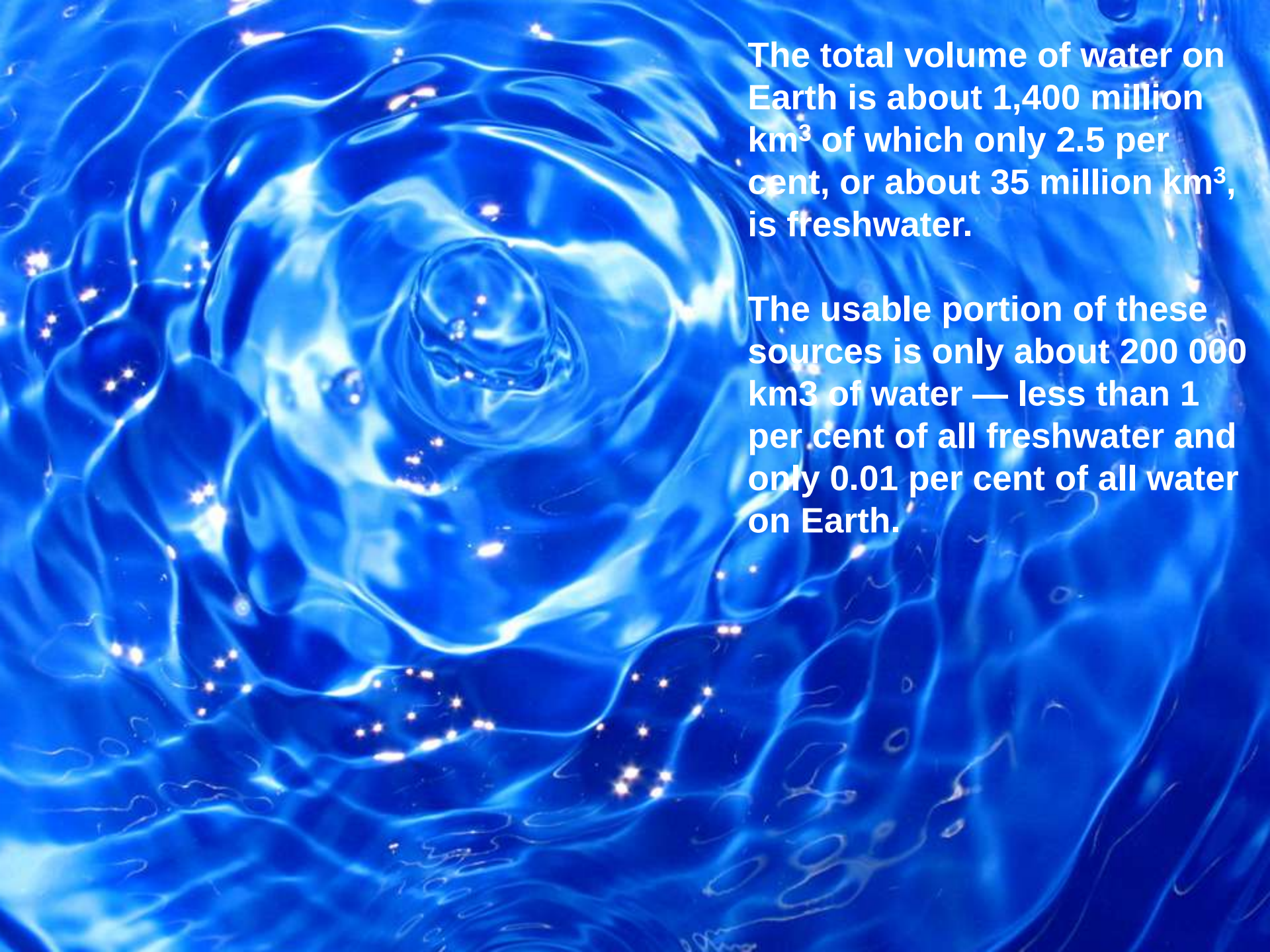
Technical Advantages of Radiation process

*. Electron Beam 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 km³)	*% 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

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

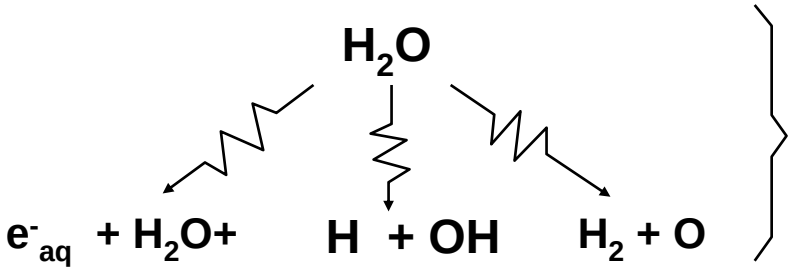
3. Remove odors with radiation chemical reaction

4. Disinfection of microorganisms by destruction of DNA

5. Destruction of endocrine disrupter with radical reaction

6. Recycle for irrigation, impoundment and individual uses

Radiation Chemistry of Water



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

$e^-_{aq} + H_2O+$ $\quad H + OH$ $\quad H_2 + O$

$e^- \longrightarrow e^-_{therm} \longrightarrow e^-_{aq}$

$H_2O^+ + H_2O \longrightarrow H_3O^+ + OH$

$e^-_{aq} + H_3O^+ \longrightarrow H + H_2O$

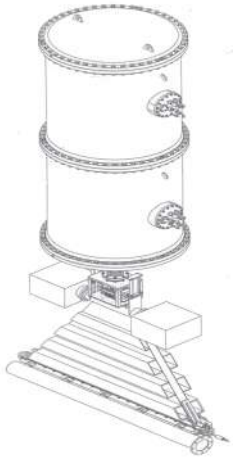
$H + H \longrightarrow H_2$

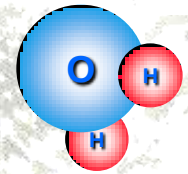
$OH + OH \longrightarrow H_2O_2$

$e^-_{aq} + OH \longrightarrow OH^-$

"Spur" reactions $\leq 10^{-8}$ s

Principles of Wastewater Treatment with E-Beam





Water Molecule

e_{aq}

OH*

H*

H_2O_2

Active Radicals

Harmful Organic in Waste-water

Complete Decomposition → H_2O, CO_2

Partial Decomposition

Suspended Solid

Monomer to Polymerization

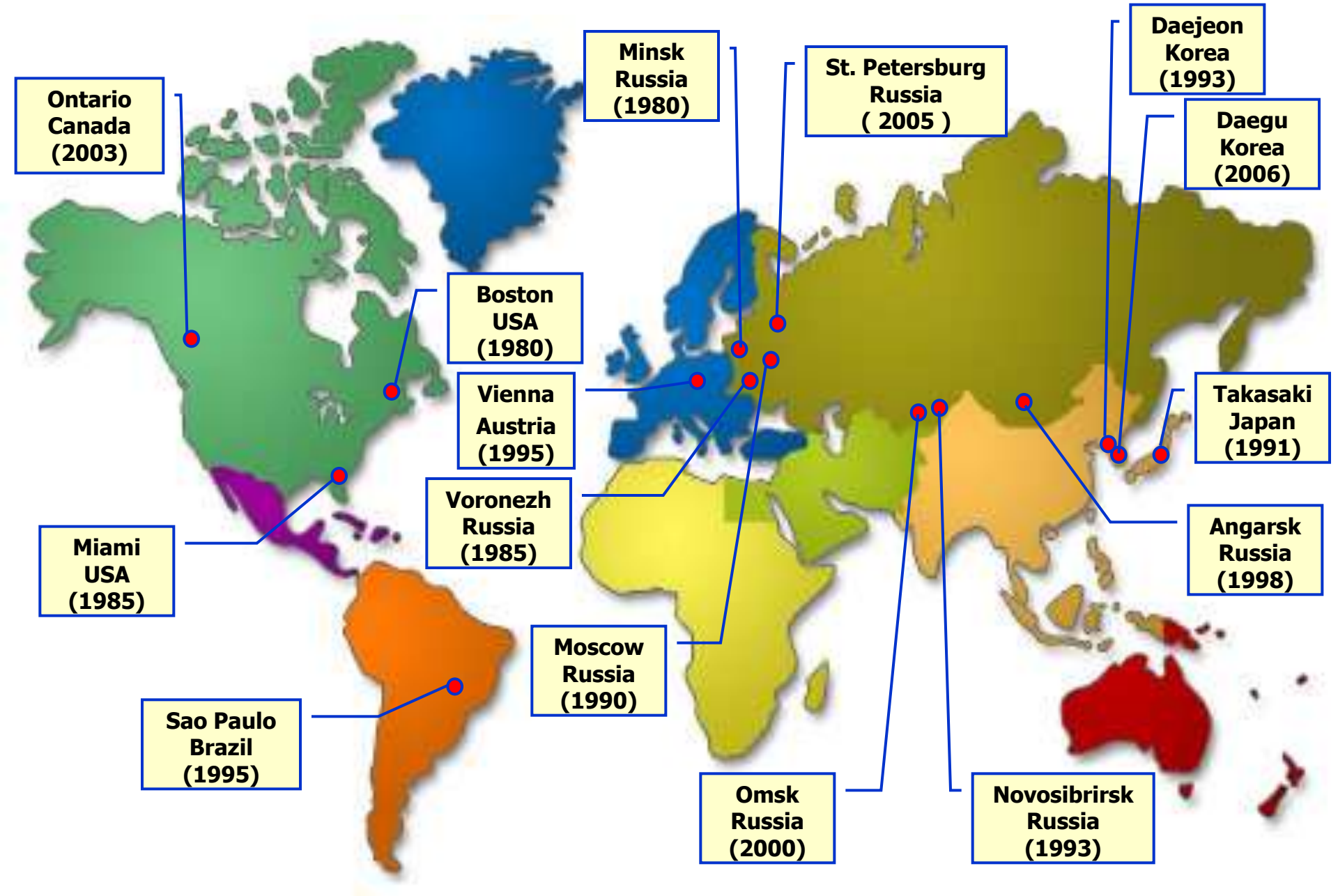
→ Coagula-tion

Removal of Toxic Group

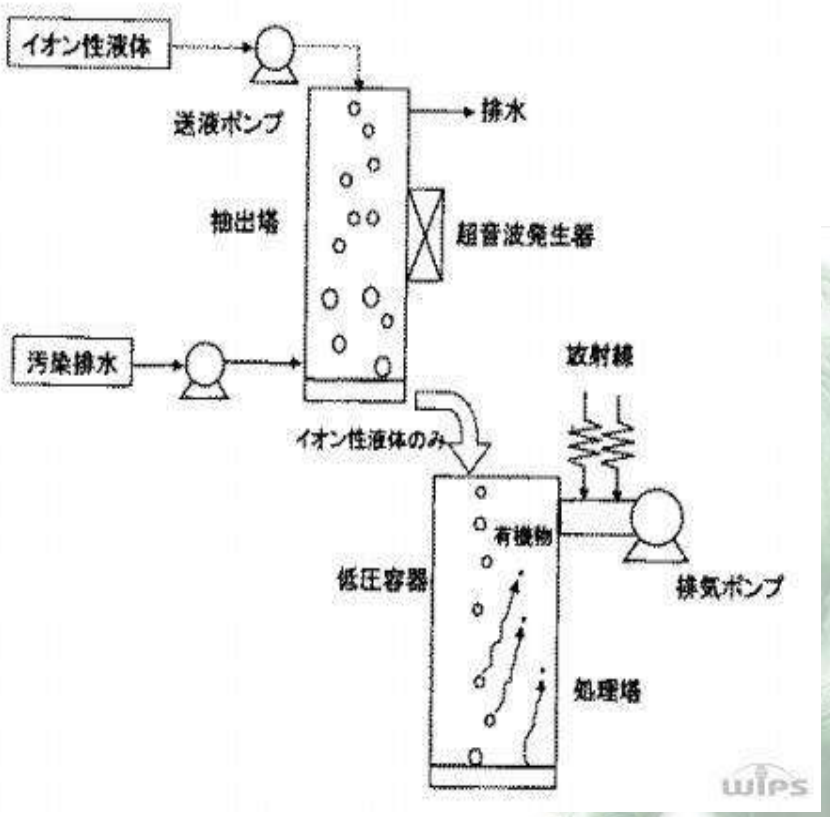
Removal of Color, Odor

→ Bio-Treat-ment

Radiation processing of water treatment plant



Place	Boston, U.S.A.
Goals	Drinking Water
Capacity	700m^3 /day
Accelerator	ICT, 1.5 MeV, 75kW



1980 Boston, U.S.A. Munic

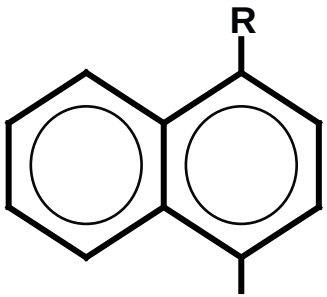
Drinki

Takasaki, Japan Textile

Leach

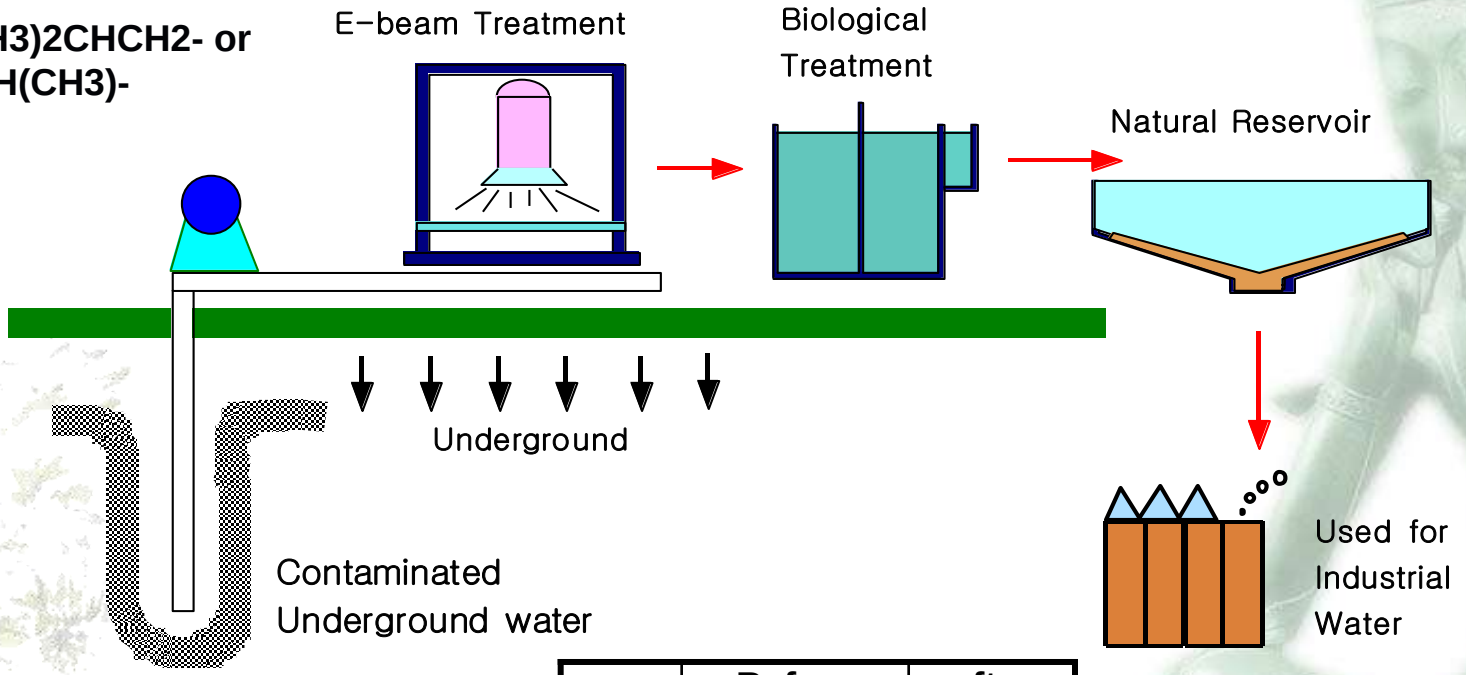
East Germany Gamma cells for Well conditioning

Voronezh, Russia Contaminated Underground Water



Nekal
(Isobutylnaphthalene sulfonates)

R = (CH3)3C-, (CH3)2CHCH2- or
CH3CH2CH(CH3)-

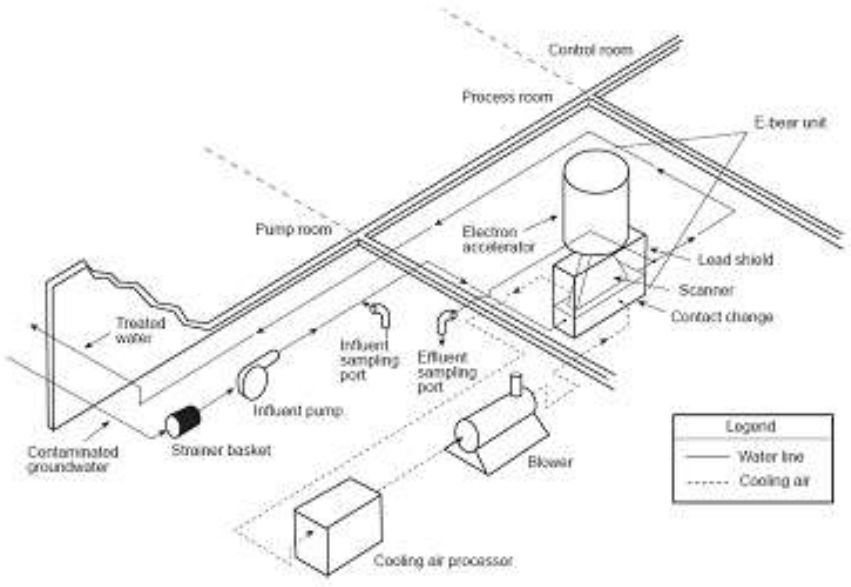


	Before	after
BOD	500-1000	7-15
COD	1600-5000	60-100

Wastewater Treating Facility with e-beam in Boronezh

EB TECH 550 yongsan-dong Yuseong-gu, Daejeon 305-500, Korea WWW.EB-TECH.COM

1990	Miami, U.S.A.	Leachate from Landfill
		Underground Water
	HVEA, U.S.A.	Underground Water
	Seibersdorf, Austria	Underground Water
	Dubna, Russia	Mixed Wastewater
	Angarsk, Russia	Mixed Petrochemical
		and Municipal wastewater
	Taegu, Korea	Textile Dyeing Wastewater
	SaoPaulo, Brazil	Dyes etc.



Nation	USA
City	Miami
Object	Wastewater treatment
Capacity	650m^3/day
Accelerator Model	ICT, 1.5MeV, 75KW

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.

Wastewater Treatment

What was done

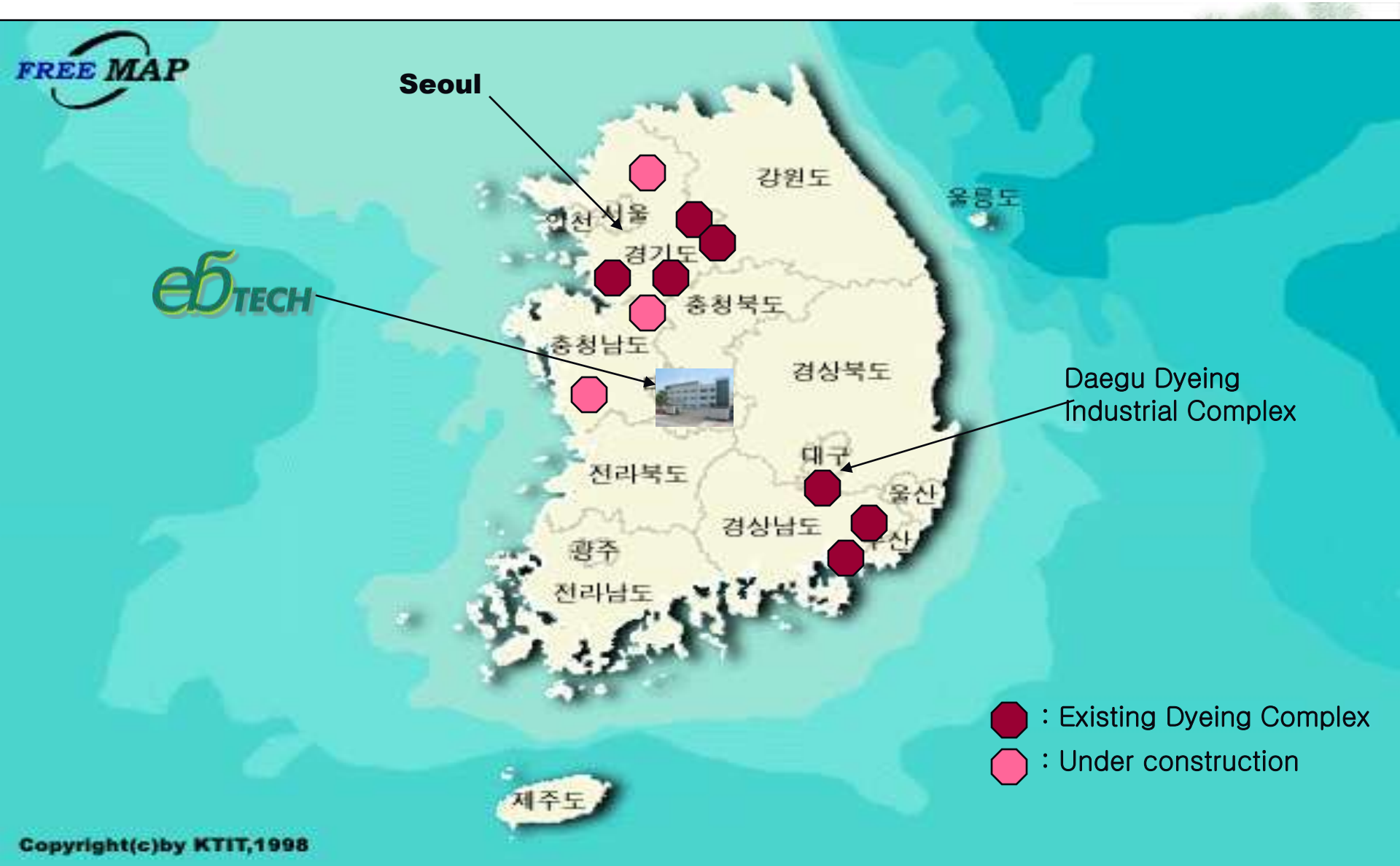
-. Textile Dyeing Wastewater (1993~2006)

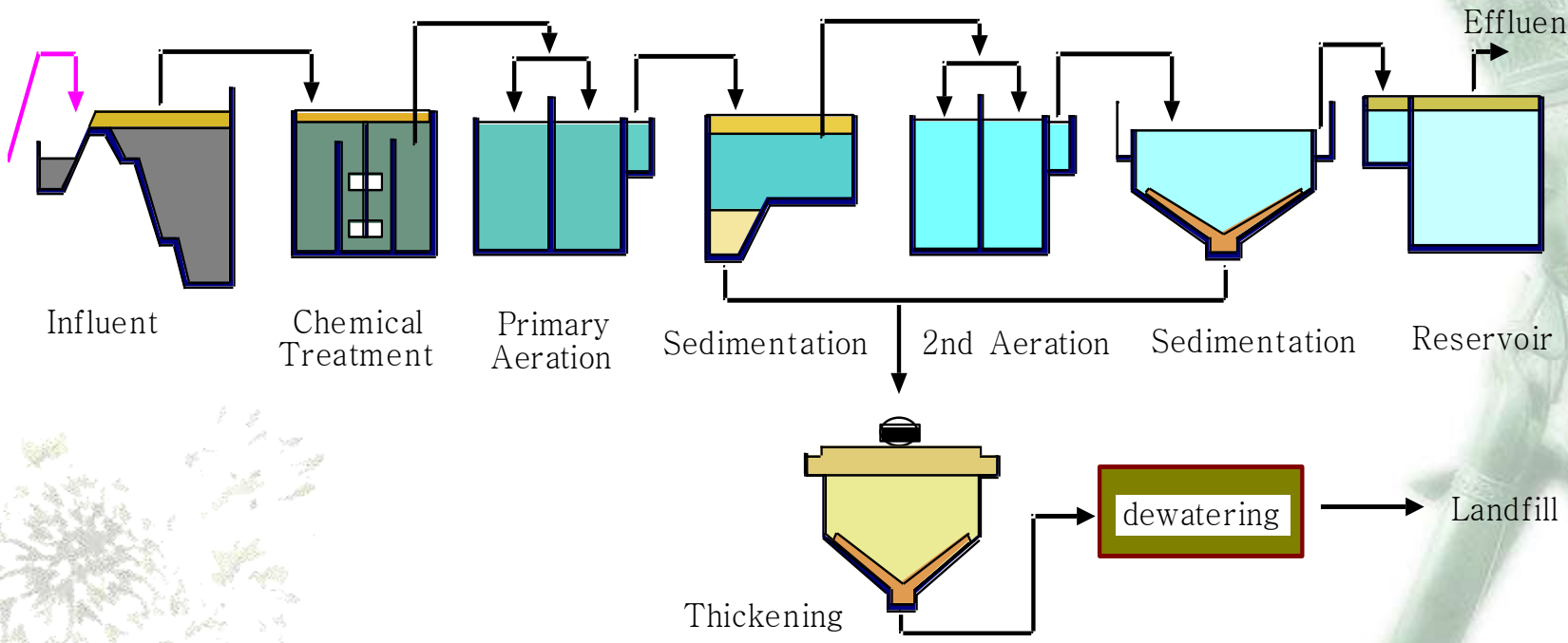
Why Textile Dyeing Wastewater ?

(1000m^3/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)

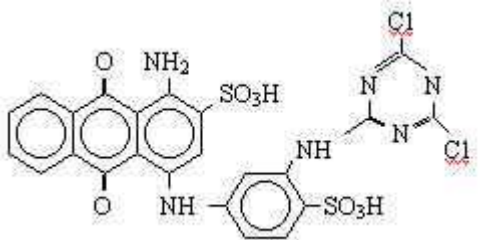
The amount of waste water generated and discharged in Korea, as of 1995

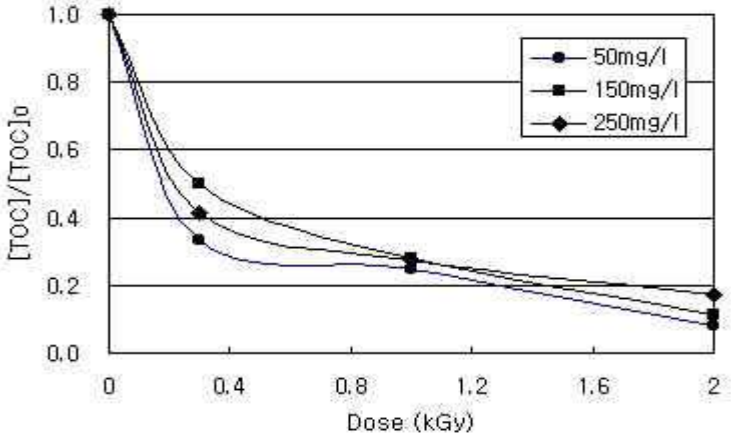

FREE MAP
Seoul
강원도
울릉도
인천
서울
경기도
충청북도
충청남도
경상북도
대구
전라북도
울산
경상남도
부산
광주
전라남도
제주도
Daegu Dyeing
Industrial Complex
: Existing Dyeing Complex
: Under construction
Copyright(c)by KTIT,1998

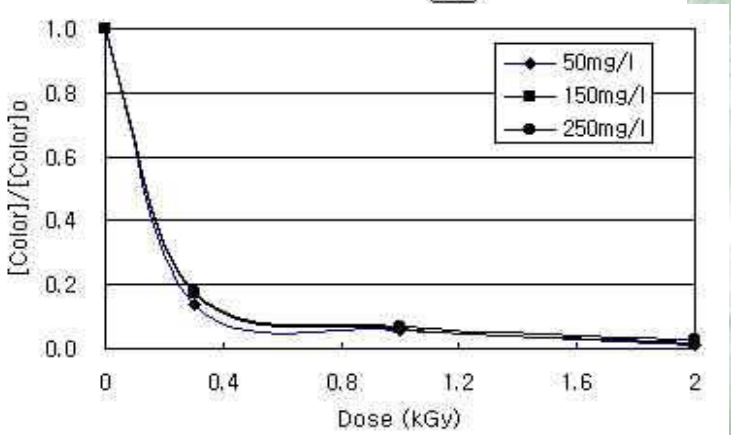


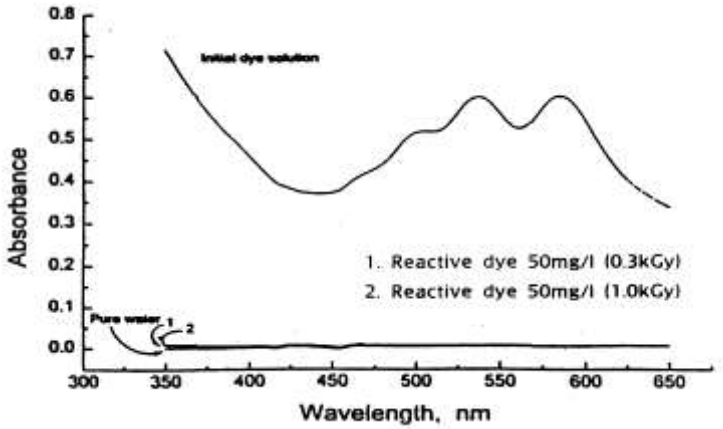
Process Flow of Existing Wastewater Treatment Facility

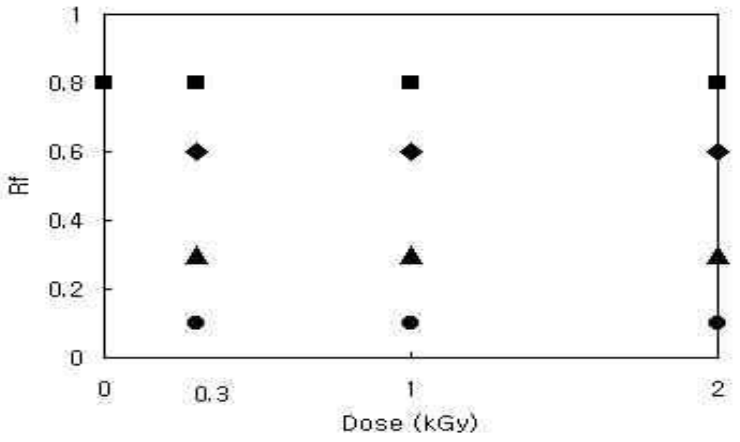
Reactive Dyes (C.I.Reactive Black 4)









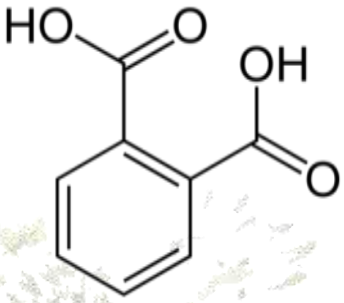


1,2-Benzenedicarboxylic acid

Formula: $C_8H_6O_4$

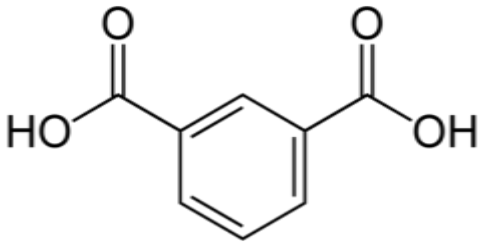
Other names: Phthalic acid;

Phthalic acid is one of three isomers with the composition benzenedicarboxylic acid, the others being isophthalic acid and terephthalic acid. Sometimes the term "phthalic acid**s**" is used to refer to this family of isomers, but in the singular, "phthalic acid", refers exclusively to the *ortho*- isomer.



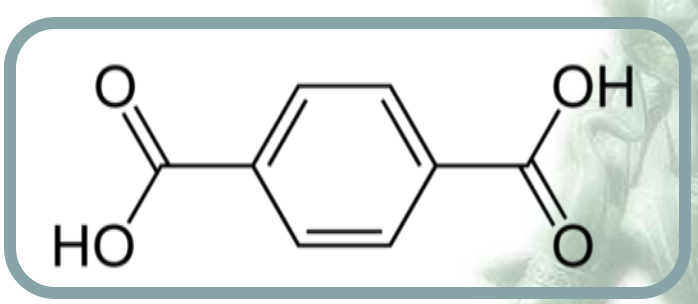
phthalic acid

(*ortho*-phthalic acid)



isophthalic acid

(*meta*-phthalic acid)

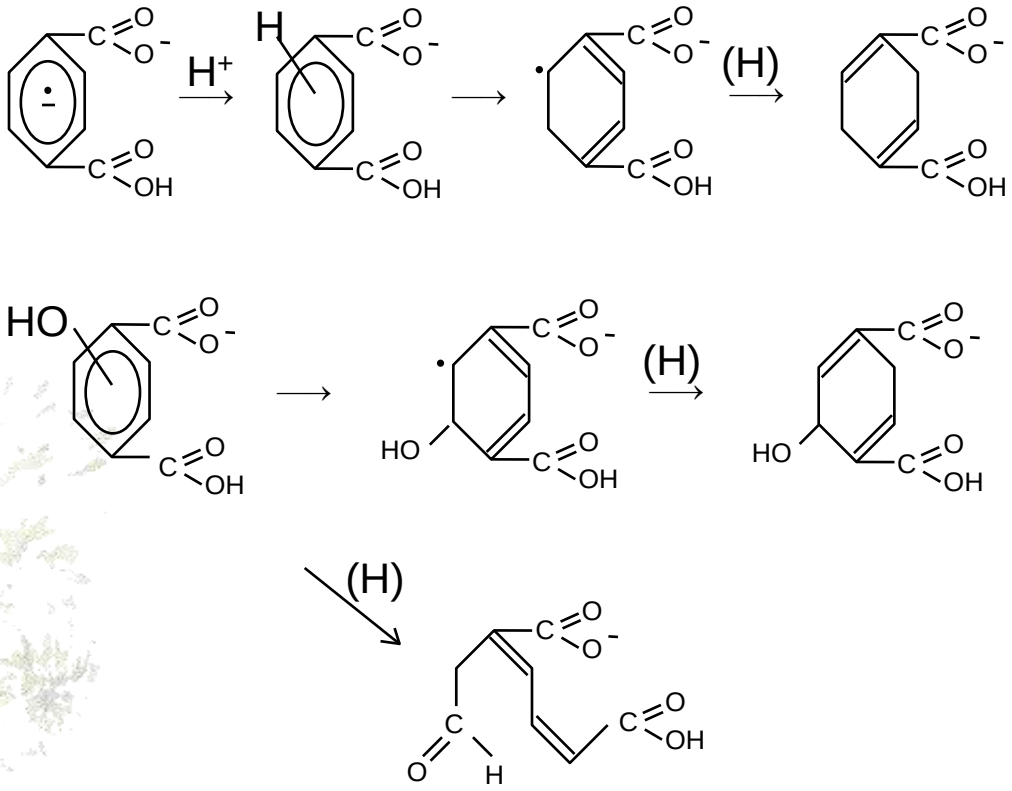


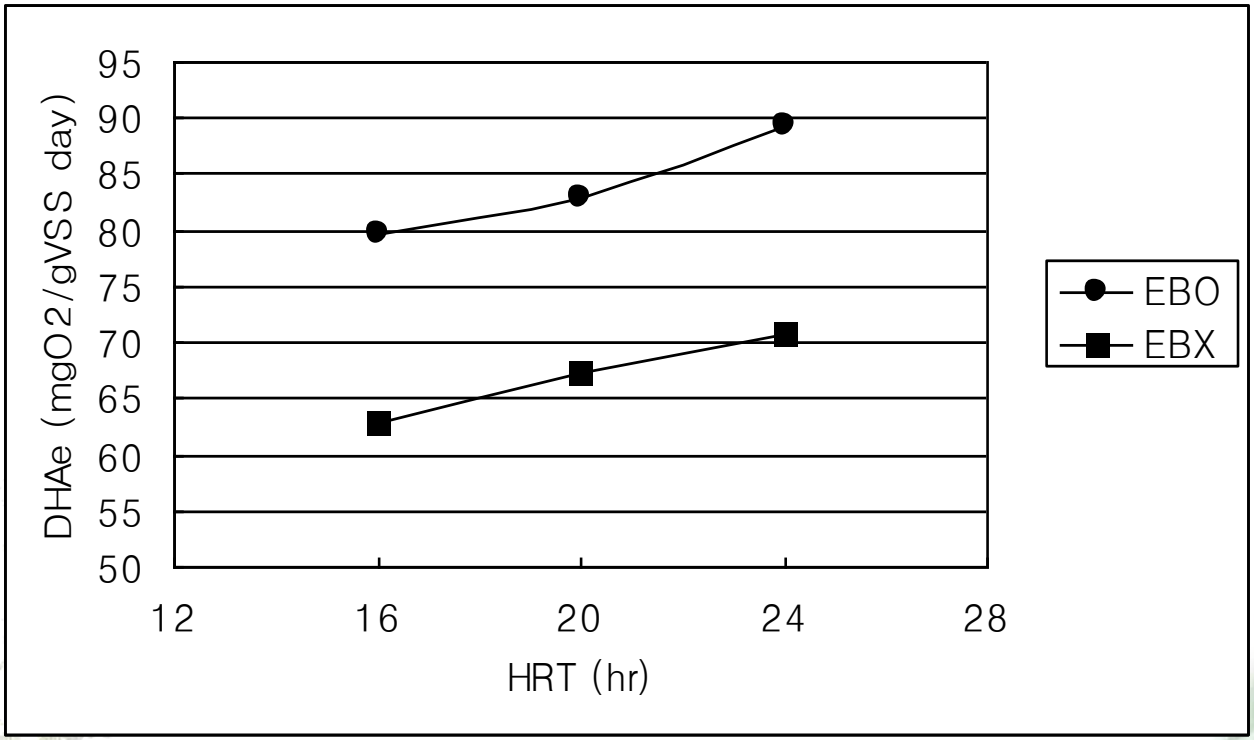
terephthalic acid (TPA)

(*para*-phthalic acid)

The toxicity of phthalic acid is low with LD50 (mouse) of 550 mg/kg. However, many phthalate esters have been implicated as endocrine sidrupters.

Further transformations of TPA radicals are realized (in reactions with other radicals donating H-atoms) in changing benzene ring into cyclodiene structure, formation of phenols and decyclization:





Average sludge activity (DHAe) at various HRT

Scientists likes

Numbers,

Equations,

Papers etc.

$$\int_0^\infty \frac{x^3}{e^x - 1}\,dx = \frac{\pi^4}{15}$$

$$\int_0^\infty \frac{\sin(x)}{x}\,dx = \frac{\pi}{2}$$

Engineers – most all

π = 3.1415926535 8979323846 2643383279 5028841971 6939937510 5820974944
5923078164 0628620899 8628034825 3421170679 8214808651 3282306647
0938446095 5058223172 5359408128 4811174502 8410270193 8521105559
6446229489 5493038196 4428810975 6659334461 2847564823 3786783165
2712019091 4564856692 3460348610 4543266482 1339360726 0249141273
7245870066 0631558817 4881520920 9628292540 9171536436 7892590360
0113305305 4882046652 1384146951 9415116094 3305727036 5759591953
0921861173 8193261179 3105118548 0744623799 6274956735 1885752724
8912279381 8301194912 9833673362 4406566430 8602139494 6395224737
1907021798 6094370277 0539217176 2931767523 8467481846 9405132
0005681271 4526356082 7785771342 7577896091 7363717872 1468440901
2249534301 4654958537 1050792279 6892589235 4201995611 2129021960
8640344181 5981362977 4771309960 5187072113 4999999837 2978049951
0597317328 1609631859 5024459455 3469083026 4252230825 3344685035
2619311881 7101000313 7838752886 5875332083 8142061717 7669147303
5982534904 2875546873 1159562863 8823537875 9375195778 1857780532
1712268066 1300192787 6611195909 2164201989.....

some people – not all of them

Scientists likes

Numbers,

Equations,

Papers etc.

$$\int_0^\infty \sqrt{x}\, e^{-x}\, dx$$

$$\int_0^1 \frac{x^3}{e^x - 1}\, dx = \frac{\pi^4}{15}$$

$$\int_0^\infty \frac{\sin(x)}{x}\, dx = \frac{\pi}{2}$$

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

Economics !!!

- cost effective

Why Scientists are poor ?

Basic Premise 1 : scientia est potentia (Knowledge is power)
(Sir Francis Bacon, 1561~1626)
Basic Premise 2 : Time is money
(Benjamin Franklin, 1706~1790)

Proof : In physics, power is the rate at which work is performed.

$$\text{Power} = \text{Work / time} = \Delta W / \Delta t$$

From premises 1 and 2,

$$\text{Power(Knowledge)} = \text{Work / time (money)}$$

Rewriting to

$$\text{Money} = \frac{\text{Work}}{\text{Knowledge}}$$

And $\lim (\text{Knowledge} \rightarrow \infty)$, $\text{Money} = \frac{\text{Work}}{\text{Knowledge}} = 0$

Less knowledge, more money ?

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

-. Laboratory test → Confirmation of process

-. Pilot plant → Industrial scale design → Commercial plants

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

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)

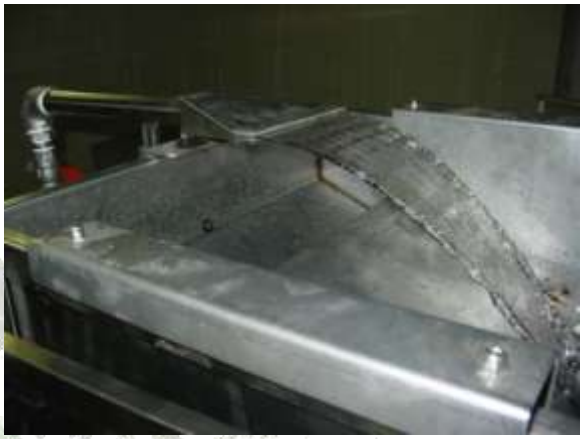
Construction of Commercial Plant (2005)

Wastewater Treatment Facility in Daegu Dyeing Industrial Complex

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

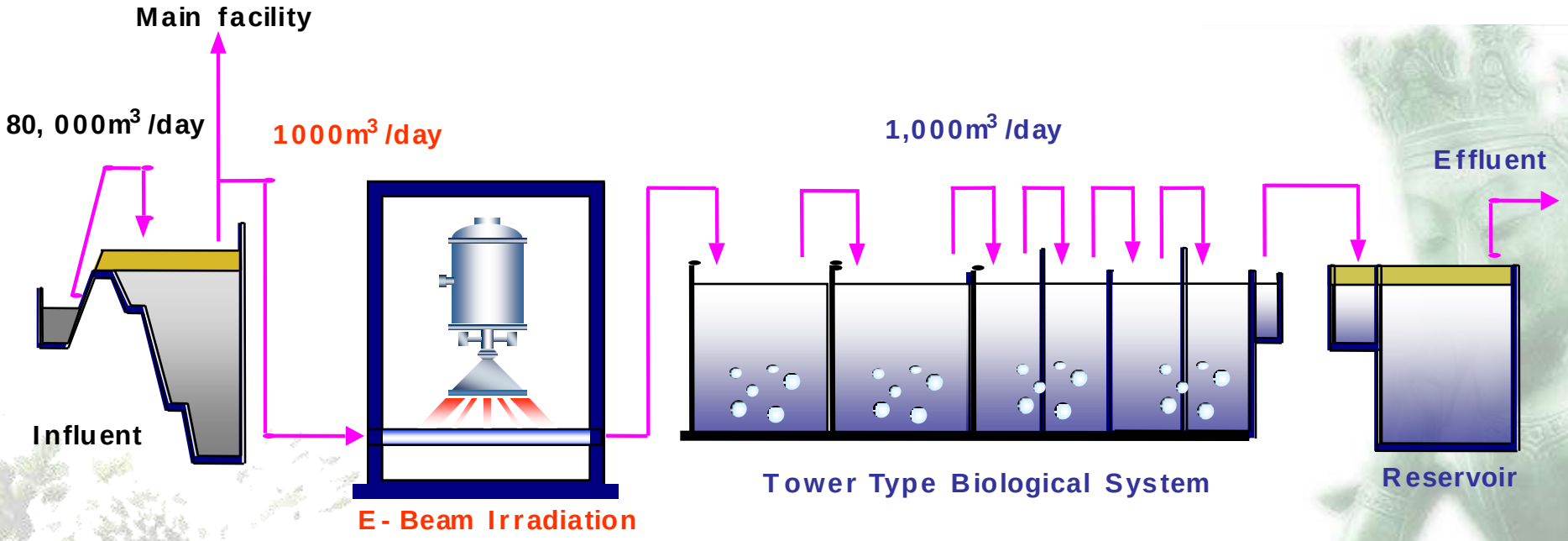
Maximum range of accelerated electrons

Nozzle-type Injectors used in Textile Dyeing Wastewater Treatment

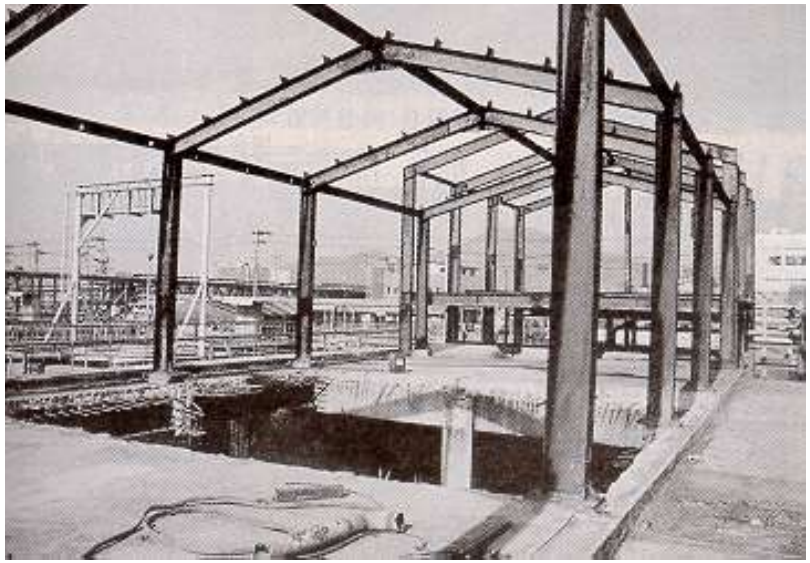


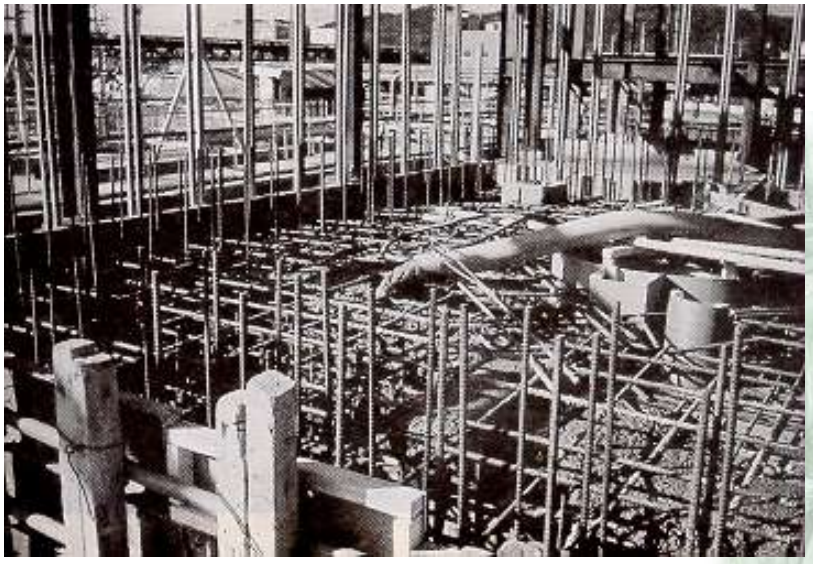
Laboratory 50m^3/day **Pilot Plant 1,000m^3/day** **Industrial Plant 10,000m^3/day**

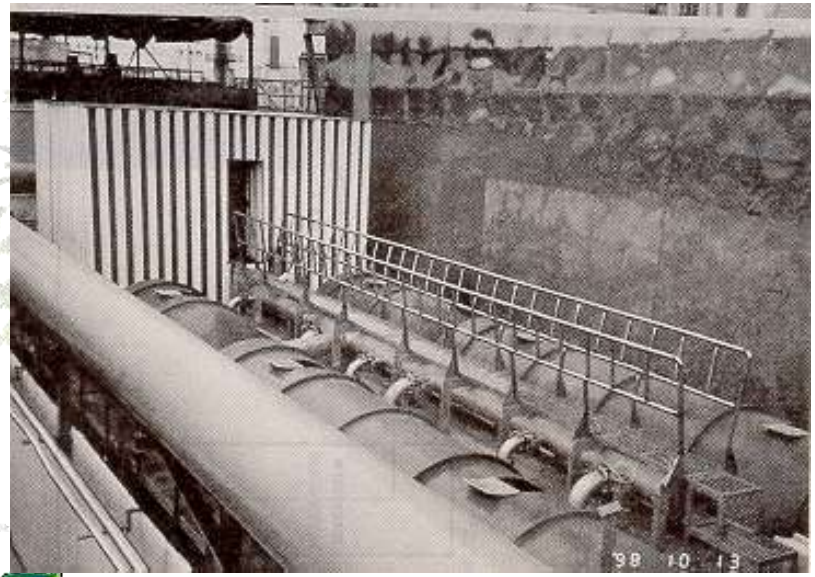
Schematic Diagram of Pilot Plant (1998)





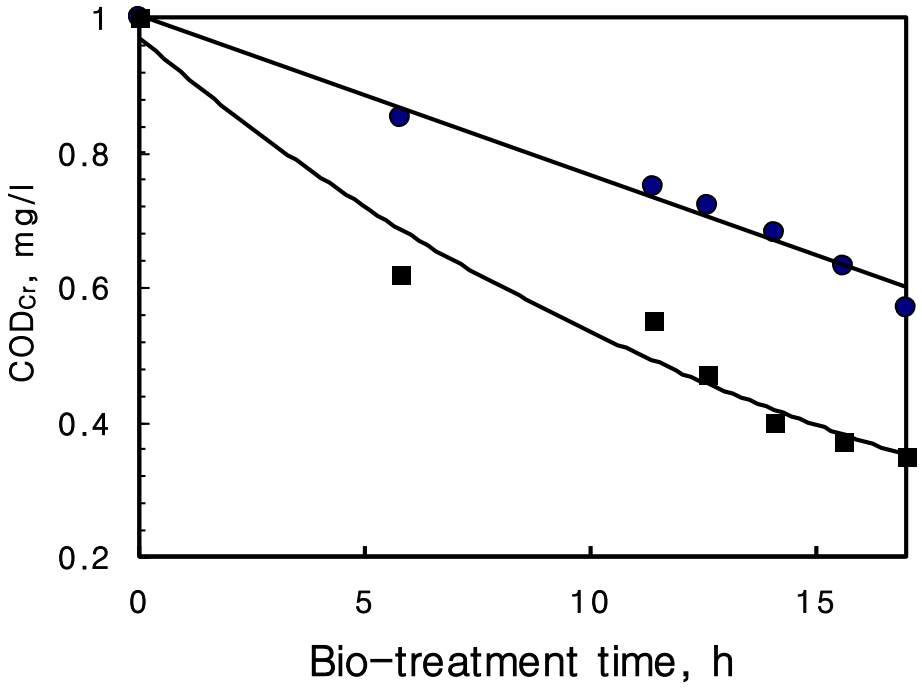



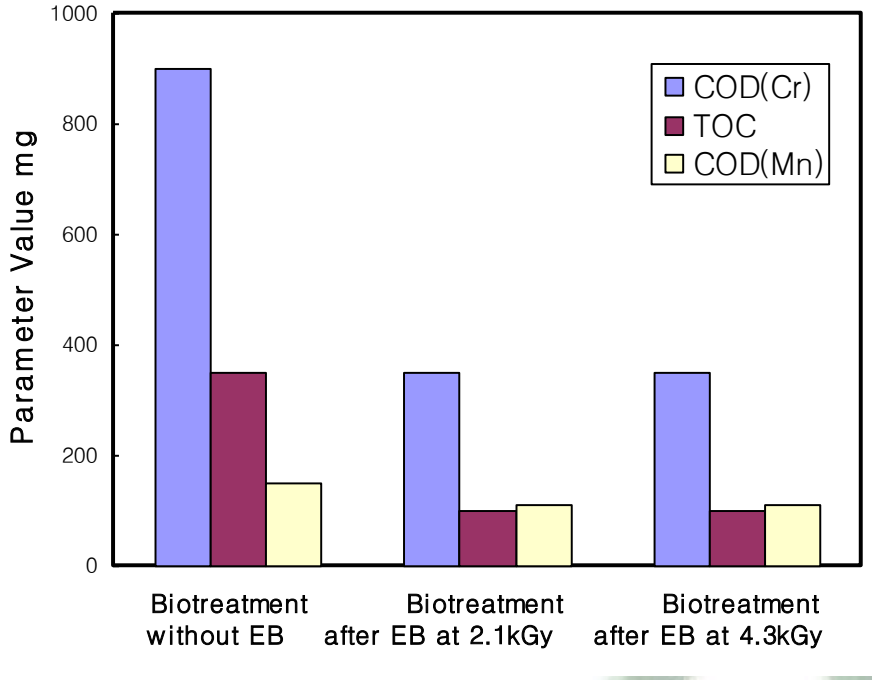





전자빔 조사원


2004





Effect of electron-beam treatment on biological treatment of dyeing wastewater:
a - kinetics of biotreatment of irradiated (*1*) and unirradiated (*2*) wastewater;
b - absorbed dose effect on combined electron-beam/biological treatment.

Researches on Wastewater Treatment

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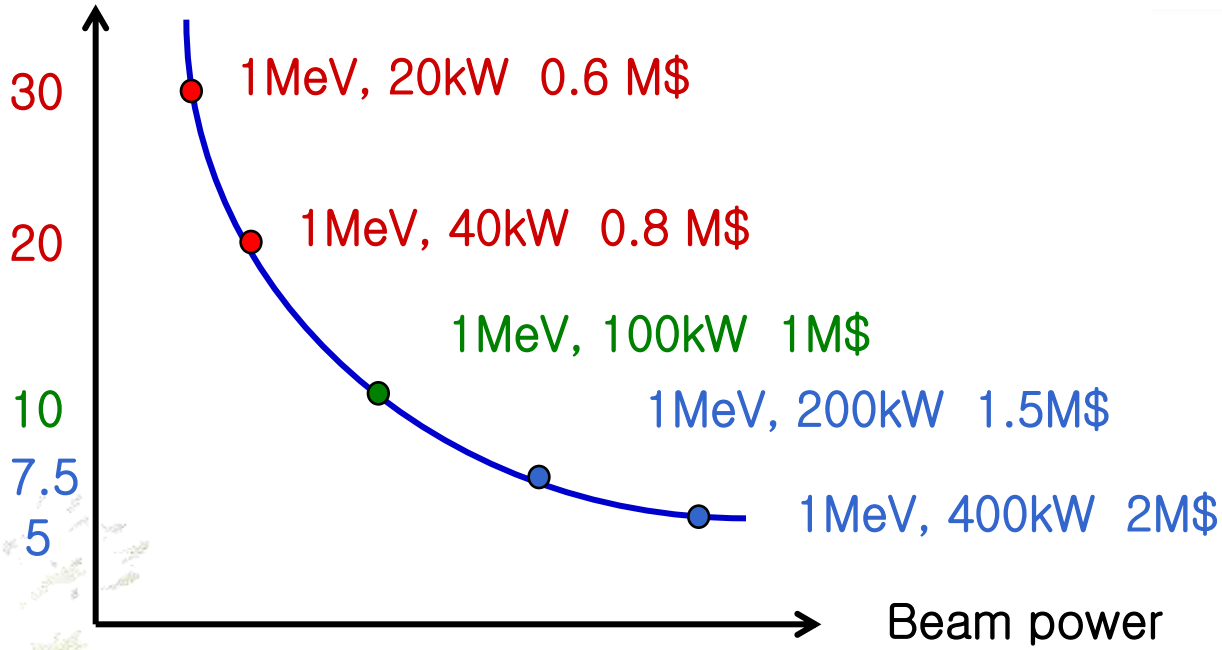
- 97.2~98.10 : Construction of e-beam Pilot Plant (1000m^3/day)
- 98.10~ : Continuous operation of treatment facility
- 1998.9.16 : KT (Korea New Technology) Award
- 2000.7.19 : IR52 Industrial Research Award
- 2001~2006 : IAEA TC Project (Demo Plant Construction)
- 2001~2003 : Preparation for Plant Construction
- 2004 : Start up of Demo Plant Construction
- 2005.12 : Operation of Industrial scale plant (10,000m^3/day)

Cost for unit power ($/W)



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

High Power Accelerator (EB TECH & BINP)

ELV-12 Accelerator:

Energy : 0.6 - 1.0 MeV

Beam power: 400 kW

Beam current: 500 mA

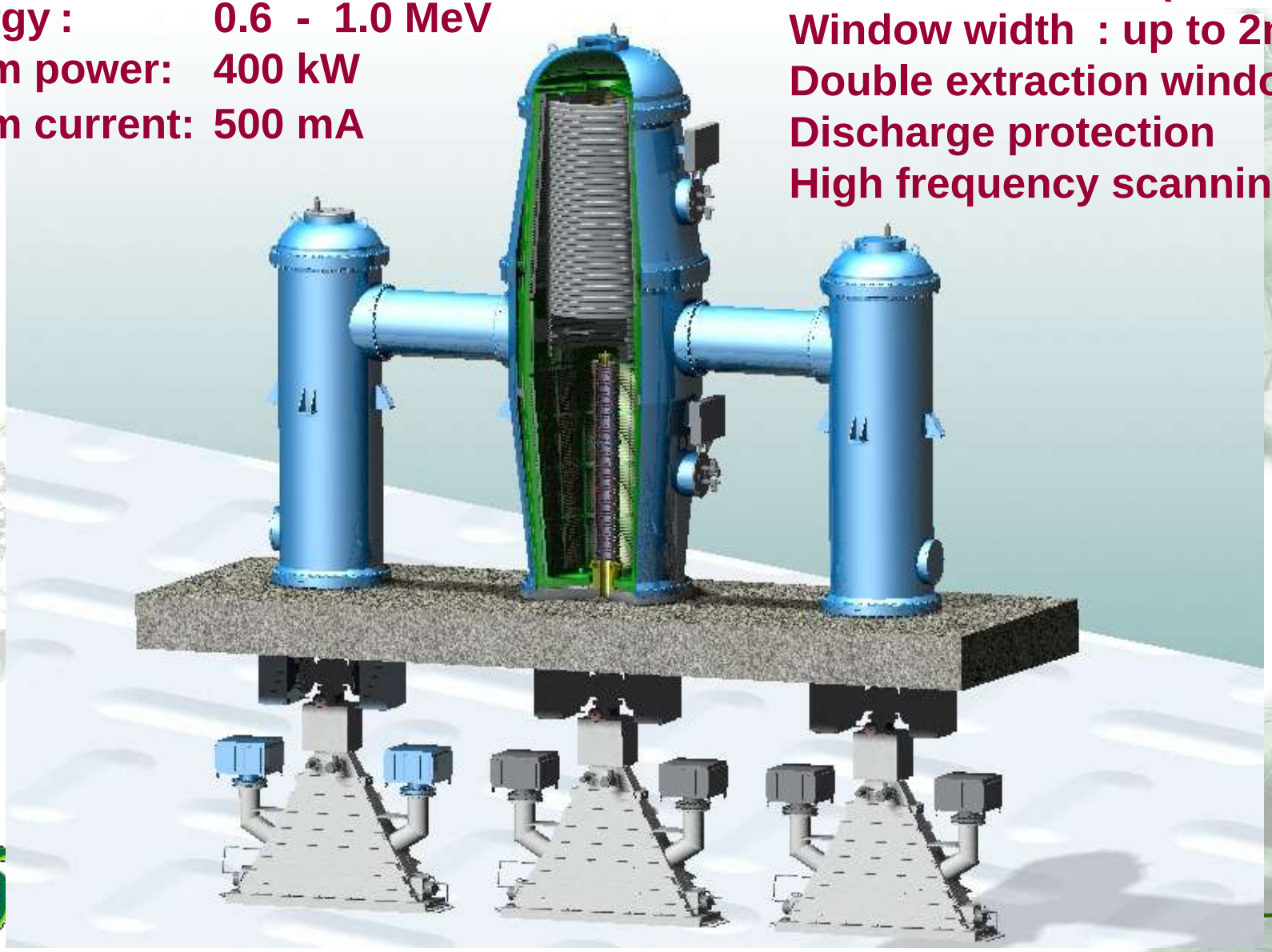
Irradiators : 3 (0~200mA)

Window width : up to 2m

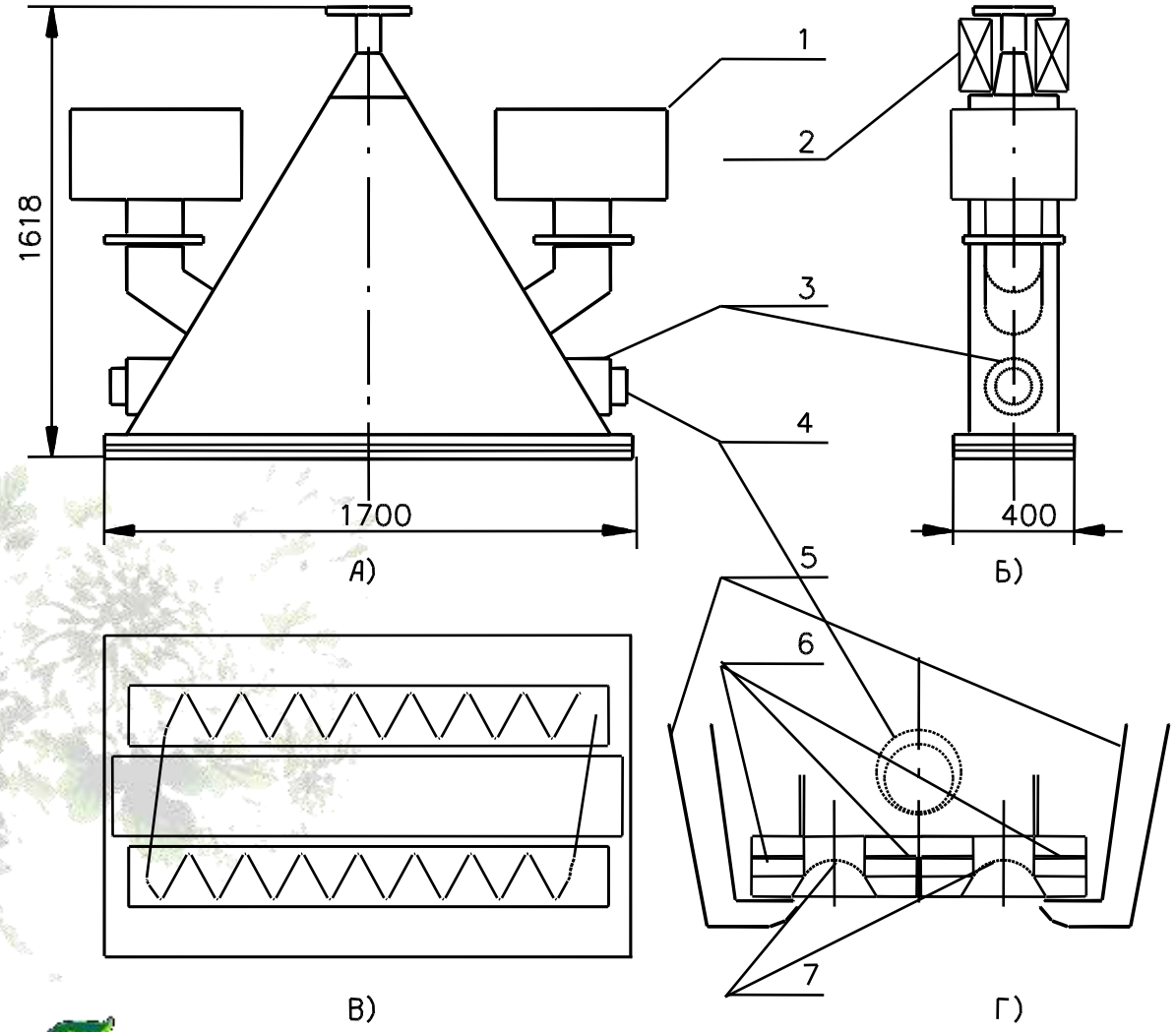
Double extraction window

Discharge protection

High frequency scanning



Double-window extraction device



1 ion pumps,

2 scanning system,

3 cylinder flange

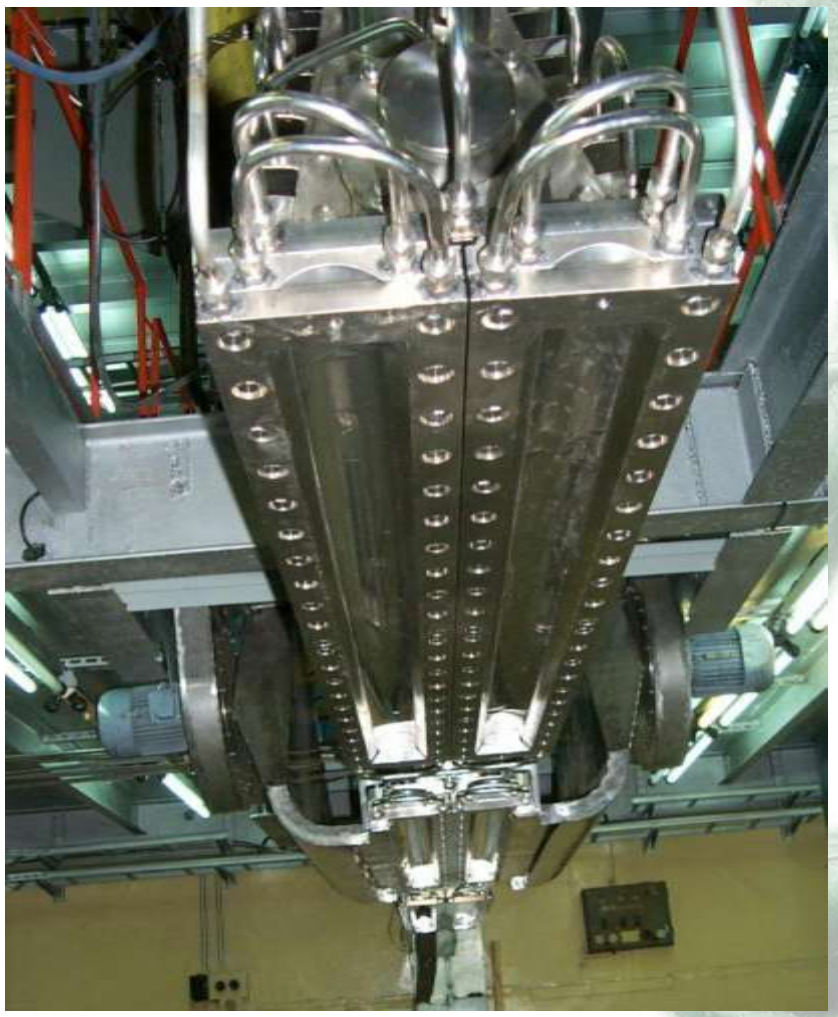
4 protection cylinder,

5 foil blow cooling,

6 foil fixation frame,

7-extraction foils.

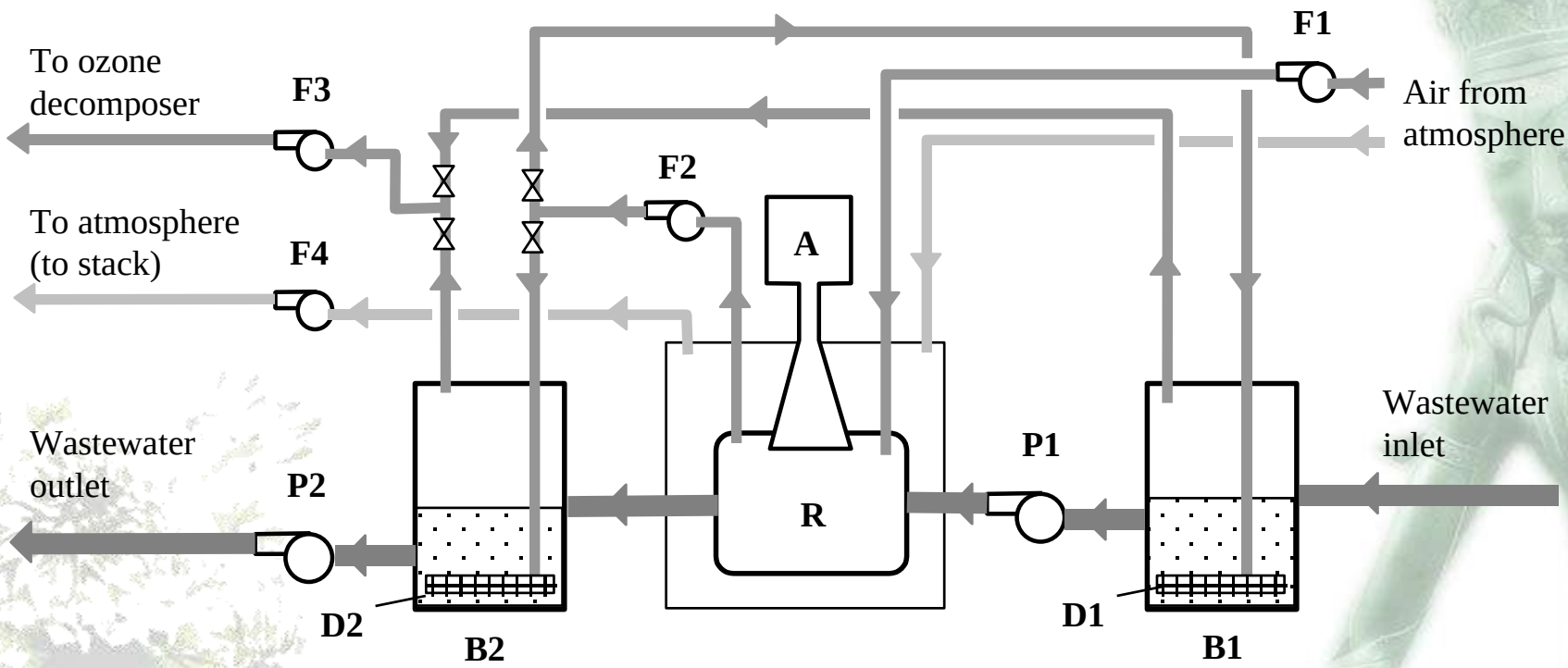
Double-window extraction device



Location of Pilot Plant and Commercial Plant

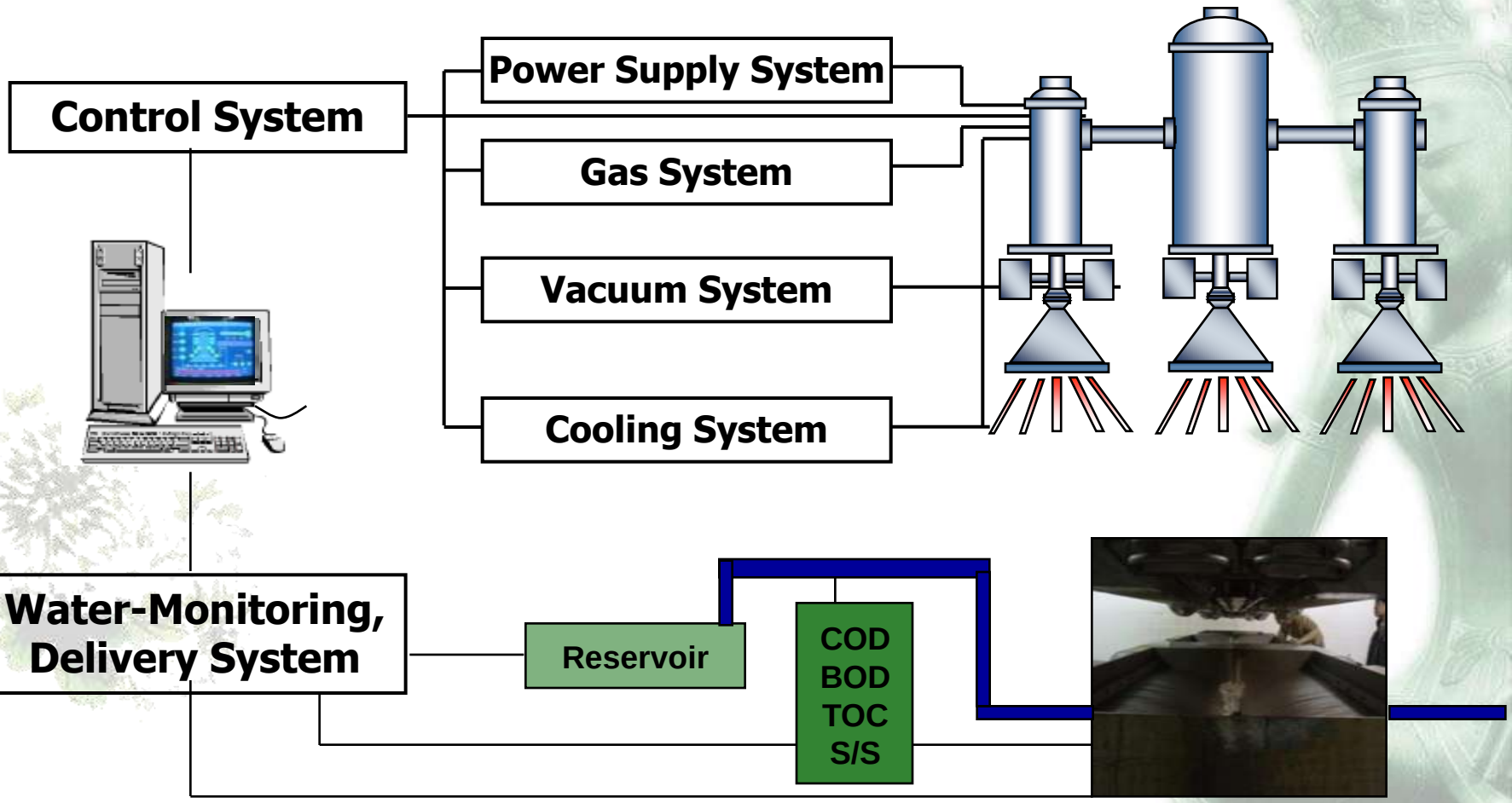
Wastewater Treatment Facility in Daegu Dyeing Industrial Complex

Technological Scheme of Commercial E-Beam Plant

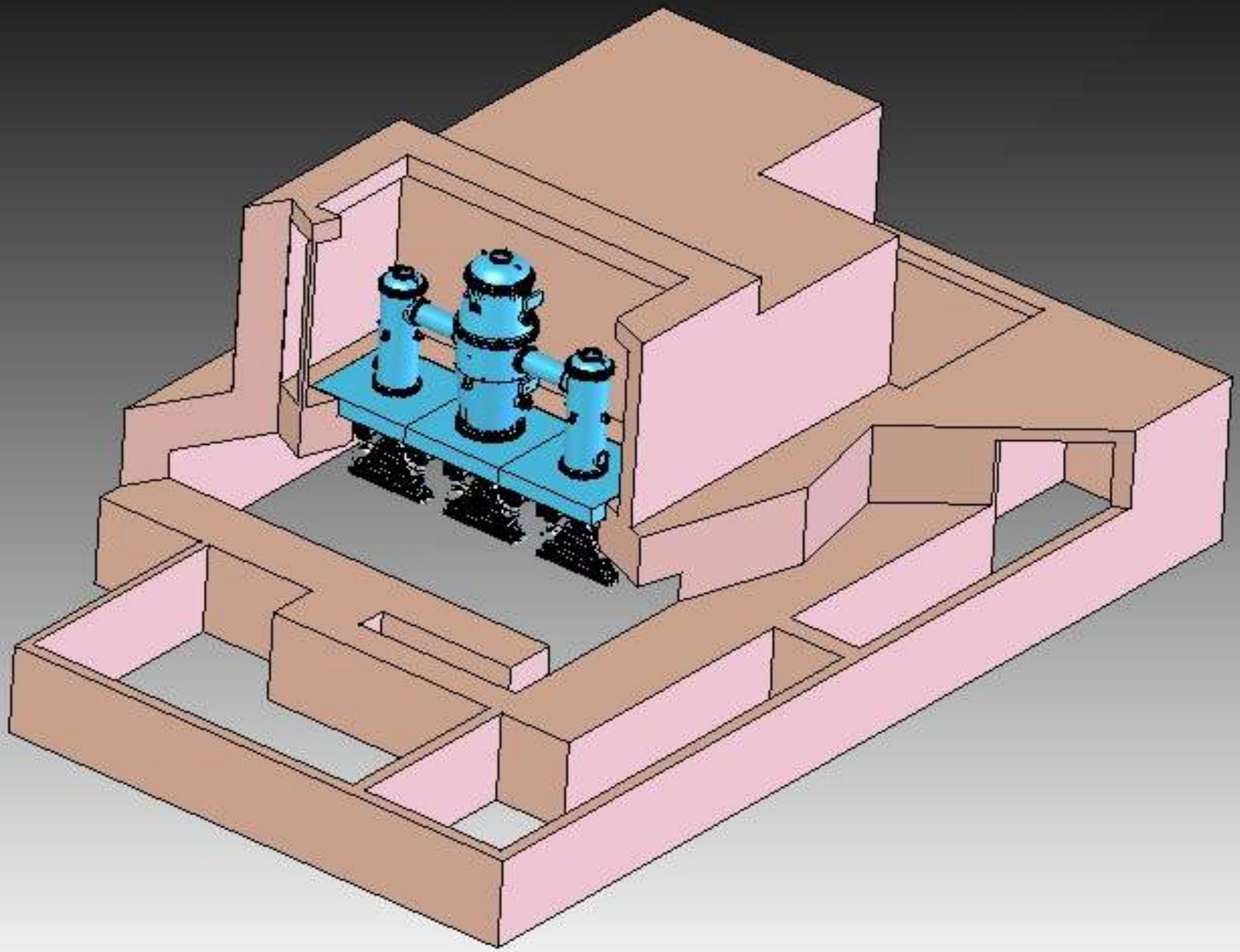


Simplified technological scheme of the plant. F1-F4 – Air fans, P1-P2 – Water pumps, D1 and D2 – Diffusers, A – Accelerator, R – Reactor, B1 and B2 – Primary and secondary basins

Configuration of E-Beam Wastewater Treatment



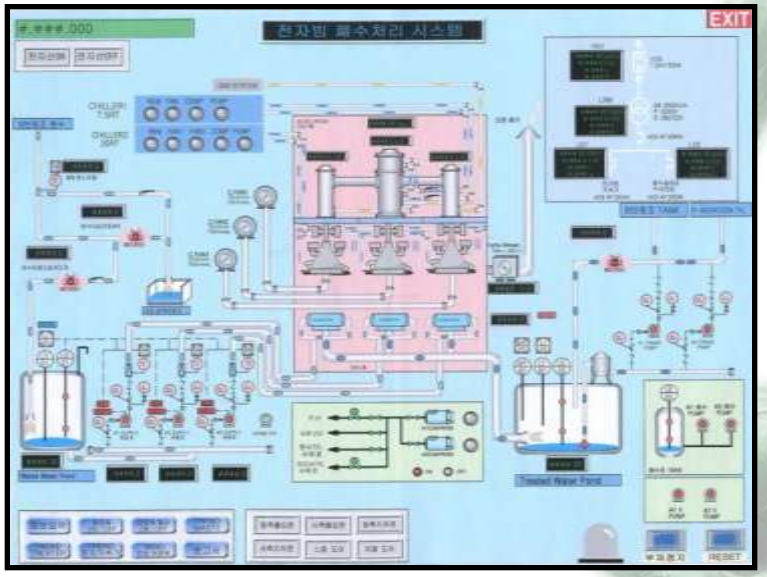
Construction of Commercial Plant



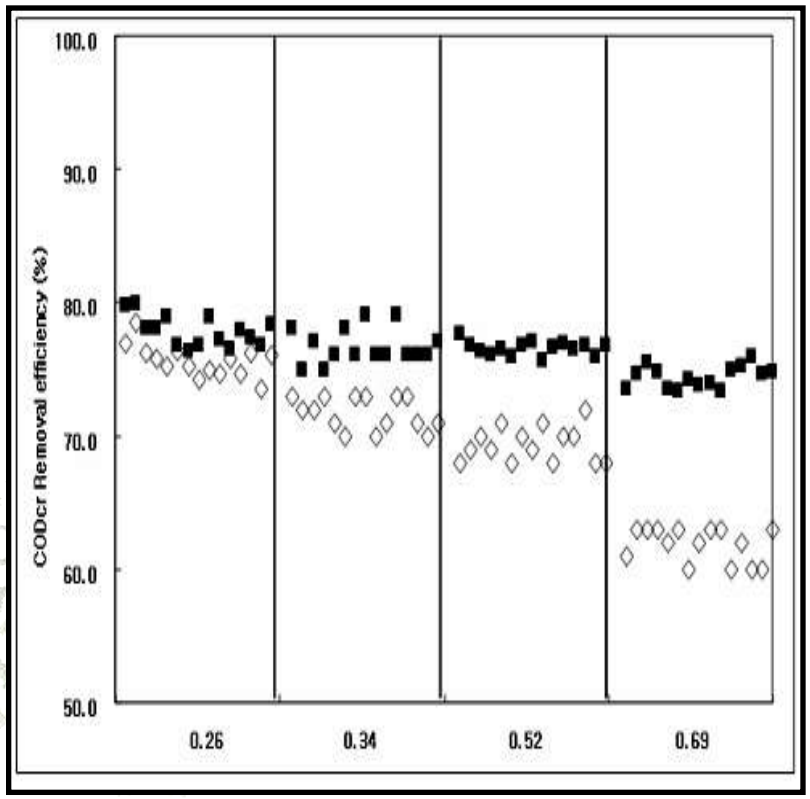
Construction of Commercial Plant

Construction of Commercial Plant

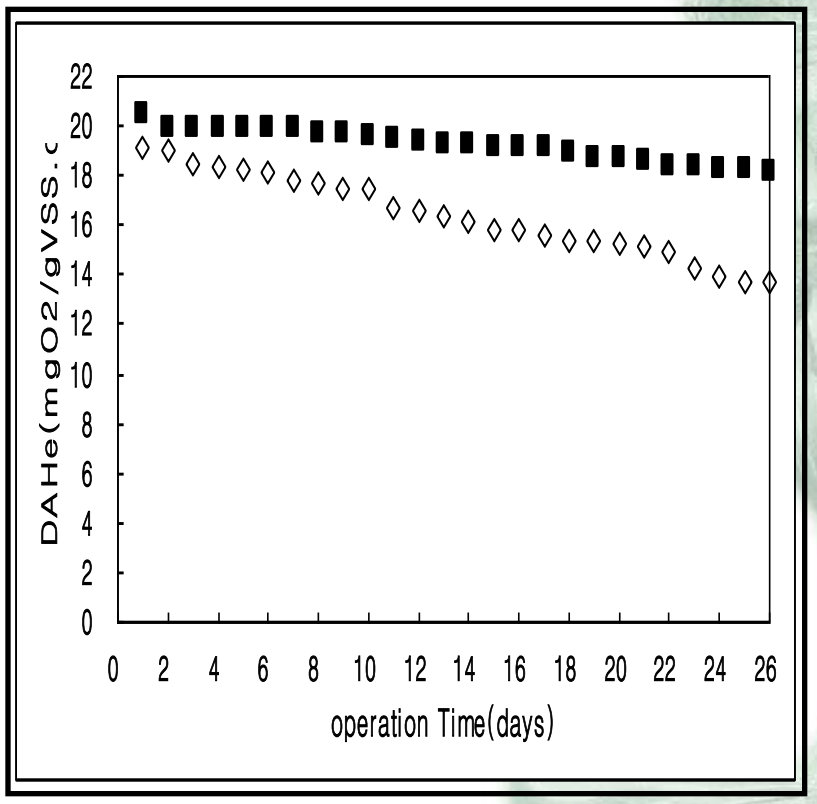
Construction of Commercial Plant



Operation of Commercial Plant



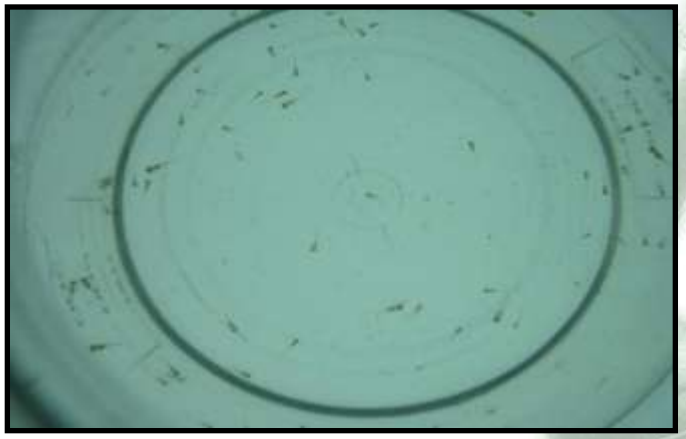
COD removal efficiency with 1kGy

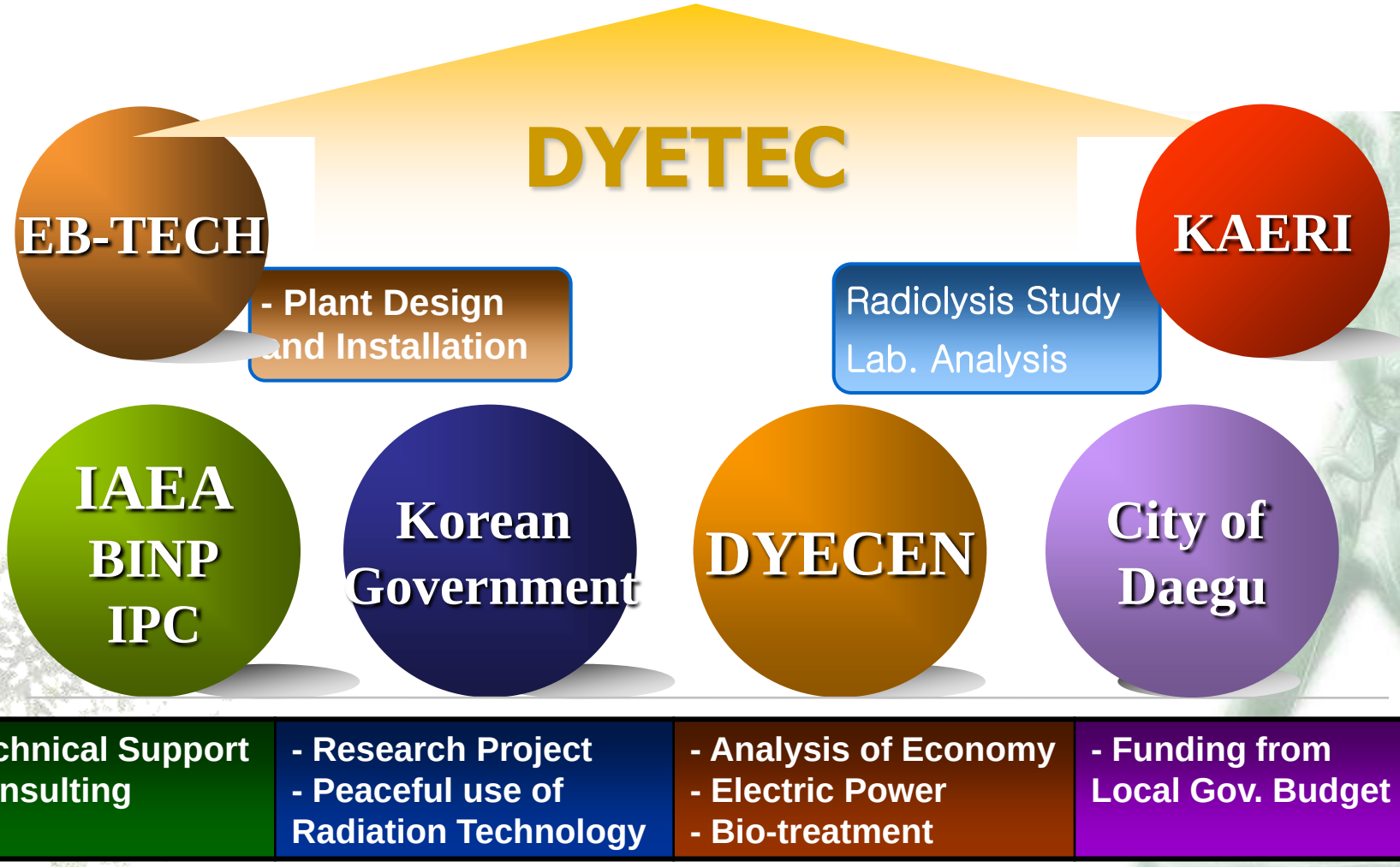


Variation of DAHe at HRT 24hr (1KGy)

(Daphina magna)

(Oryzias latipes)




DYETEC
EB-TECH
- Plant Design
and Installation
KAERI
Radiolysis Study
Lab. Analysis
IAEA
BINP
IPC
Korean
Government
DYECEN
City of
Daegu
-Technical Support
-Consulting
- Research Project
- Peaceful use of
Radiation Technology
- Analysis of Economy
- Electric Power
- Bio-treatment
- Funding from
Local Gov. Budget

Master Schedule

Project reporting (Dec. 2005)

Decision of Process (Mar. 2004)

Dec. 2003

Long-term Operation (Nov. 2005)

Basic Design (Mar. 2004)

Detail Design (May 2004)

Operation of Plant (July 2005)

Purchase Orders (Jul. 2004)

Shield Room Construction (Oct. 2004)

Dec. 2004

Installation of Accelerator (May. 2005)

Piping & Equipment (Nov. 2004)

Exhibition at 50th General Meeting of IAEA, Vienna 2006

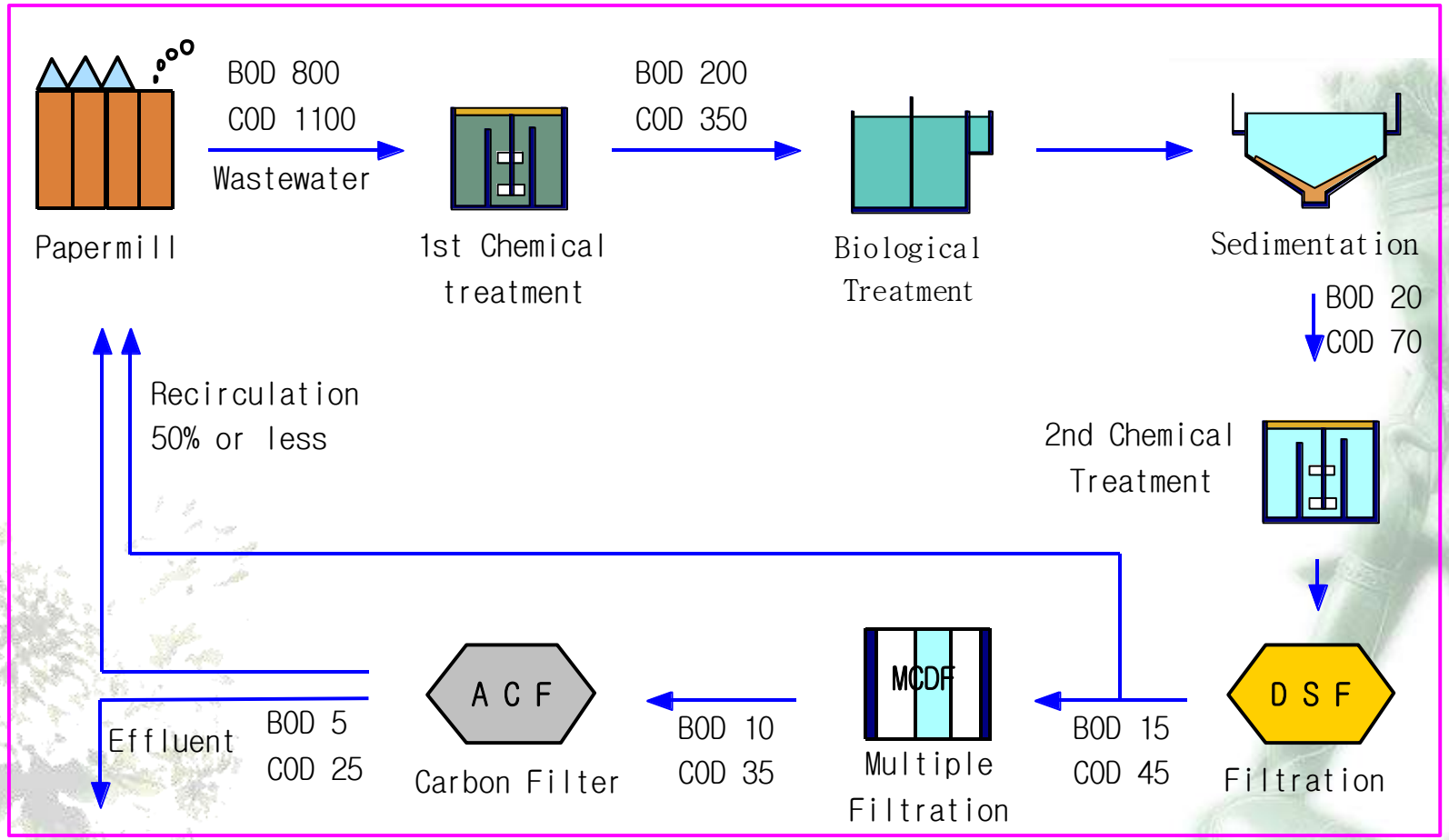
Wastewater Treatment

What was done

-. Textile Dyeing Wastewater (1993~2006)

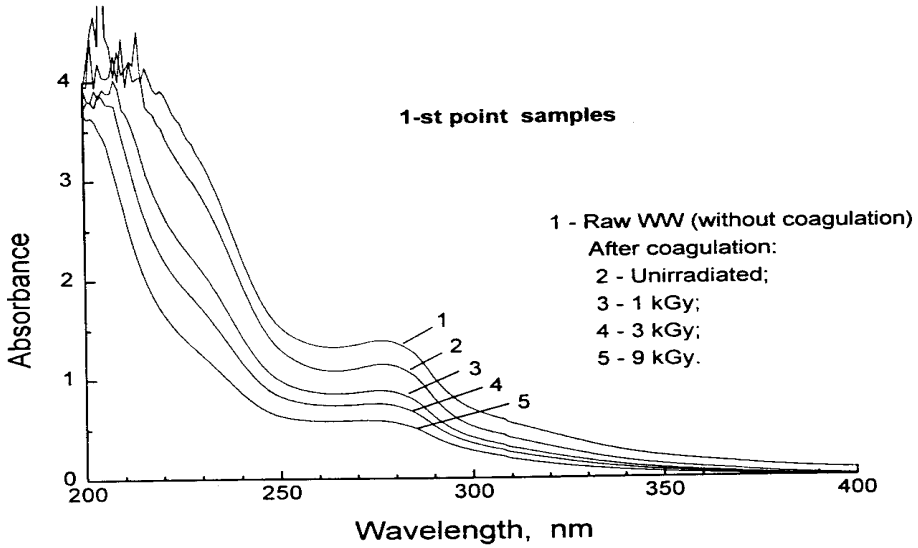
-. Leachate from Land filling (1993~1997)

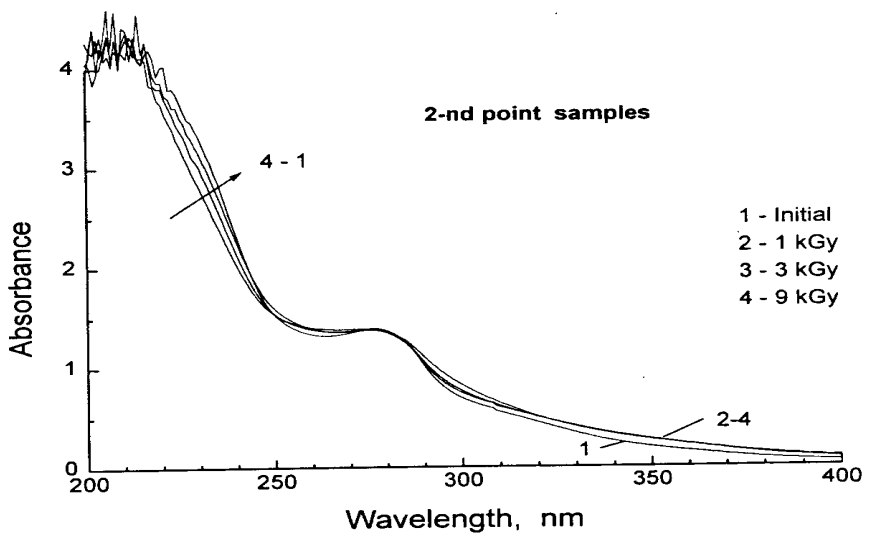
-. Wastewater from Paper Mill (1995~1998)

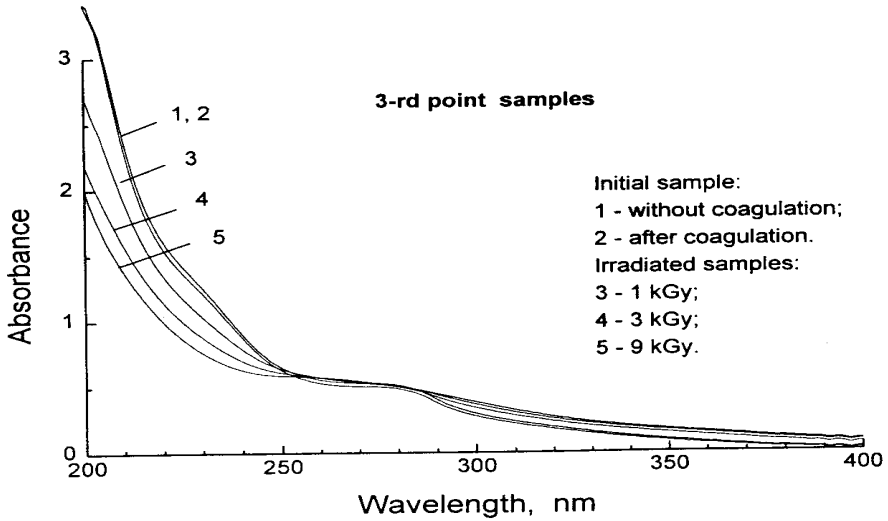


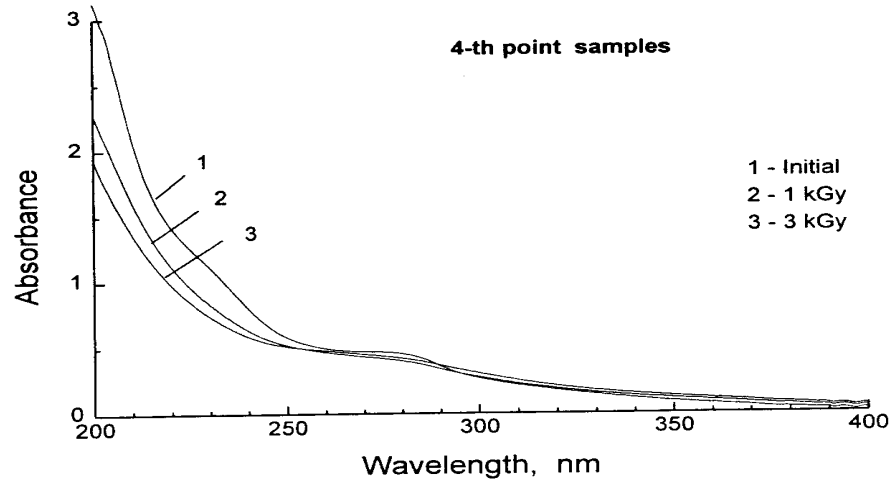
Process Flow of Papermill Wastewater Treatment

Nozzle Type Injector used in Bench-scale Experiments

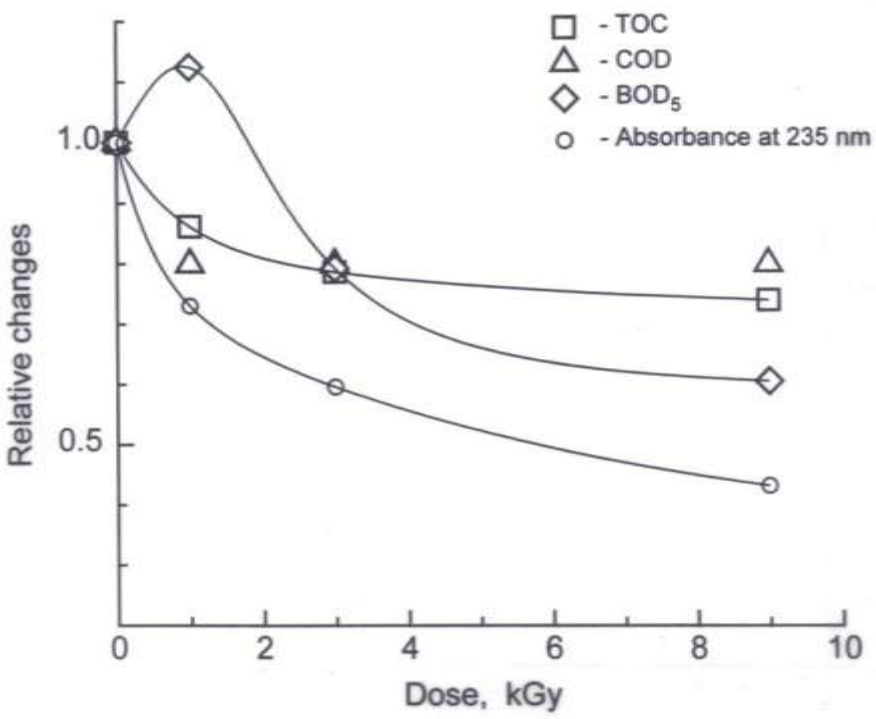




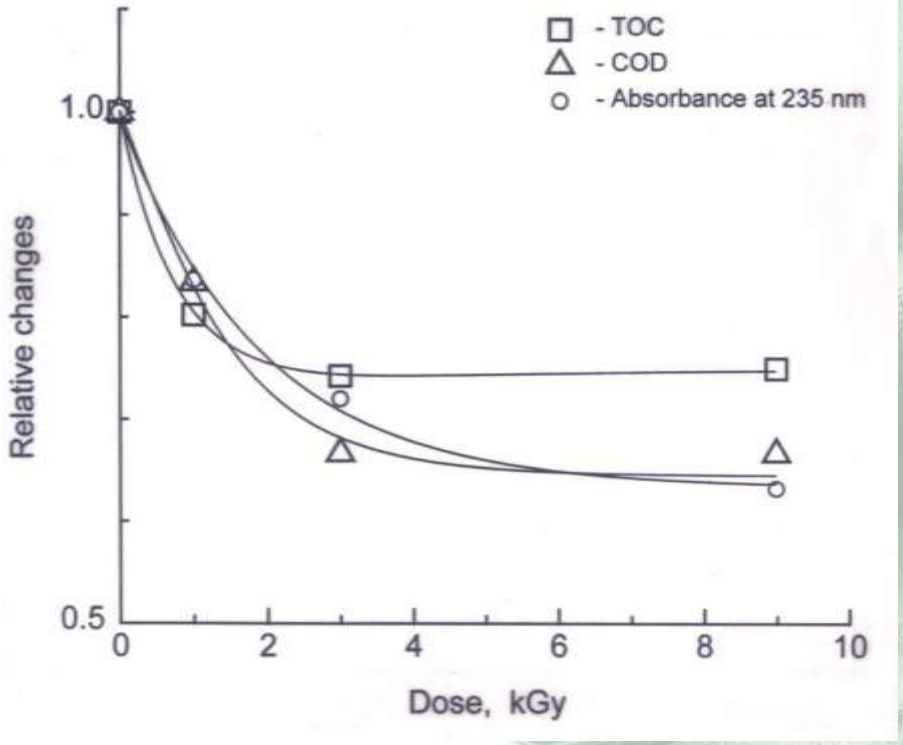




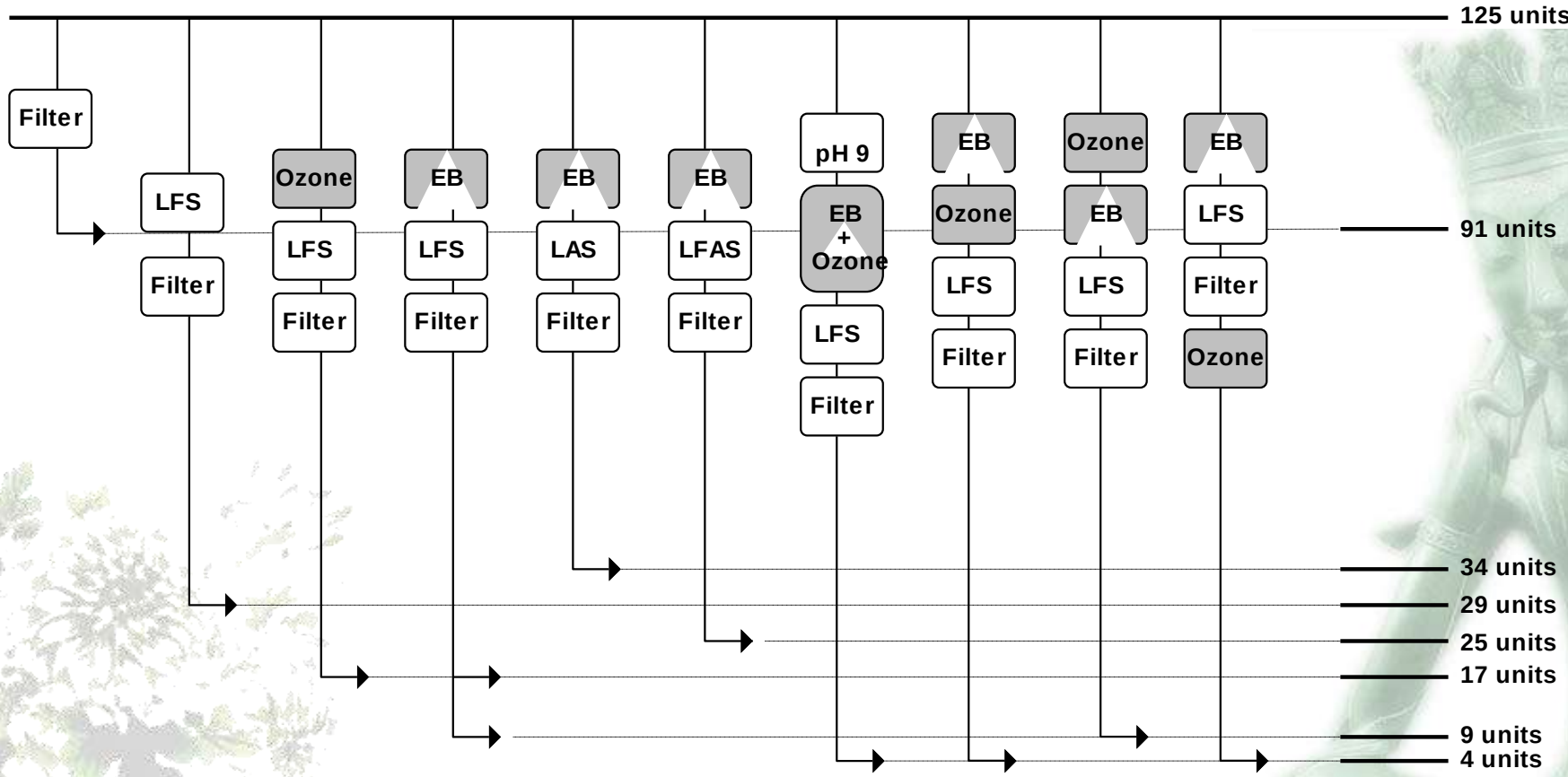
S-PAPERMILL WASTEWATER



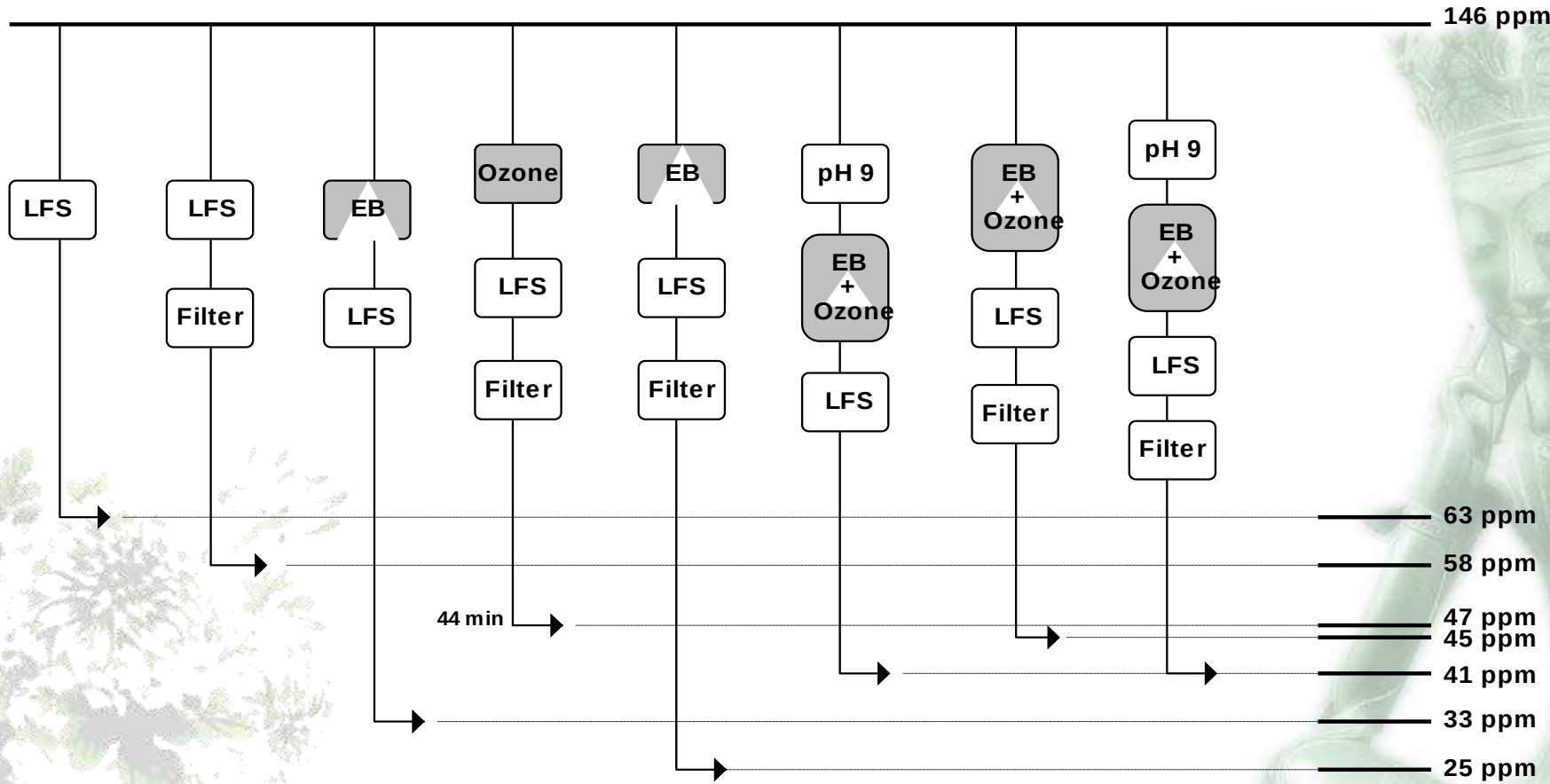
Raw Wastewater



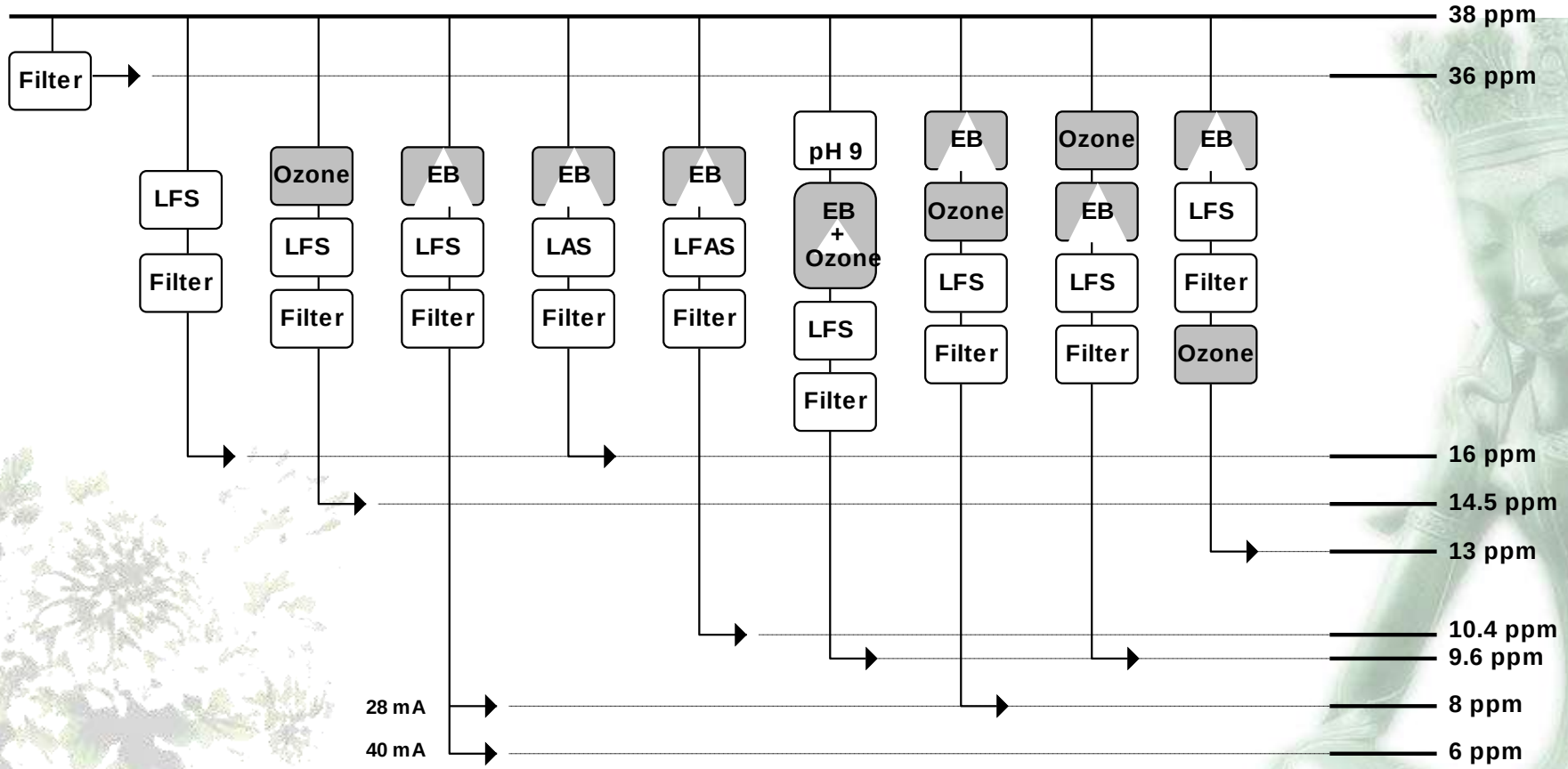
After biological Treatment



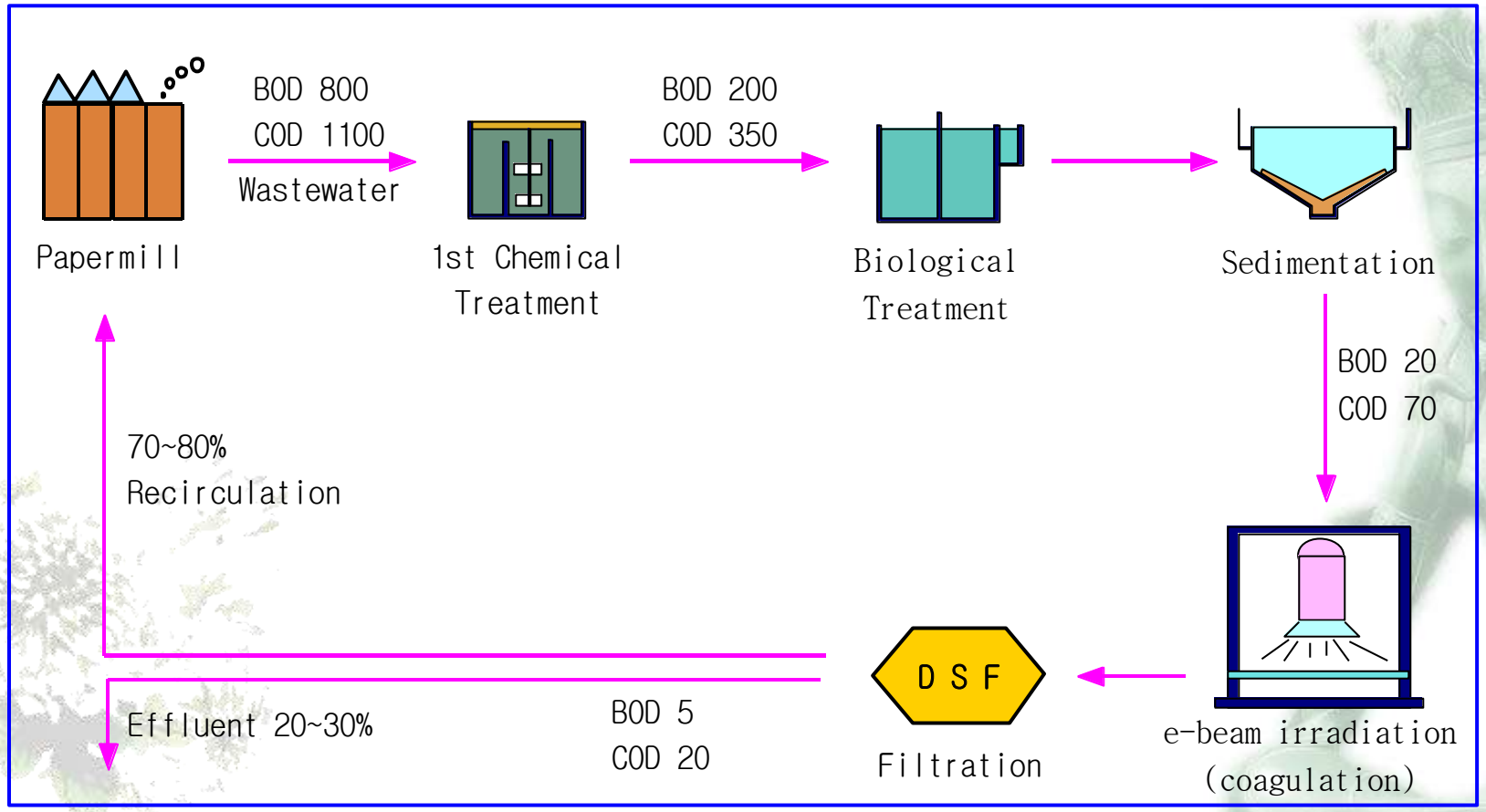
Effects of Irradiation and Coagulation (Color)



Effects of Irradiation and Coagulation (COD_{Cr})



Effects of Irradiation and Coagulation (TOC)



E-Beam Treatment of Papermill Wastewater

Wastewater Treatment

What was done

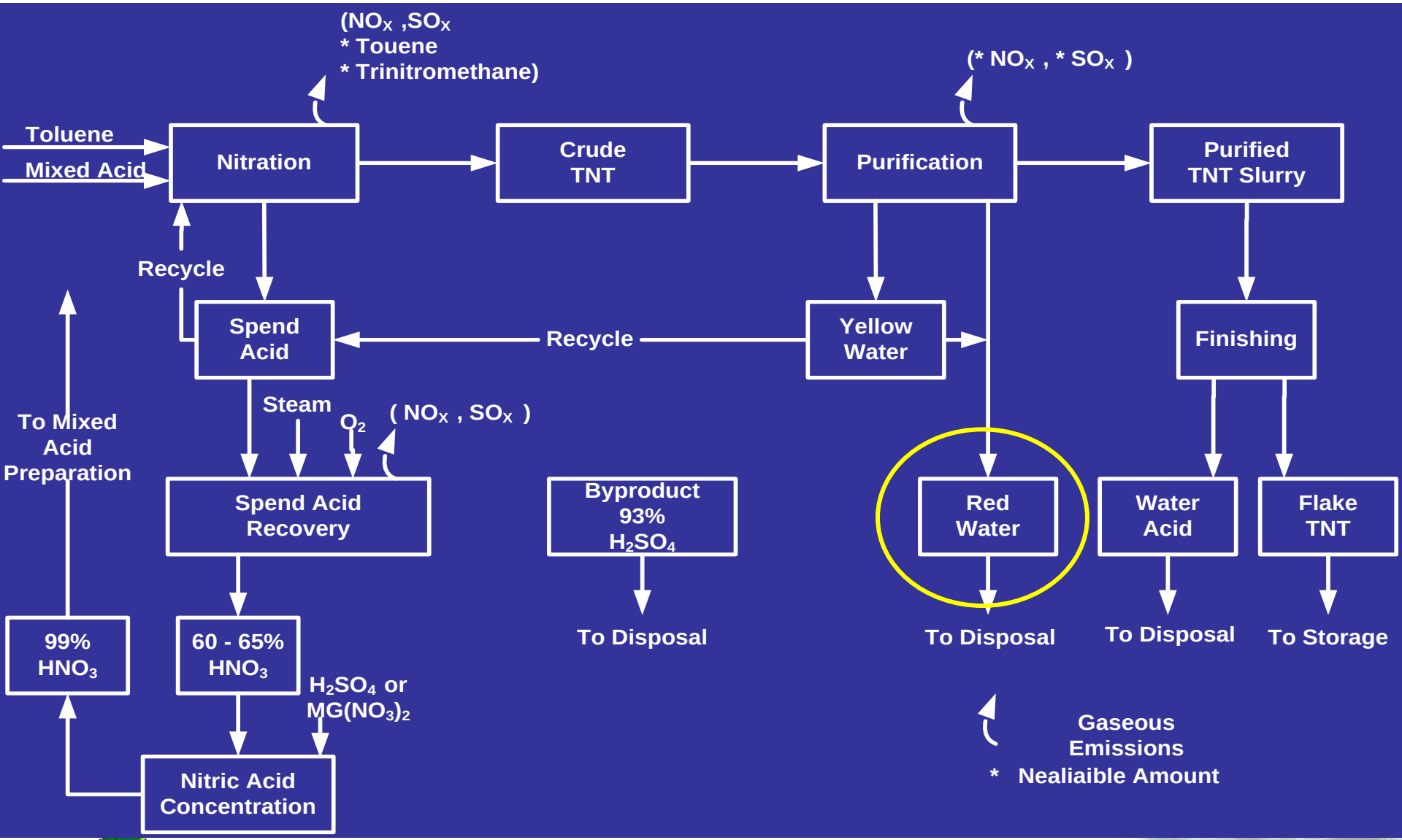
-. Textile Dyeing Wastewater (1993~2006)

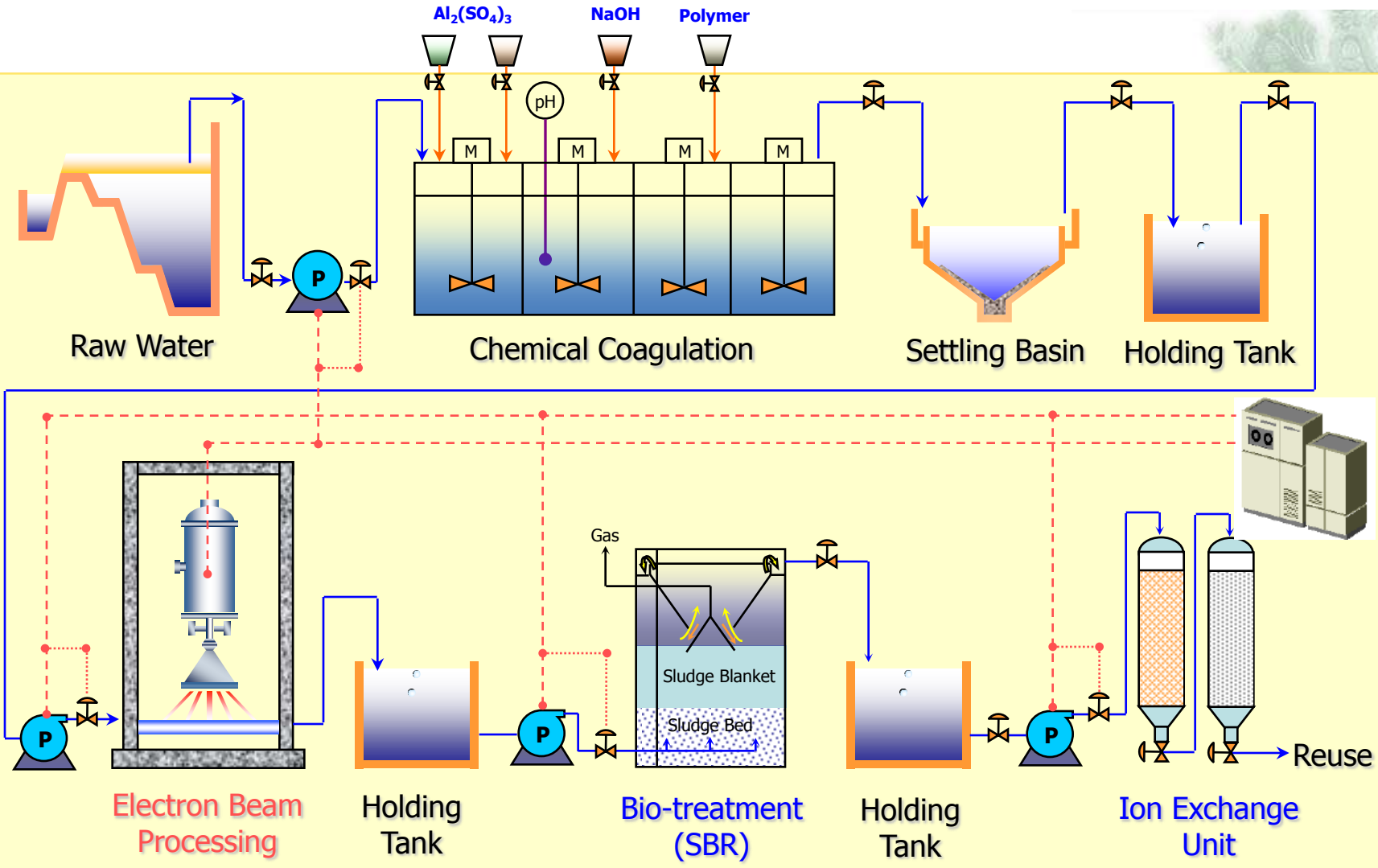
-. Leachate from Land filling (1993~1997)

-. Wastewater from Paper Mill (1995~1998)

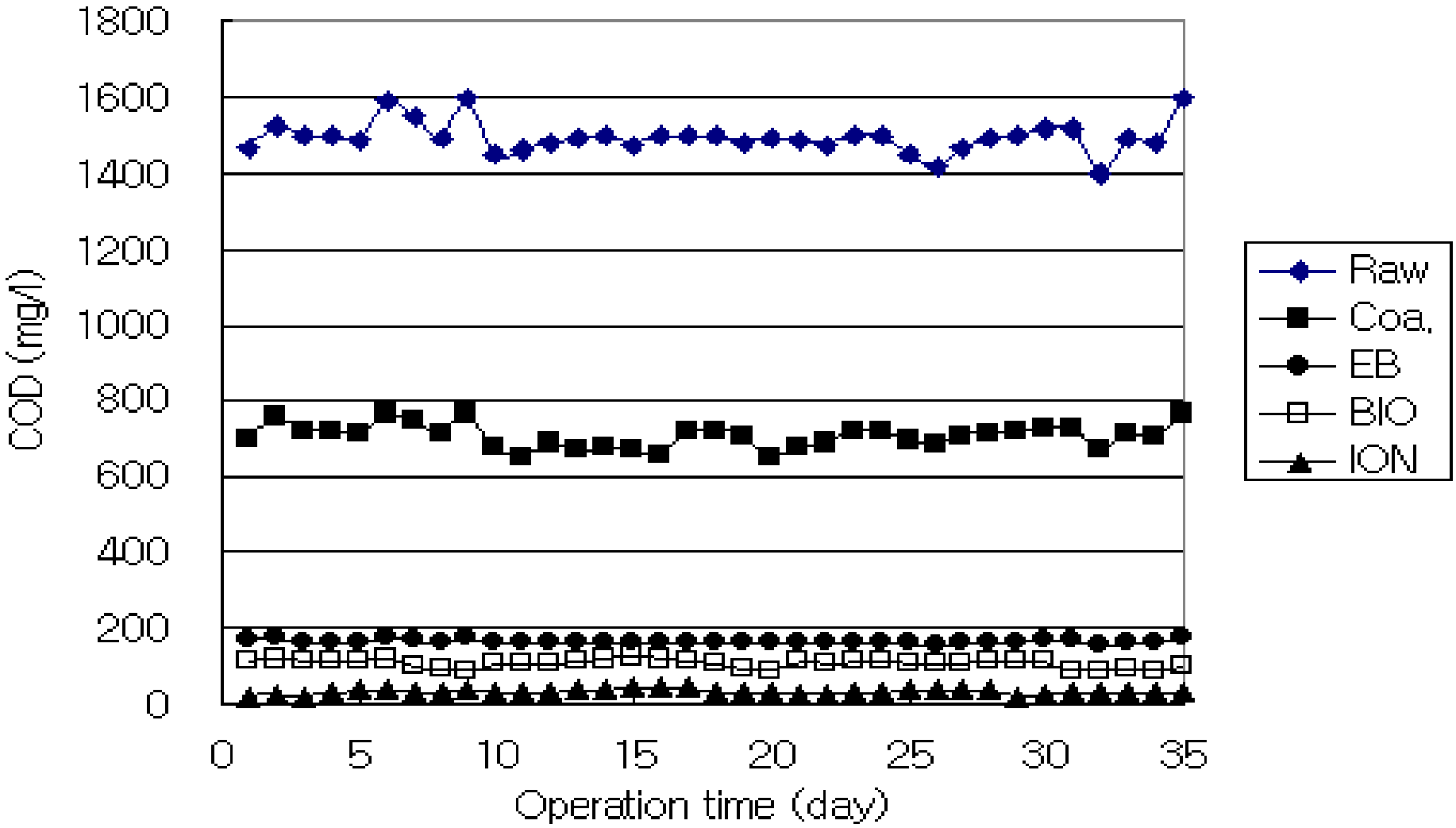
-. Wastewater with Heavy Metal (1995~1997)

A Flow Chart for TNT Production

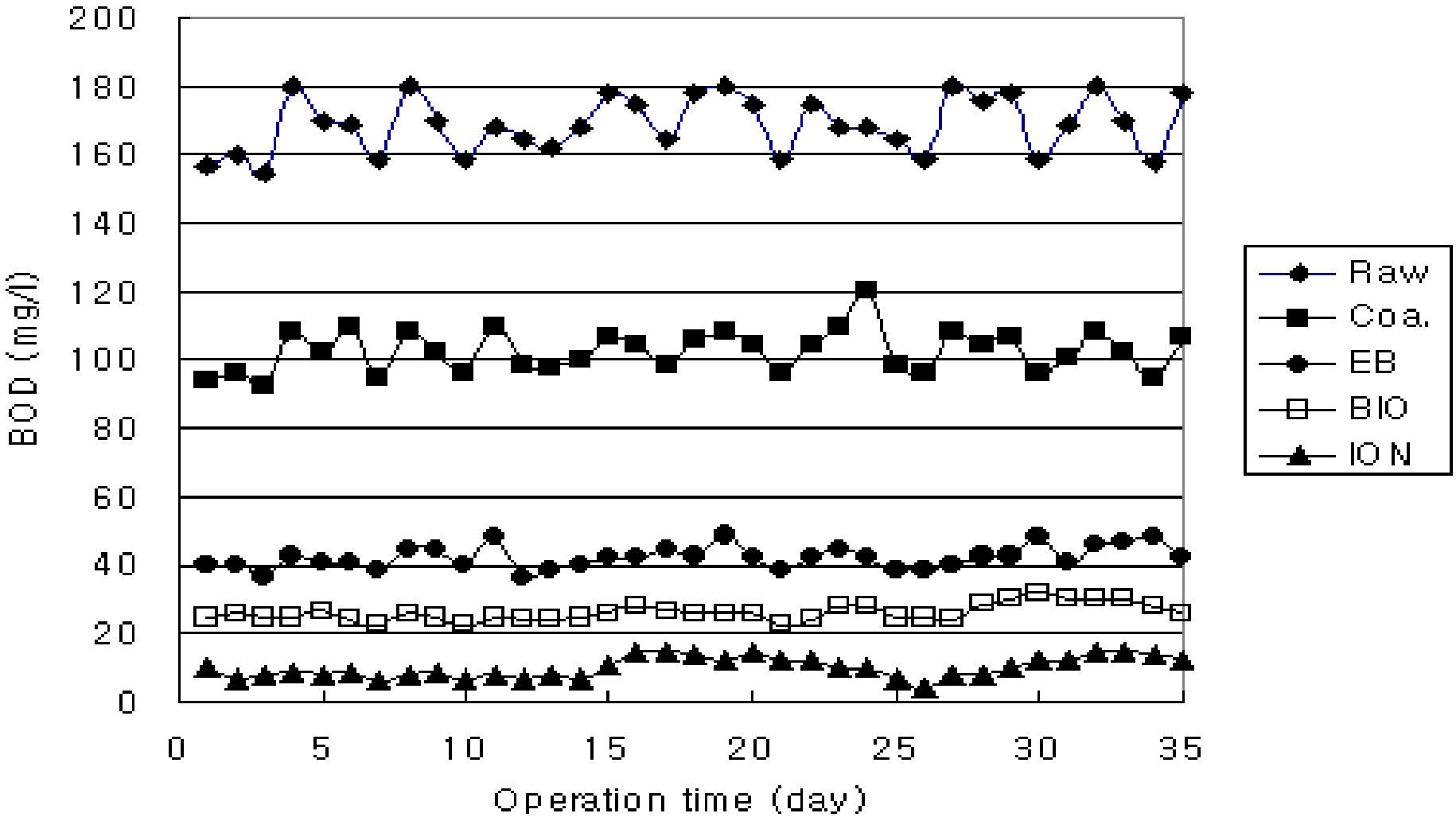



$Al_2(SO_4)_3$
NaOH
Polymer
pH
M
M
M
M
P
Raw Water
Chemical Coagulation
Settling Basin
Holding Tank
Gas
Sludge Blanket
Sludge Bed
P
P
P
Reuse
Electron Beam Processing
Holding Tank
Bio-treatment (SBR)
Holding Tank
Ion Exchange Unit

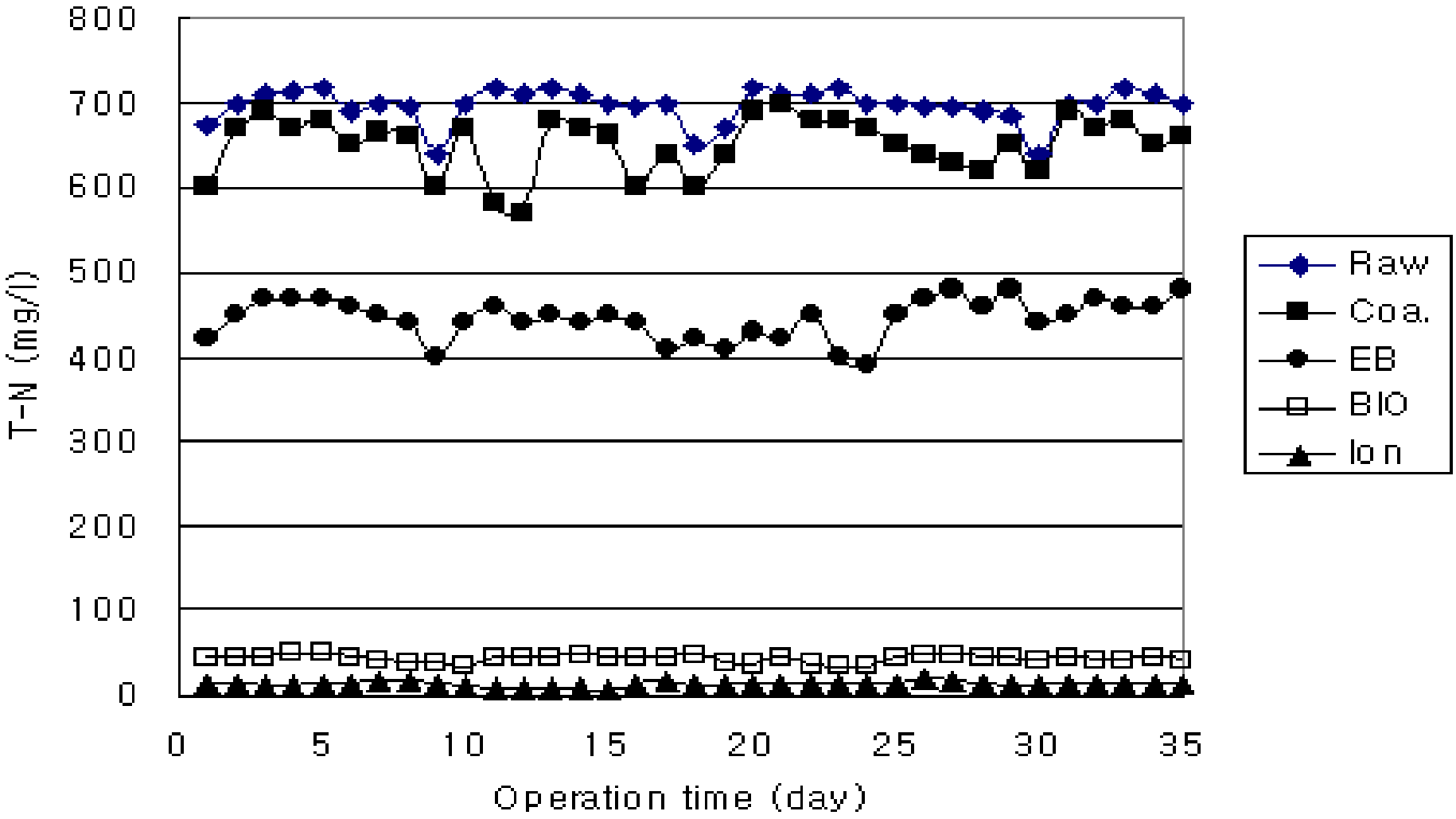
Variation of COD concentration during the experimental period

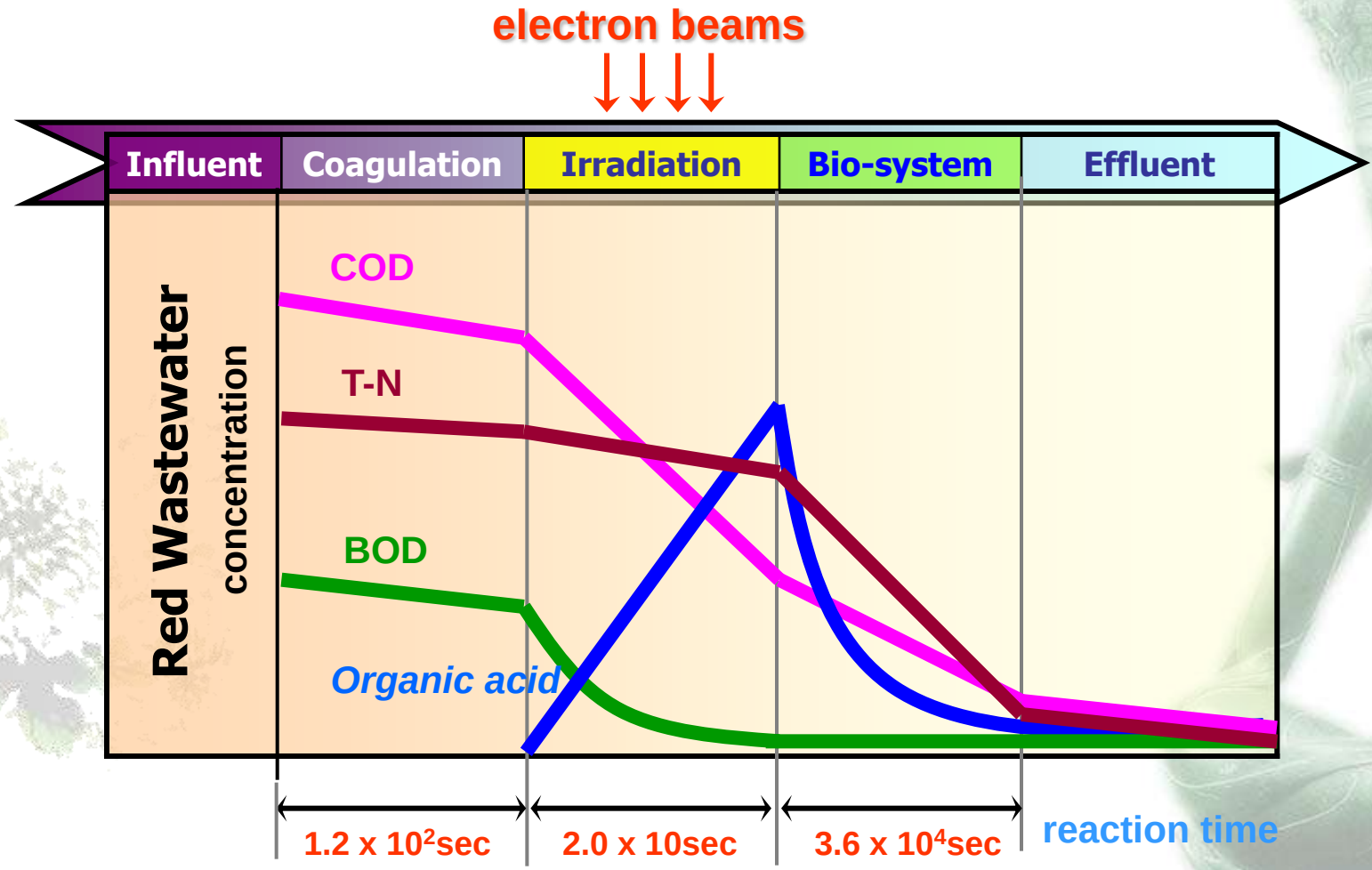


Variation of BOD concentration during the experimental period



Variation of TN during the experimental period

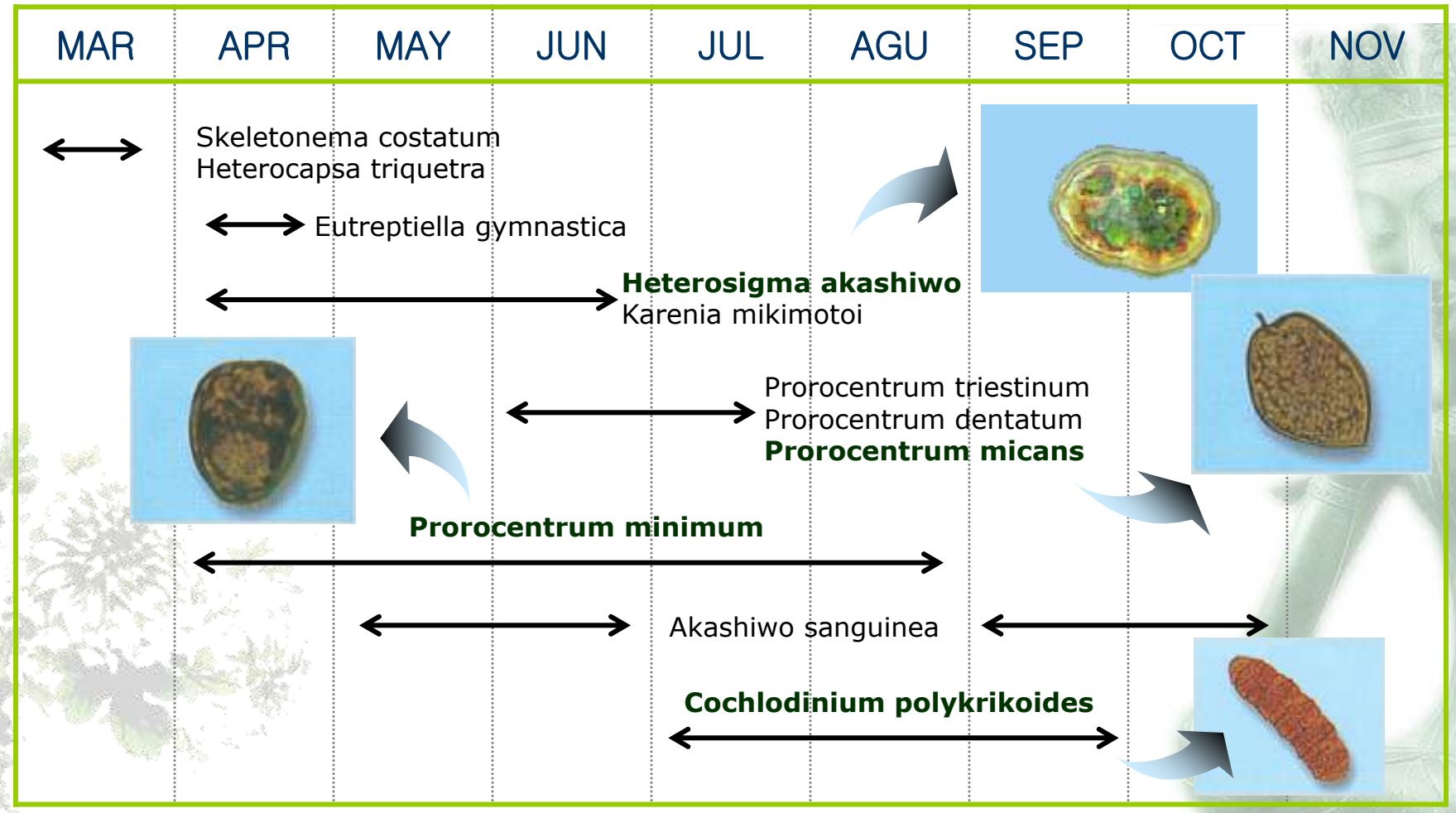



electron beams
Influent
Coagulation
Irradiation
Bio-system
Effluent
Red Wastewater
concentration
COD
T-N
BOD
Organic acid
1.2 x 10²sec
2.0 x 10sec
3.6 x 10⁴sec
reaction time

WastewaterTreatment

What was done

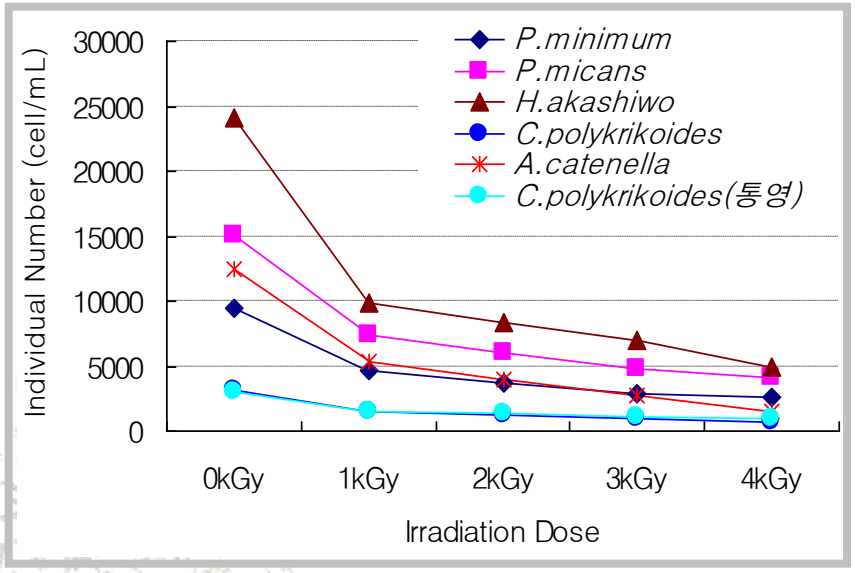
-. Textile Dyeing Wastewater (1993~2006)
-. Leachate from Land filling (1993~1997)
-. Wastewater from Paper Mill (1995~1998)
-. Wastewater with Heavy Metal (1995~1997)
-. Wastewater from Power plant (1997~1998)
-. Wastewater from explosives (2000~2004)
-. Algal bloom control (2002~2006)


MAR
APR
MAY
JUN
JUL
AGU
SEP
OCT
NOV
Skeletonema costatum
Heterocapsa triquetra
Eutreptiella gymnastica
Heterosigma akashiwo
Karenia mikimotoi
Prorocentrum triestinum
Prorocentrum dentatum
Prorocentrum micans
Prorocentrum minimum
Akashiwo sanguinea
Cochlodinium polykrikoides

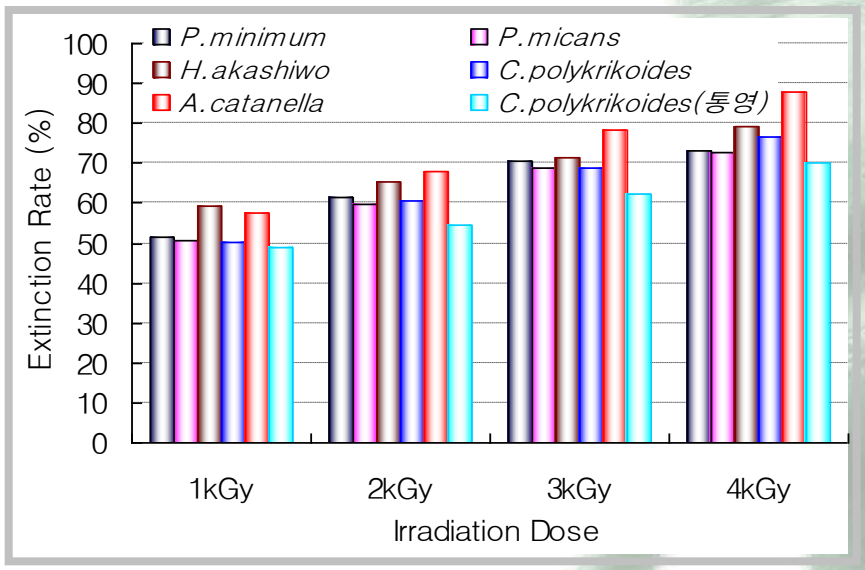
Continuous flow under-beam water treatment facility

● Reduction of Algae

Decrease in Algae with e-beam

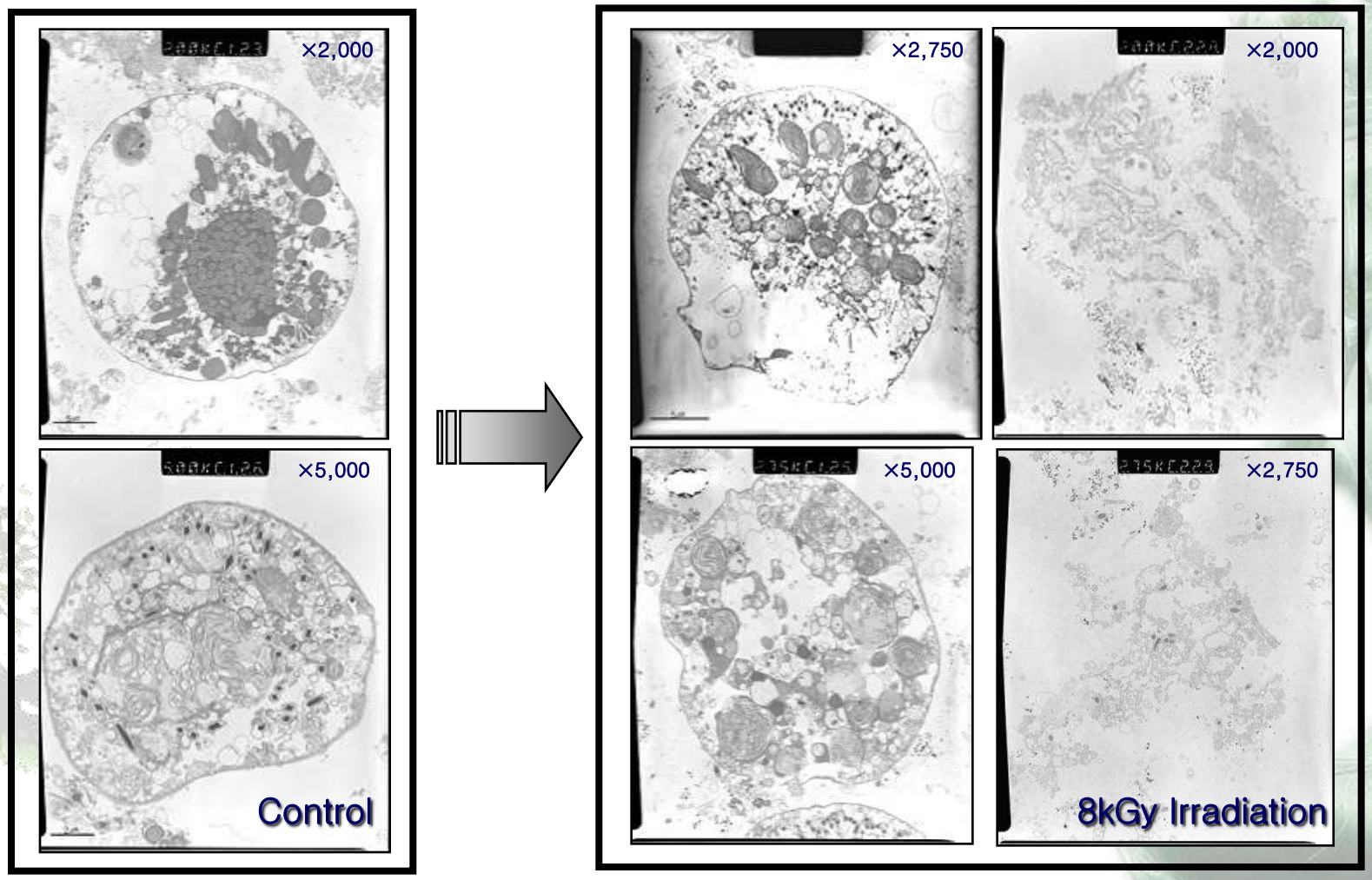


Removal efficiency



- **Depending on the Algae,**
  Removal of 50~60% at 1kGy, 60~70% at 2 kGy

- **TEM observation (*C.polykrikoides*)**



WastewaterTreatment

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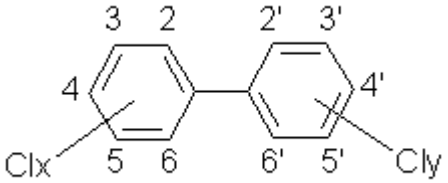
-. Wastewater from Power plant (1997~1998)
-. Wastewater from explosives (2000~2004)
-. Algal bloom control (2002~2006)
-. Destruction of PCBs from Transformer Oil (2006~2008)

Removal of PCBs in Transformer Oil

PCB (PolyChlorinatedBiphenyl) :



WastewaterTreatment

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-. Wastewater from Power plant (1997~1998)
-. Wastewater from explosives (2000~2004)
-. Algal bloom control (2002~2006)
-. Destruction of PCBs from Transformer Oil (2006~2008)

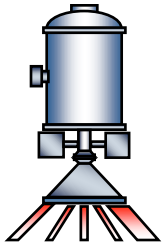
What is going on

-. Effluent from Municipal plant for re-use (with Pele and HDR, 2008~)

Types of Water/Wastewater Treatment

High contamination

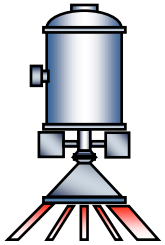
Textile dyeing wastewater
Leachate from landfill area
from petrochemical plant
from paper mills
from mines (coal, metals)
from chemical plants



→ 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

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)

		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 lowly-polluted industrial wastewater

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)

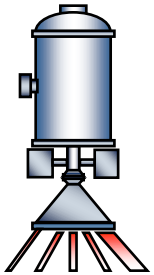
Existing System

Discharge after Bio treatment

Microorganisms, EDs etc.

Residual odor, colors

Proposed System



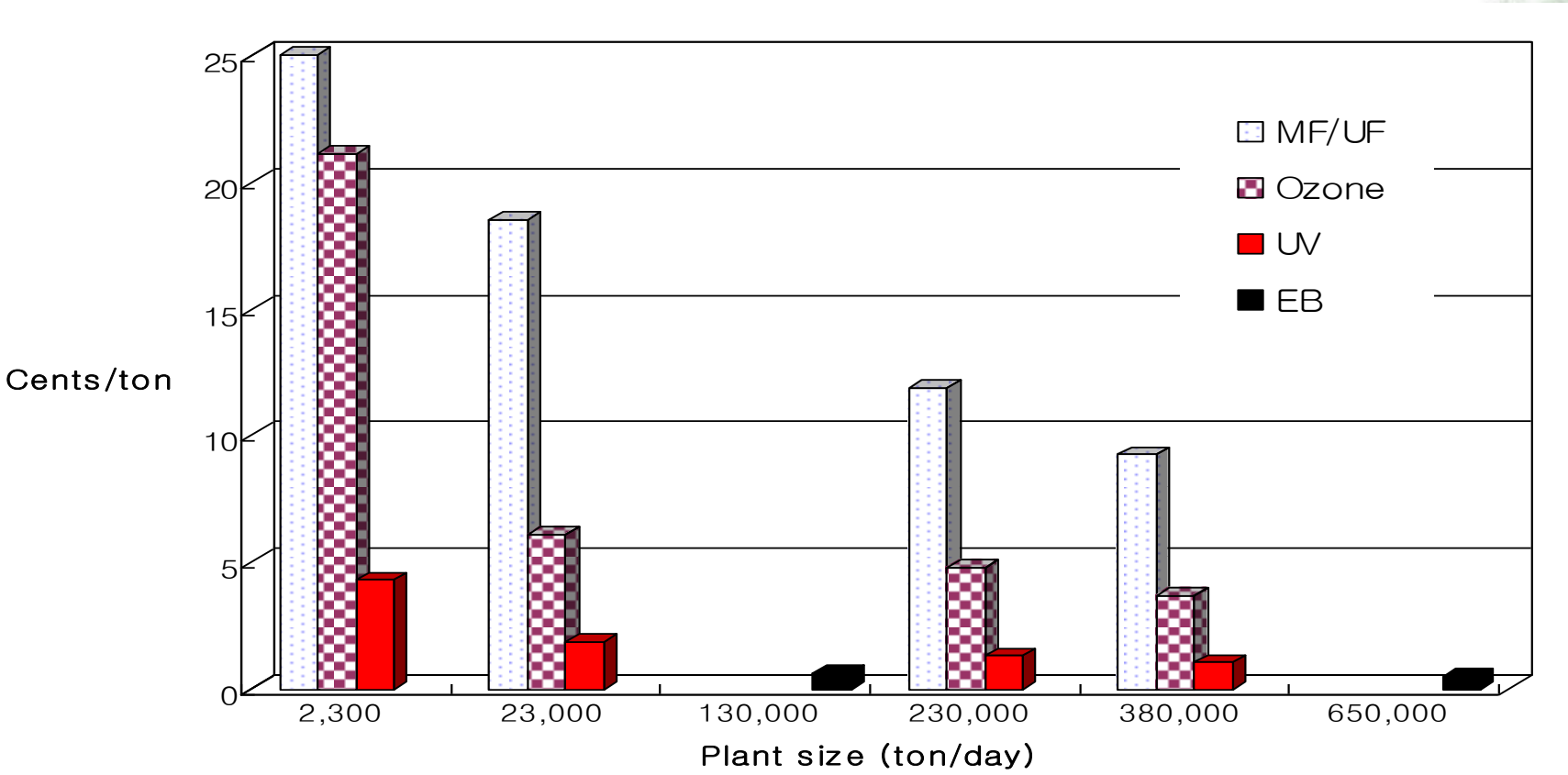
Radiation

Disinfection, Removal of odor, colors, EDs

Irrigation

Industries

Re-use



Reference : 1999 Drinking Water Infrastructure Needs Survey, Modeling the Cost of Infrastructure [EPA 816-R-01-005] February 2001

(EB data is based on the experiments from EB TECH)

WastewaterTreatment

What was done

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-. Leachate from Land filling (1993~1997)
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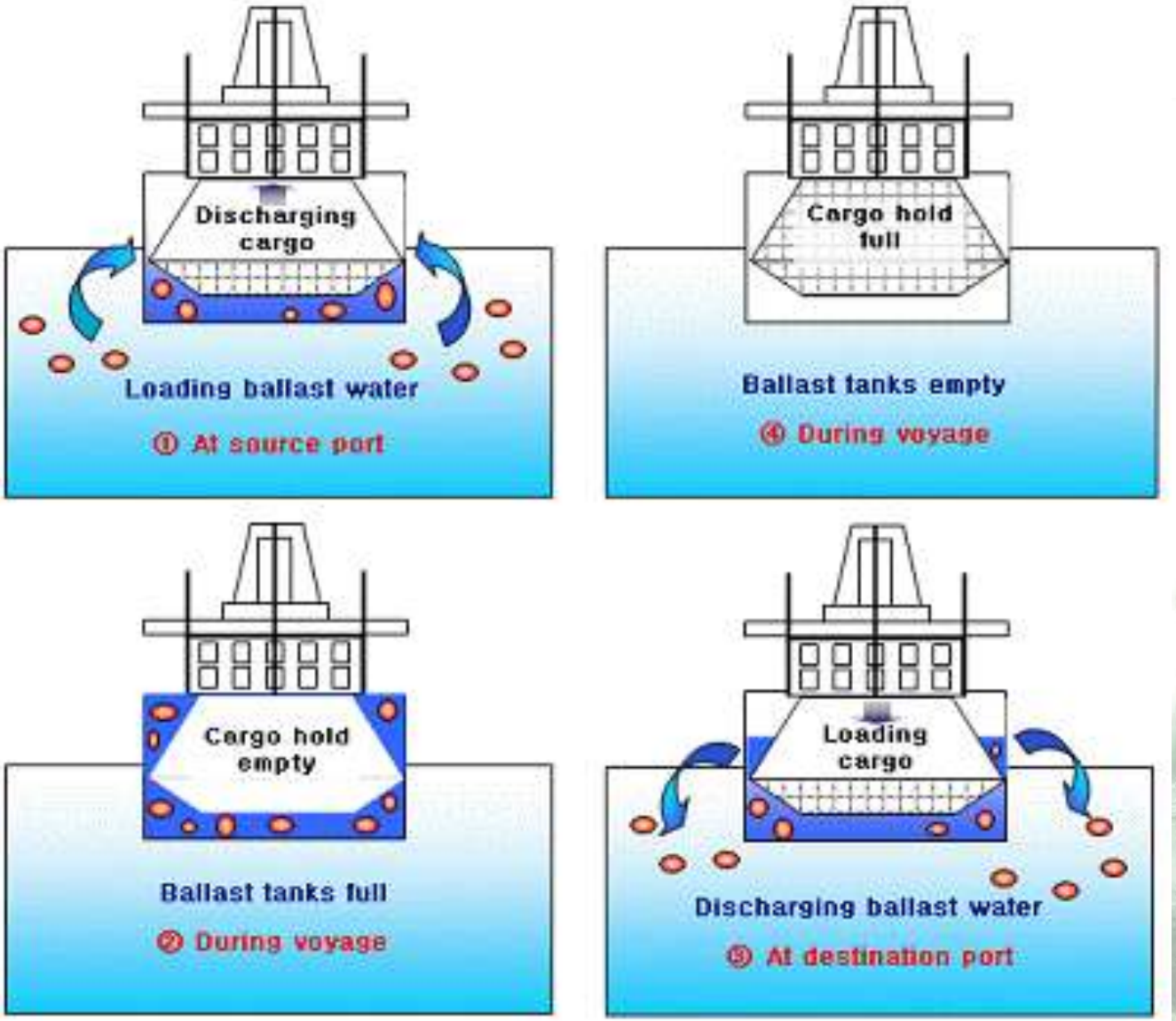
-. Wastewater with Heavy Metal (1995~1997)
-. Wastewater from Power plant (1997~1998)
-. Wastewater from explosives (2000~2004)
-. Algal bloom control (2002~2006)
-. Destruction of PCBs from Transformer Oil (2006~2008)

What is going on

-. Effluent from Municipal plant for re-use (with Pele and HDR, 2008~)
-. Marine Ballast water (with U. Akron, 2010~)


Discharging cargo
Loading ballast water
① At source port
Cargo hold full
Ballast tanks empty
④ During voyage
Cargo hold empty
Ballast tanks full
② During voyage
Loading cargo
Discharging ballast water
⑤ At destination port

Ten of the Most Unwanted

Marine plants, animals and microbes are being carried around the world attached to the hulls of ships and in ships' ballast water. When discharged into new environments, they may become invaders and seriously disrupt the native ecology and economy. Introduced pathogens may cause diseases and death in humans.

Cholera

Vibrio cholerae (various strains)

Native to: Various strains with broad ranges.

Introduced to: South America, Gulf of Mexico and other areas.

Impacts: Some cholera epidemics appear to be directly associated with ballast water. One example is an epidemic that began simultaneously at three separate ports in Peru in 1991, sweeping across South America, affecting more than a million people and killing more than ten thousand by 1994. This strain had previously been reported only in Bangladesh.

Cladoceran Water Flea

Cercopagis pengoi

Native to: Black and Caspian Seas

Introduced to: Baltic Sea

Impacts: Reproduces to form very large populations that dominate the zooplankton community and clog fishing nets and trawls, with associated economic impacts.

Mitten Crab

Eriocheir sinensis

Native to: Northern Asia

Introduced to: Western Europe, Baltic Sea and West Coast North America

Impacts: Undergoes mass migrations for reproductive purposes. Burrows into river banks and dykes causing erosion and siltation. Preys on native fish and invertebrate species, causing local extinctions during population outbreaks. Interferes with fishing activities.

Toxic Algae (Red/Brown/Green Tides)

Various species

Native to: Various species with broad ranges.

Introduced to: Several species have been transferred to new areas in ships' ballast water.

Impacts: May form Harmful Algae Blooms. Depending on the species, can cause massive kills of marine life through oxygen depletion, release of toxins and/or mucus. Can foul beaches and impact on tourism and recreation. Some species may contaminate filter-feeding shellfish and cause fisheries to be closed. Consumption of contaminated shellfish by humans may cause severe illness and death.

North American Comb Jelly

Mnemiopsis leidyi

Native to: Eastern Seaboard of the Americas

Introduced to: Black, Azov and Caspian Seas

Impacts: Reproduces rapidly (self-fertilising hermaphrodite) under favourable conditions. Feeds excessively on zooplankton. Depletes zooplankton stocks; altering food web and ecosystem function. Contributed significantly to collapse of Black and Azov Sea fisheries in 1990s, with massive economic and social impact. Now threatens similar impact in Caspian Sea.

North Pacific Seastar

Asterias amurensis

Native to: Northern Pacific

Introduced to: Southern Australia

Impacts: Reproduces in large numbers, reaching 'plague' proportions rapidly in invaded environments. Feeds on shellfish, including commercially valuable scallop, oyster and clam species.

Zebra Mussel

Dreissena polymorpha

Native to: Eastern Europe (Black Sea)

Introduced to: Western and northern Europe, including Ireland and Baltic Sea; eastern half of North America

Impacts: Fouls all available hard surfaces in mass numbers. Displaces native aquatic life. Alters habitat, ecosystem and food web. Causes severe fouling problems on infrastructure and vessels. Blocks water intake pipes, sluices and irrigation ditches. Economic costs to USA alone of around US$750 million to $1 billion between 1989 and 2000.

Asian Kelp

Undaria pinnatifida

Native to: Northern Asia

Introduced to: Southern Australia, New Zealand, West Coast of USA, Europe and Argentina

Impacts: Grows and spreads rapidly, both vegetatively and through dispersal of spores. Displaces native algae and marine life. Alters habitat, ecosystem and food web. May affect commercial shellfish stocks through space competition and alteration of habitat.

Round Goby

Neogobius melanostomus

Native to: Black, Azov and Caspian Seas

Introduced to: Baltic Sea and North America

Impacts: Highly adaptable and invasive. Increases in numbers and spreads quickly. Competes for food and habitat with native fishes including commercially important species, and preys on their eggs and young. Spawns multiple times per season and survives in poor water quality.

European Green Crab

Carcinus maenas

Native to: European Atlantic Coast

Introduced to: Southern Australia, South Africa, USA and Japan

Impacts: Highly adaptable and invasive. Resistant to predation due to hard shell. Competes with and displaces native crabs and becomes a dominant species in invaded areas. Consumes and depletes wide range of prey species. Alters inter-tidal rocky shore ecosystem.

Further information:

Global Ballast Water Management Programme
International Maritime Organization, London, UK
Fax: +44 (0)20 7587 3210
Web: http://globallast.imo.org

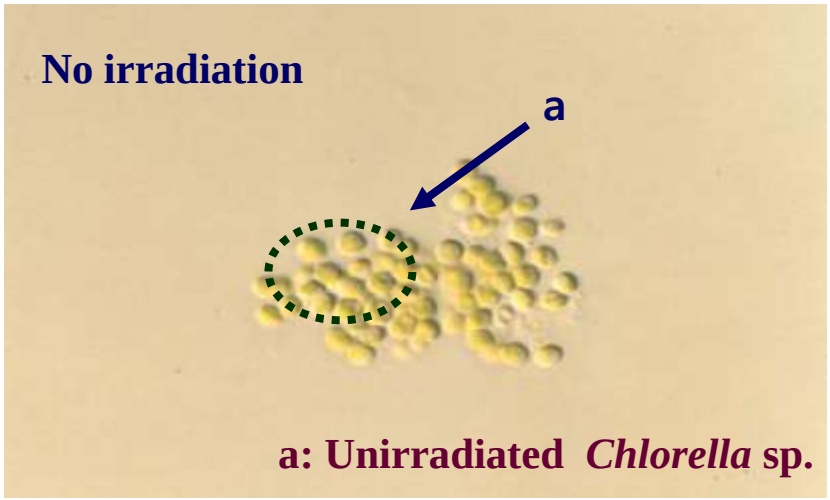
Photo credits: Ship discharging Ballast Water – CSIRO; CHRO Mitten Crab – Australia; Zebra Mussel – Bengt Olsen; Cladoceran Water Flea – Hugh Bromberg, Ontario – Gleb Lindin, Comb Jelly – Richard Harbison, Asian Kelp & North Pacific Seastar – CSIRO Australia; European Green Crab – T. Hayward; Toxic Algae – U.S. Navy; Cholera – Stephen Ballard; Round Goby – David Lees

Concept, research and design: Steve Raaymakers and Liz Arnold (designs@bigpond.com)

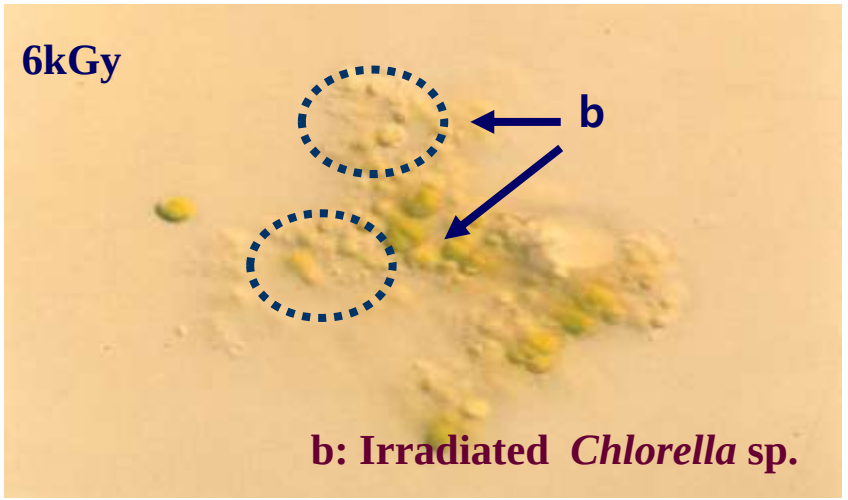
The species presented here are for illustrative purposes only. Their introduced ranges may be greater than depicted. There are numerous other examples of serious marine bio-invasions around the world.

Global Ballast Water Management Programme
GEF
undp

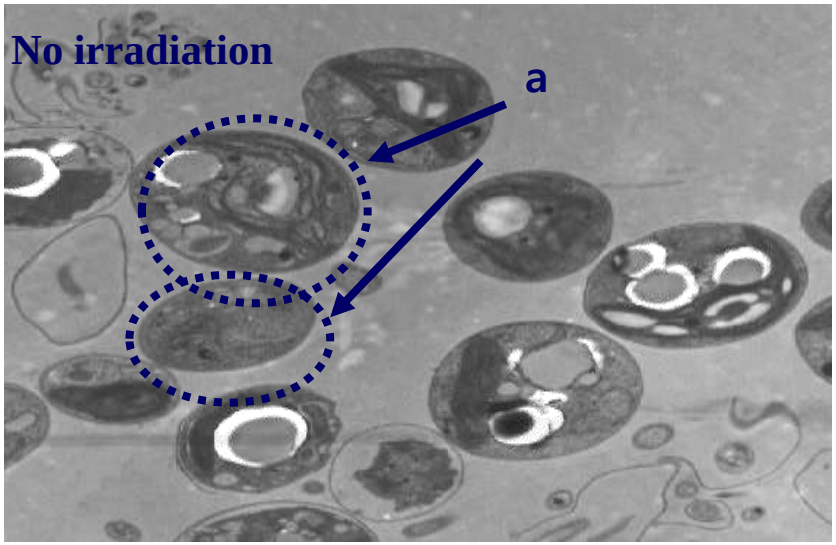
Optical Microscope Observation of Irradiated Algal Cell

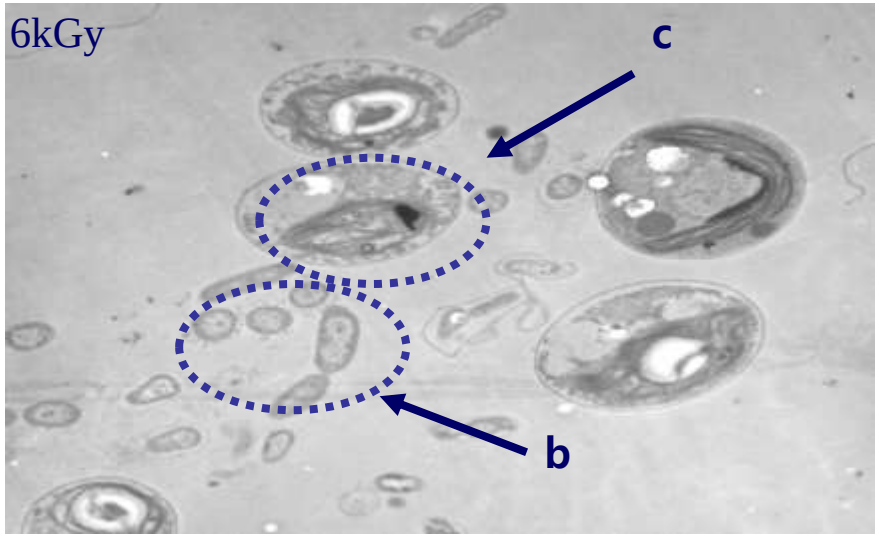


a: Unirradiated *Chlorella* sp.



b: Irradiated *Chlorella* sp.





a: Unirradiated *Chlorella* sp.

b: High molecular substance leaching out from the disintergrated *chlorella* sp.

c: Disintegrated *Chlorella* sp.

WastewaterTreatment

What was done

-. Textile Dyeing Wastewater (1993~2006)
-. Leachate from Land filling (1993~1997)
-. Wastewater from Paper Mill (1995~1998)
-. Wastewater with Heavy Metal (1995~1997)
-. Wastewater from Power plant (1997~1998)
-. Wastewater from explosives (2000~2004)
-. Algal bloom control (2002~2006)
-. Destruction of PCBs from Transformer Oil (2006~2008)

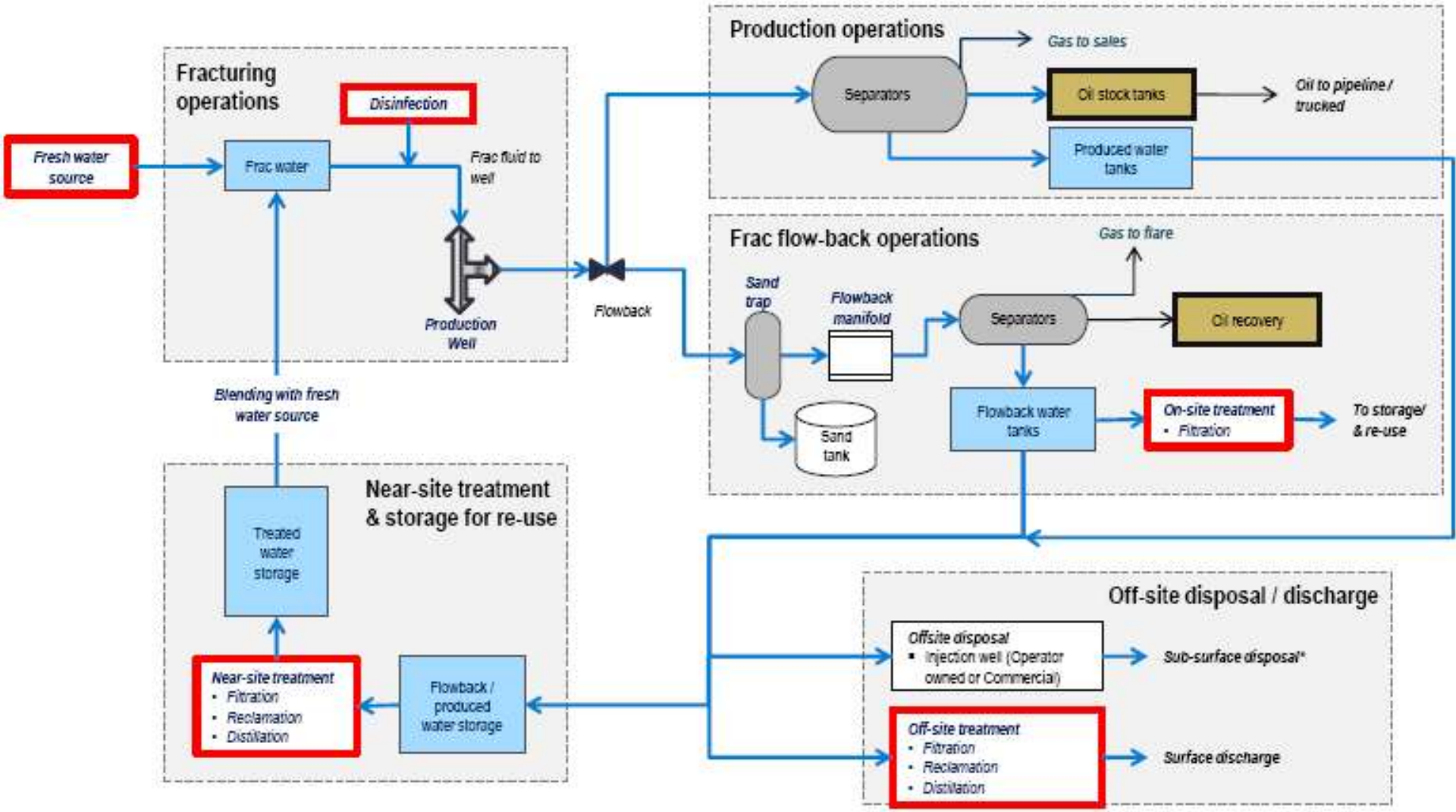
What is going on

-. Effluent from Municipal plant for re-use (with Pele and HDR, 2008~)
-. Marine Ballast water (with U. Akron, 2010~)

What will be

-. Disinfection of Frac water

Overview of Frac Water Treatment



Disinfection – Two new technologies: Chlorine Dioxide & Mixed Oxidants

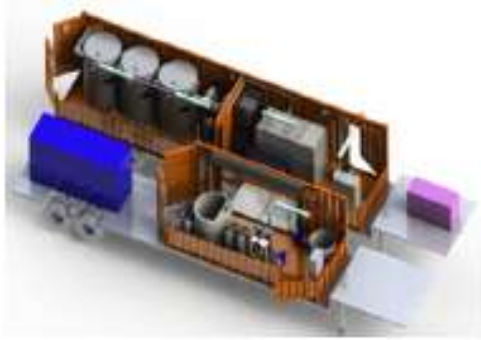
Adaptation of ClO_2 to frac operations

- **Technology**
  - On-site, on-demand generation of Chlorine Dioxide from the blend of three precursor chemicals
  - Technology has been used to disinfect water for over 30 years. Effectiveness is not limited in treating produced water as is the current version of the MIOX technology
  - Based on well established ClO_2 generating technology from Dupont, being adapted to frac site environment (Dupont owns the IP on the blending generator)
  - Higher operating safety risk than MIOX due to (handling of the precursors, but it can be mitigated

- **Status**
  - Pilot unit designed and currently being built
  - Pilot unit design is one that will be able to be made commercial pending adjustments determined during trials.

Mixed oxidants through partnership with MIOX

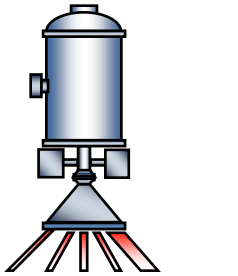
- **Technology**
  - On-site, on-demand generation of mixed oxidant by electrolysis of sodium chloride solution
  - Eliminates toxic biocides/ full disclosure
  - Does not interact with slickwater or X-linked frac fluids
  - Small footprint & low CAPEX
- **Partnership**, New Mexico-based company developing novel water disinfectant solutions
  - Equity investment to develop mixed oxidant system for flow-back water and on-site Bromine or quat ammonia generator
  - Exclusive rights in all aspects of water treatment for fracturing/stimulation operations.



- **Status**
  - Full scale prototype completed with 2 field trials, one for SWN, one for CHK.
  - Currently working for CHK in the EagleFord.

E- Beam Sludge Treatment

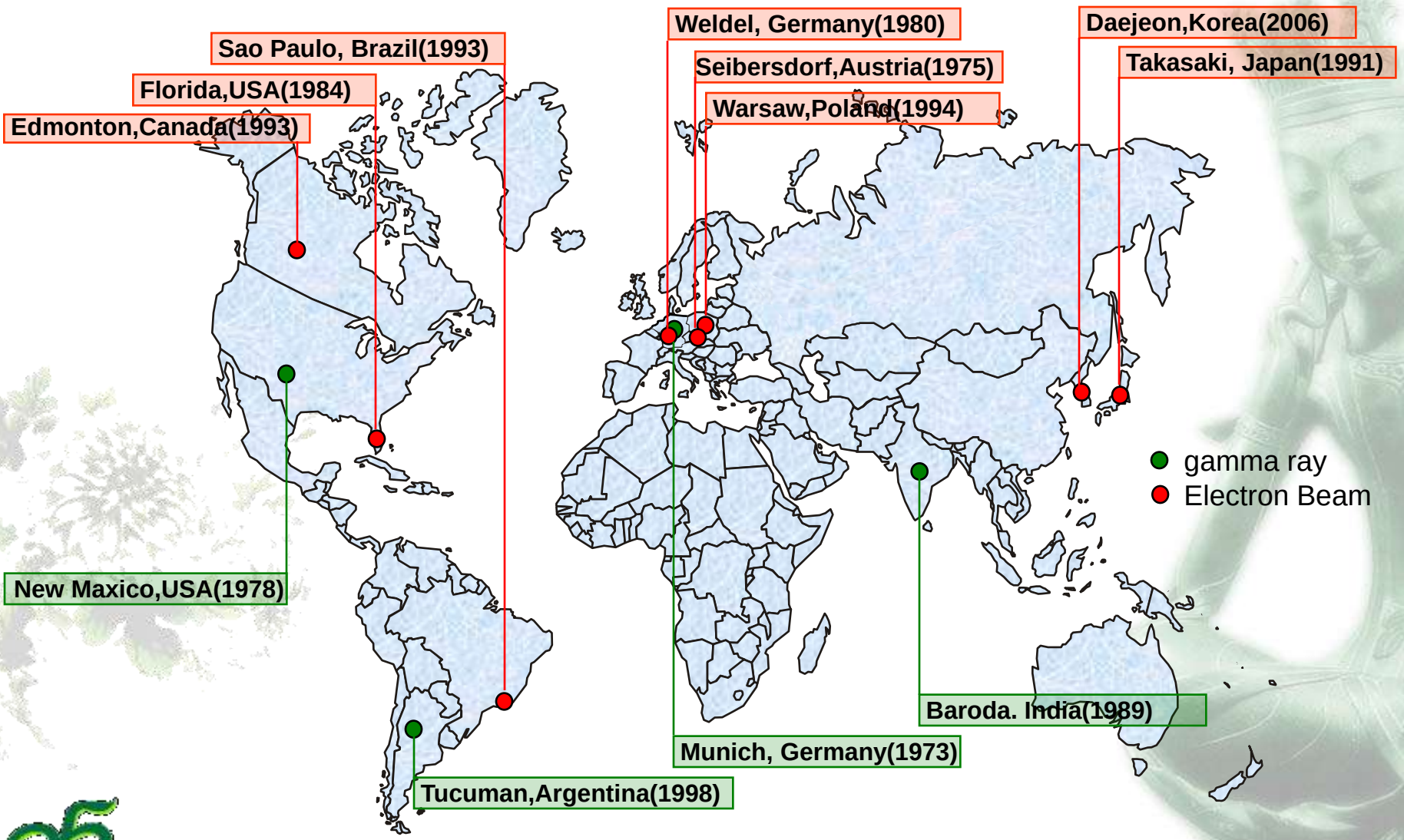
+. Sludge Hygienization



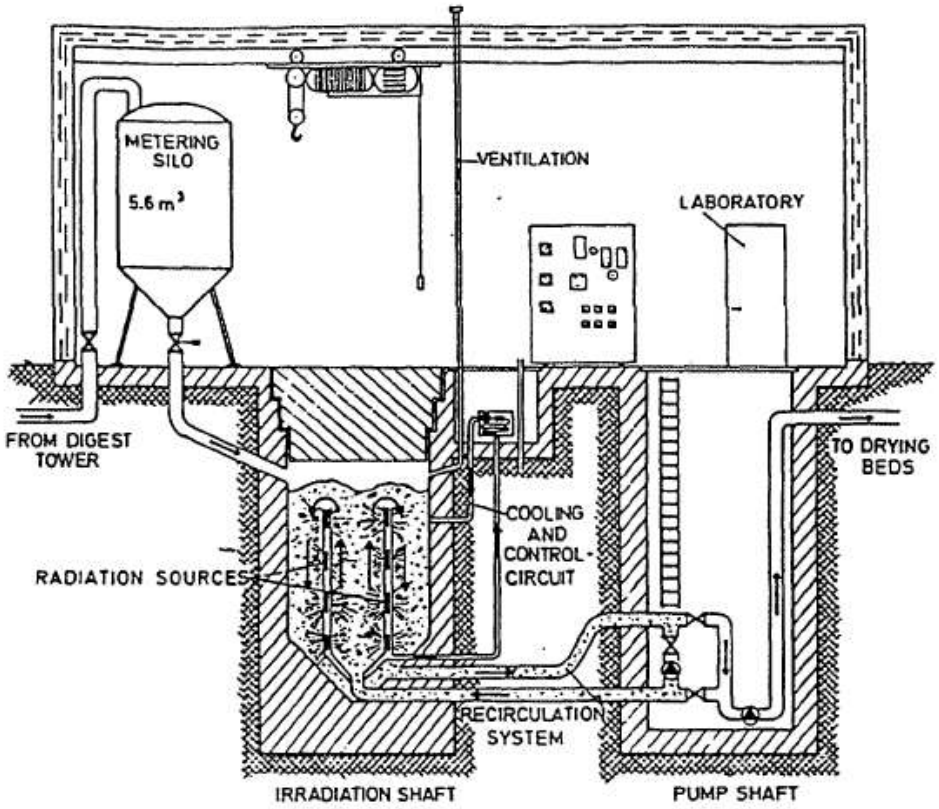
H_2O → (Radiation) → $\bullet OH$, $H\bullet$, e^-_{aq}, H_2, H_2O_2

$\bullet OH, H\bullet, e^-_{aq}$ + DNA of microorganism → Damage in DNA (no duplication)

Sludge Disinfection Plant in the World



Munich, Germany(1973-1984)



Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Geiselbullach, Germany(1973-1984)	Gamma-ray(Co-60, Cs-137) 0.57Mci	Liquid Sewage sludge, 145m3/day	2-3kGy	Commercial plant

Bild 12 : Außenansicht der Bestrahlungsanlage

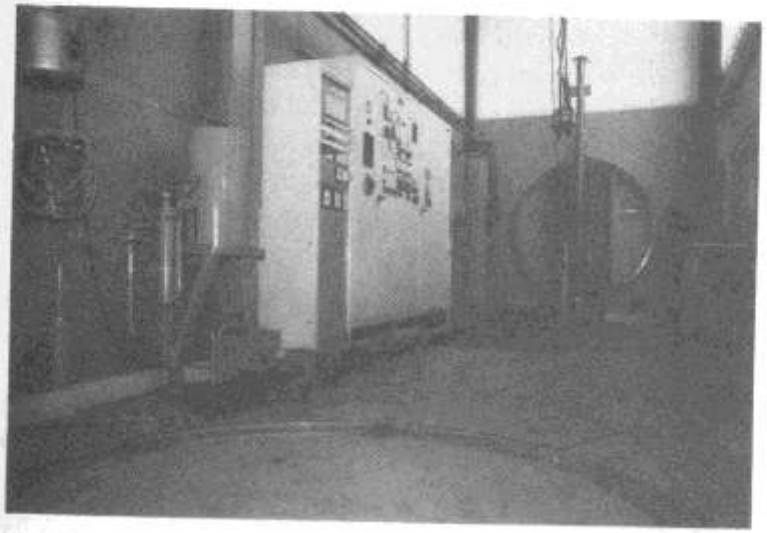


Bild 13 : Betriebsraum der Bestrahlungsanlage

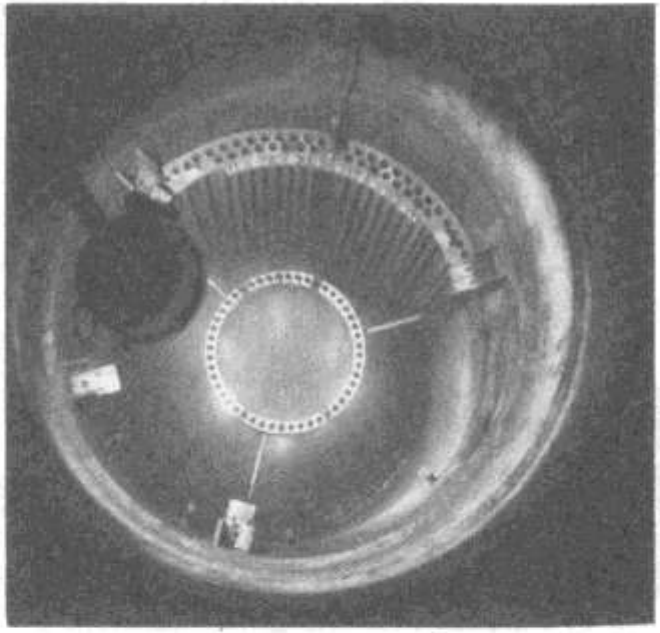


Bild 14 : Blick in den Bestrahlungsschacht

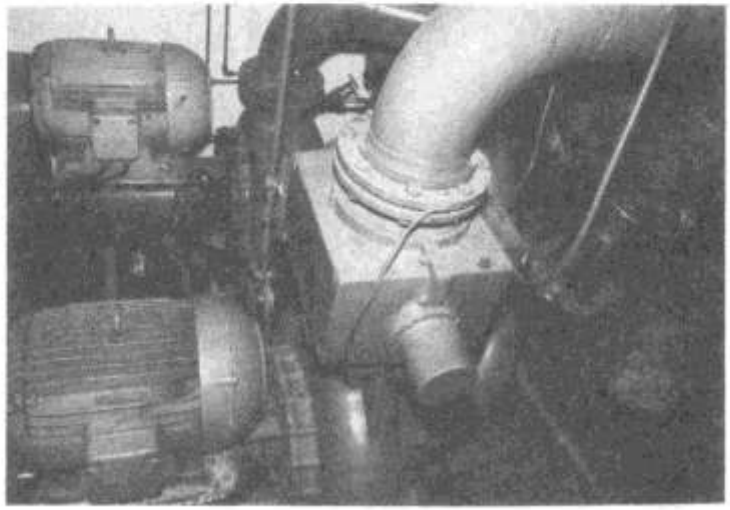
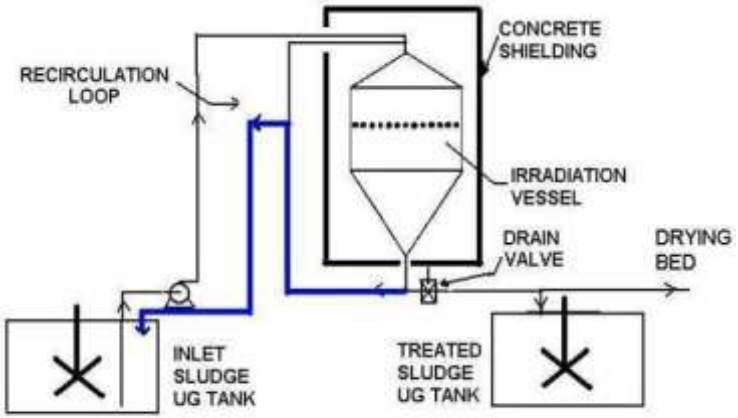
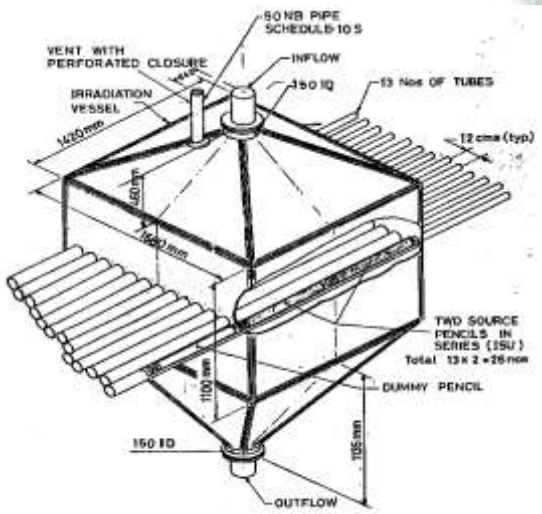


Bild 15 : Blick in den Pumpenschacht

Baroda. India(1989)



RADIATION PROCESS -MODIFIED



THE SOURCE FRAME INSIDE THE IRRADIATOR

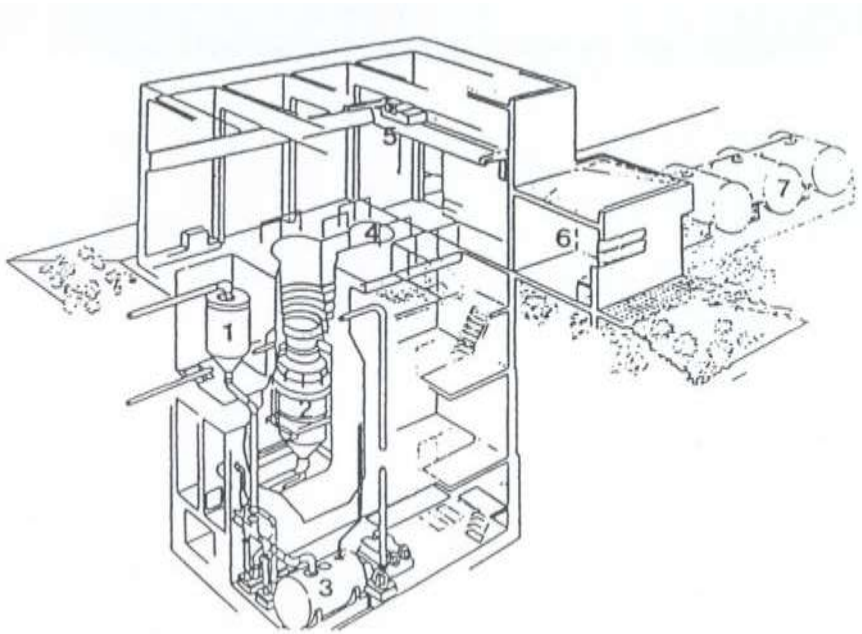
Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Baroda, India (1989)	Gamma-ray(60Co) 0.5Mci	Liquid Sewage sludge, 110m^3/day(4%SS)	3-5kGy	Commercial plant

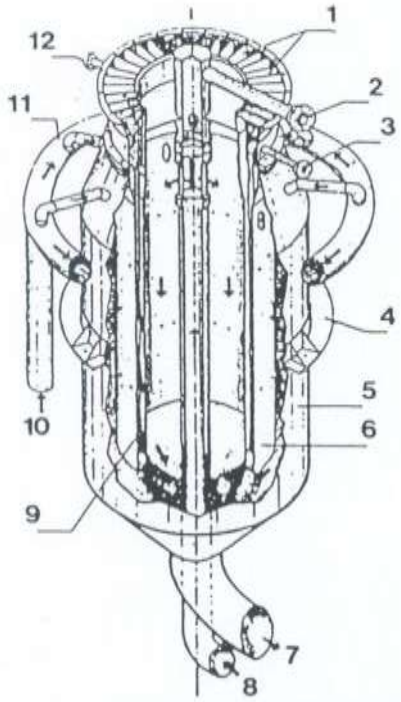

2006 3 14


2006 3 14


2006 3 13

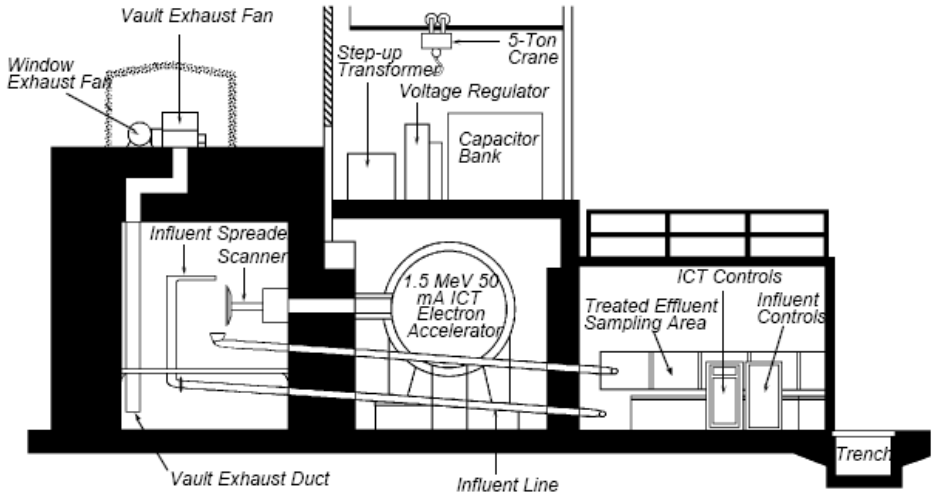
Tucuman,Argentina(1998)

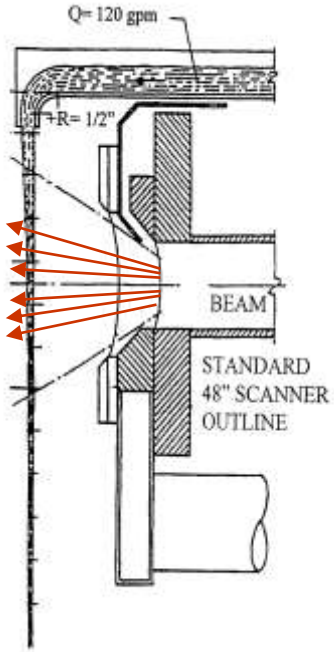




Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Tucuman, Argentina (1998)	Gamma-ray(60Co) 0.7Mci	Liquid Sewage sludge, 180m^3/day(8-10%SS)	3kGy	

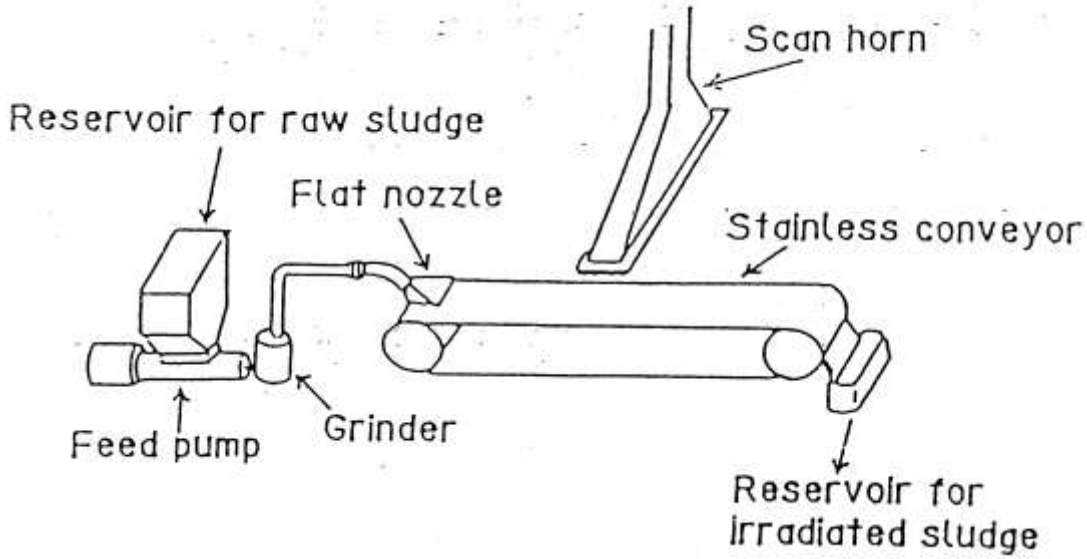
Florida, USA(1984)





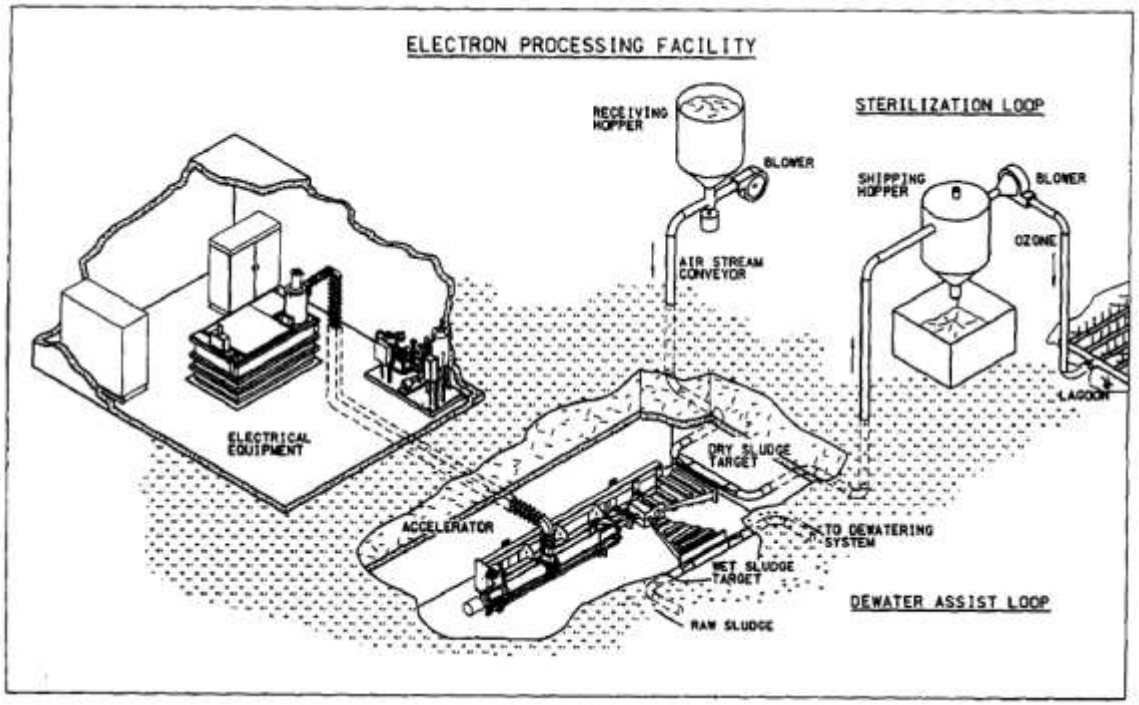
Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Verginia Key Florida, USA(1984)	Electron beam(ICT type) (75kW/1.5MeV/50mA)	Liquid Sewage sludge, 645m^3/hr, 4%ss	4kGy 10mm-thick	Pilot plant

Takasaki, Japan(1991)



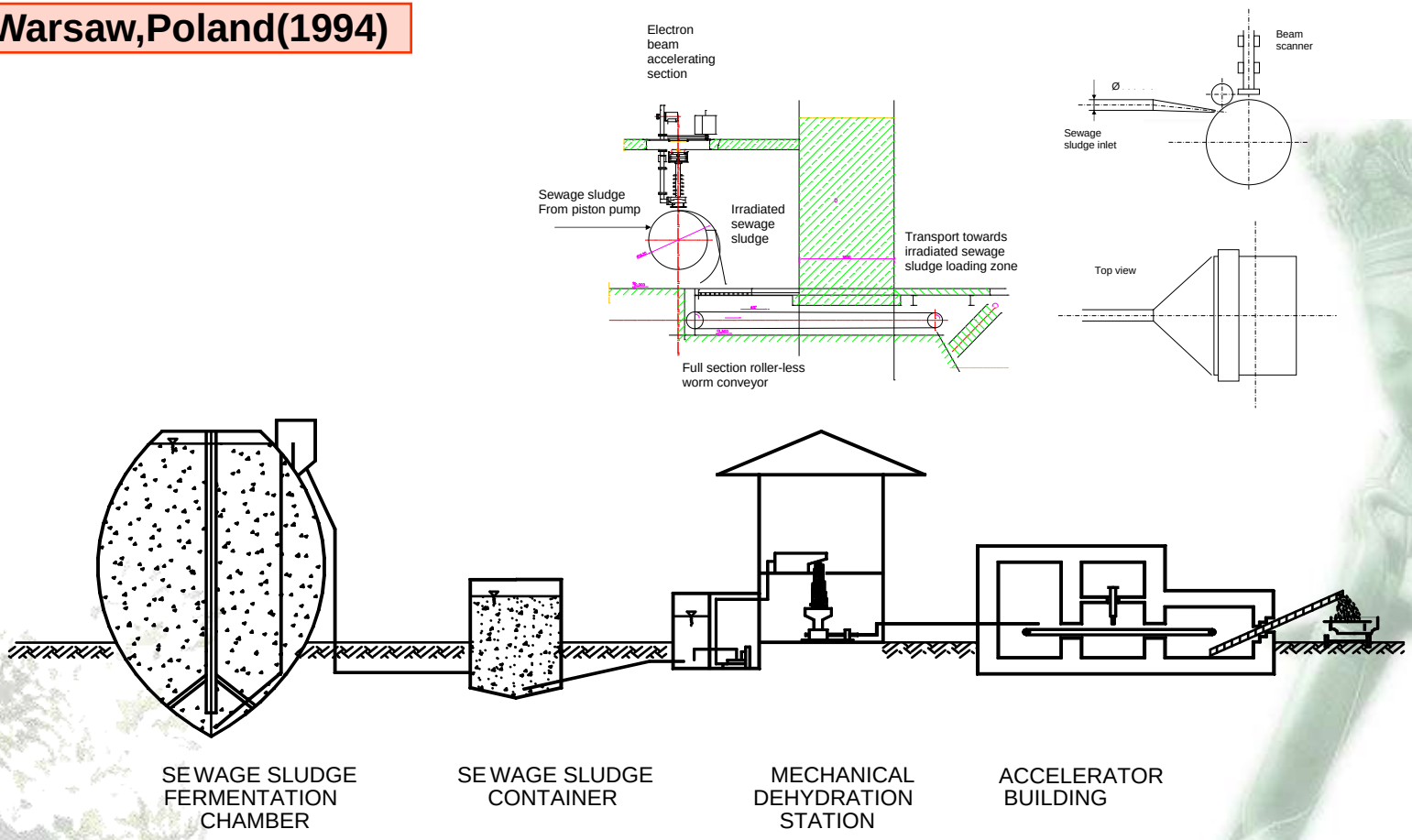
Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Takasaki, Japan (1991)	Electron beam (Cockcroft-walton) (15kW/2MeV/15kW)	Sewage sludge cake 300kg/h	5kGy 1-10mm thick	Conveyor/ Nozzle

Edmonton,Canada(1993)



Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Edmonton, Canada (1993)	Electron beam (IMPELA) 50kW(10MeV, 5mA)	Dewatered Sludge, 63t/d	5-15kGy	Proposal

Warsaw,Poland(1994)



Facilities	Irradiation Source	Irradiated material	Operation condition	Remarks
Warsaw, Poland (1994)	Electron beam (LAE13/9) (10MeV, 15kW)	Sewage sludge cake, 70t/day	5-7kGy 2-3cm thick	

Sludge Treatment

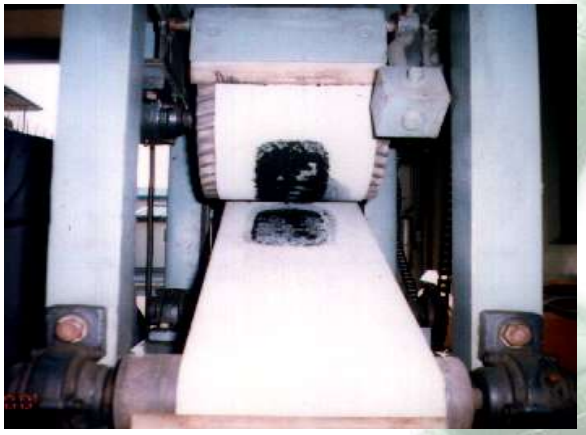
What was done

-. Improving dewatering efficiency of Sludge (1996~2000)

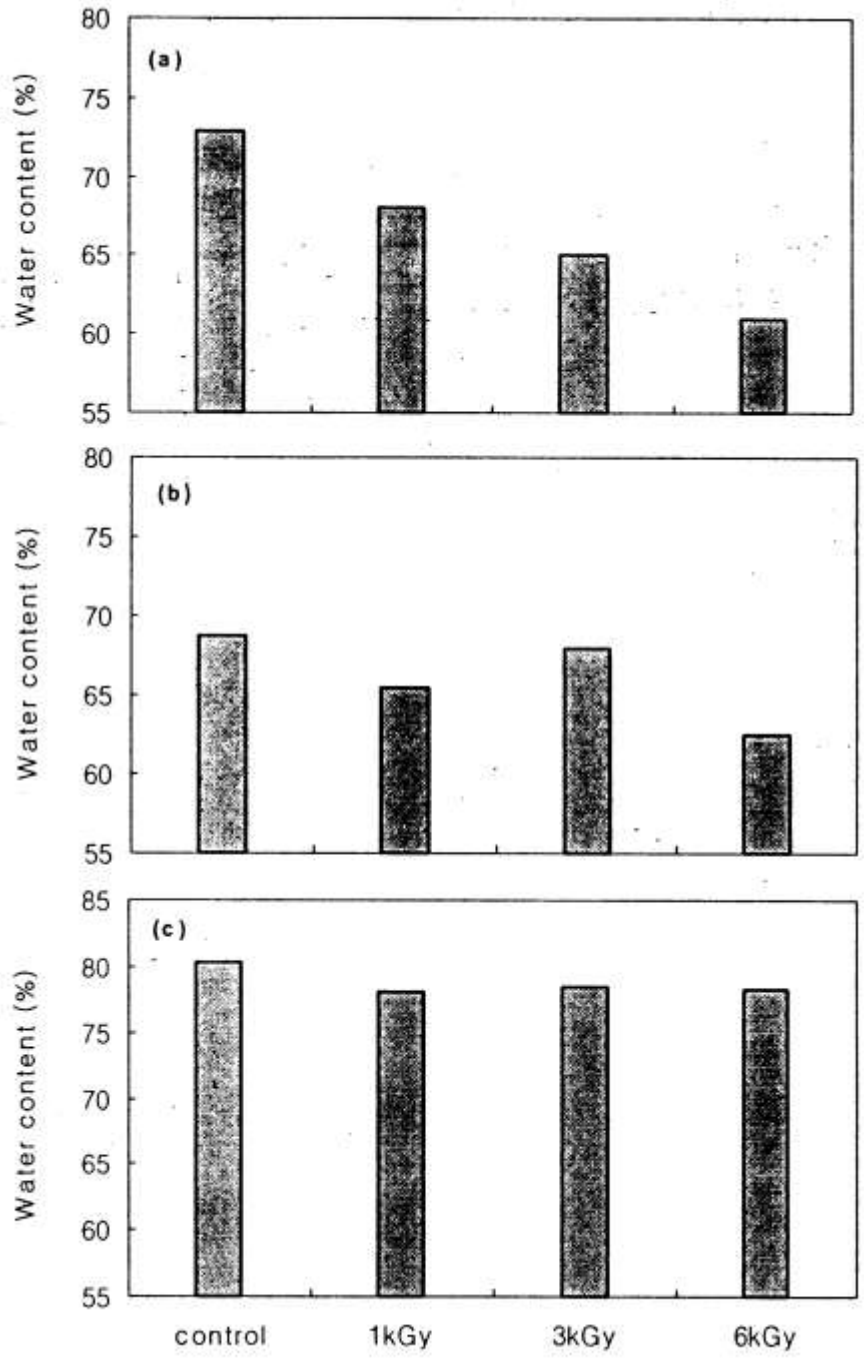
Dewatering of anaerobic digested sludge (EB Tech, 2000)

<Samples of Digested sludge>

<Belt press>



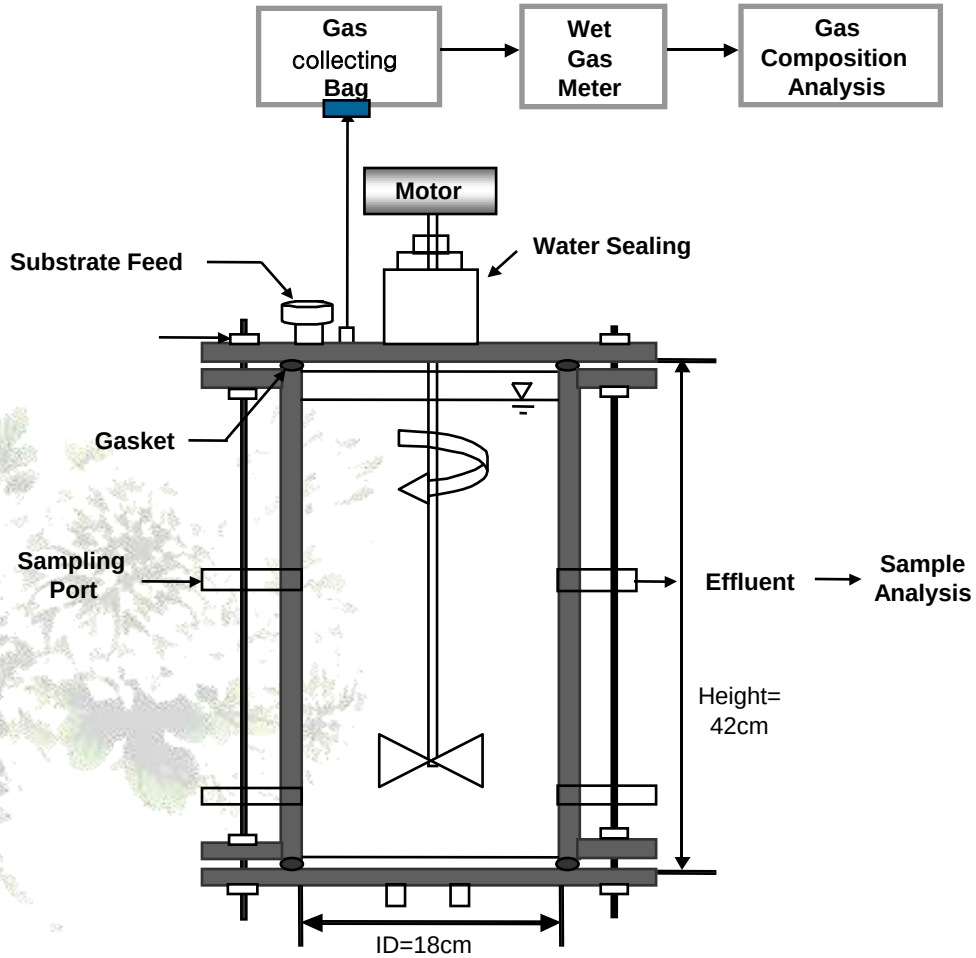
<Dewatering by Belt press>

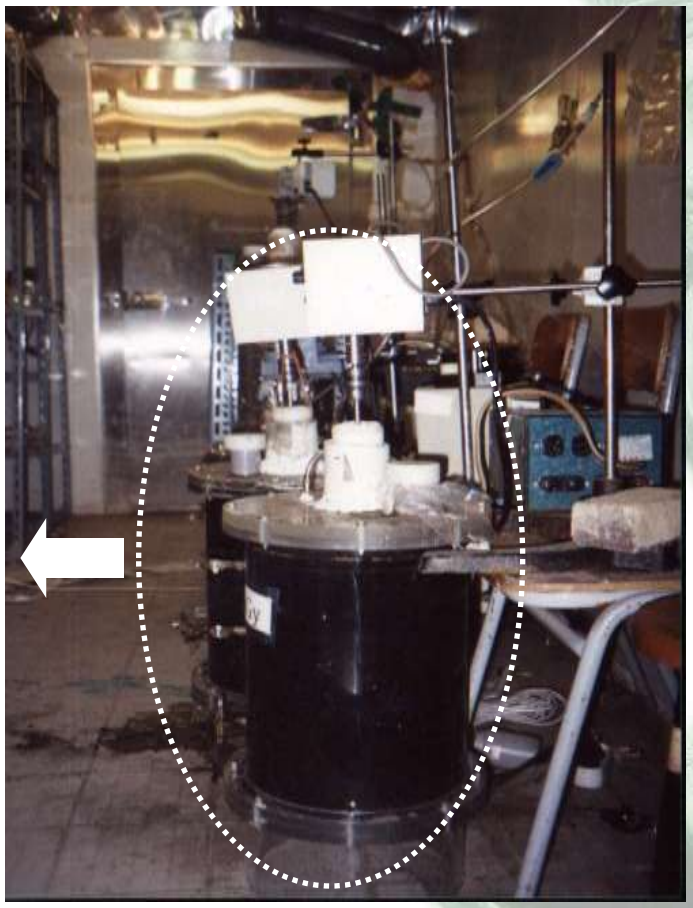


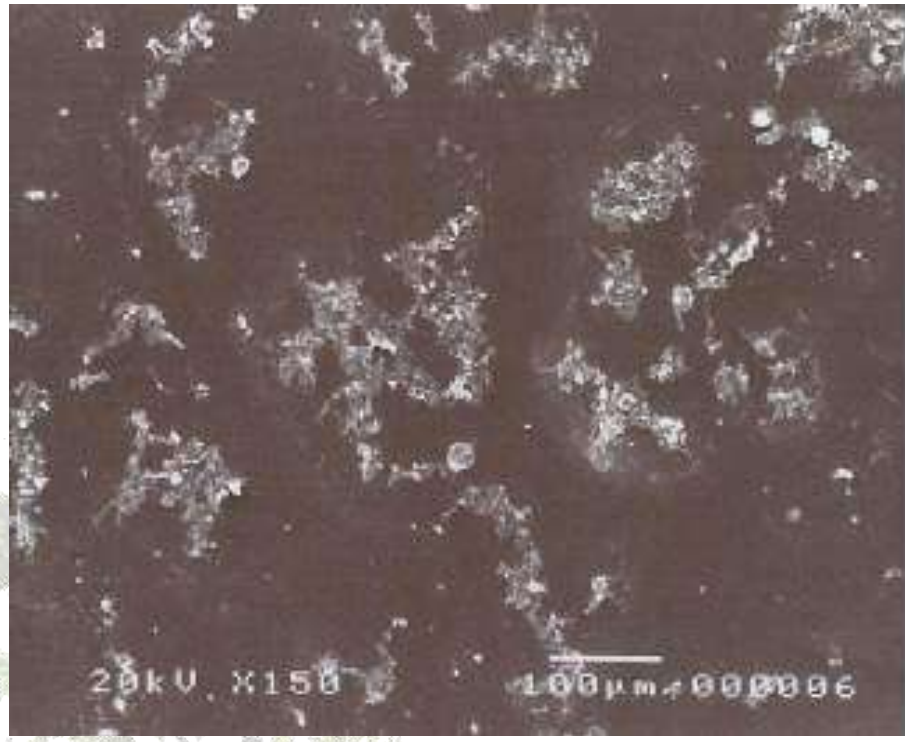
(a): Centrifuge
(b) : Vacuum filtration
(c) : Belt press

Effect of electron beam irradiation dose and dewatering methods on water content of dewatered sludge cake

Batch and CSTR with EB Pretreated Sludge







Untreated T-S

EB 6kGy

Scanning electron microscopic(SEM) examination of unirradiated sewage sludge (left) and irradiated sludge at 6kGy(right)

Sludge Treatment

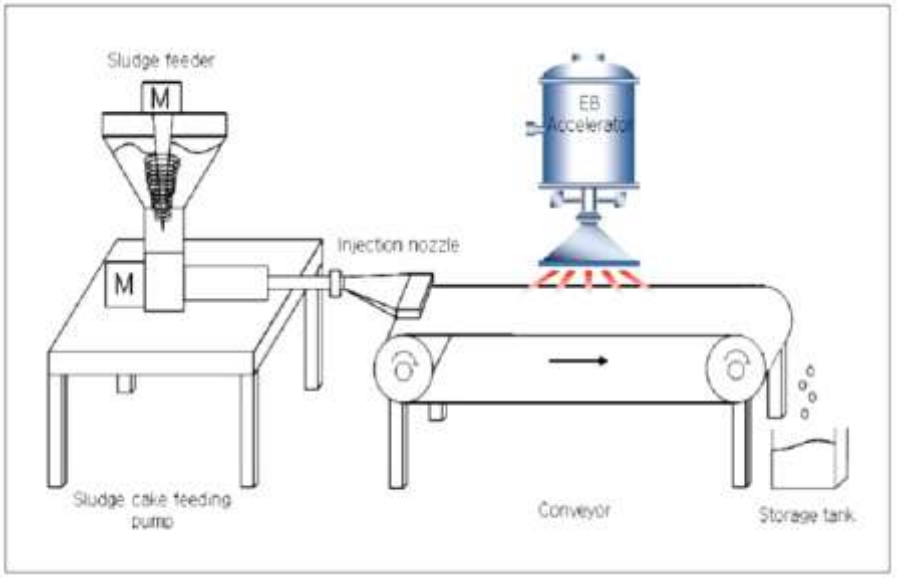
What was done

-. Improving dewatering efficiency of Sludge (1996~2000)

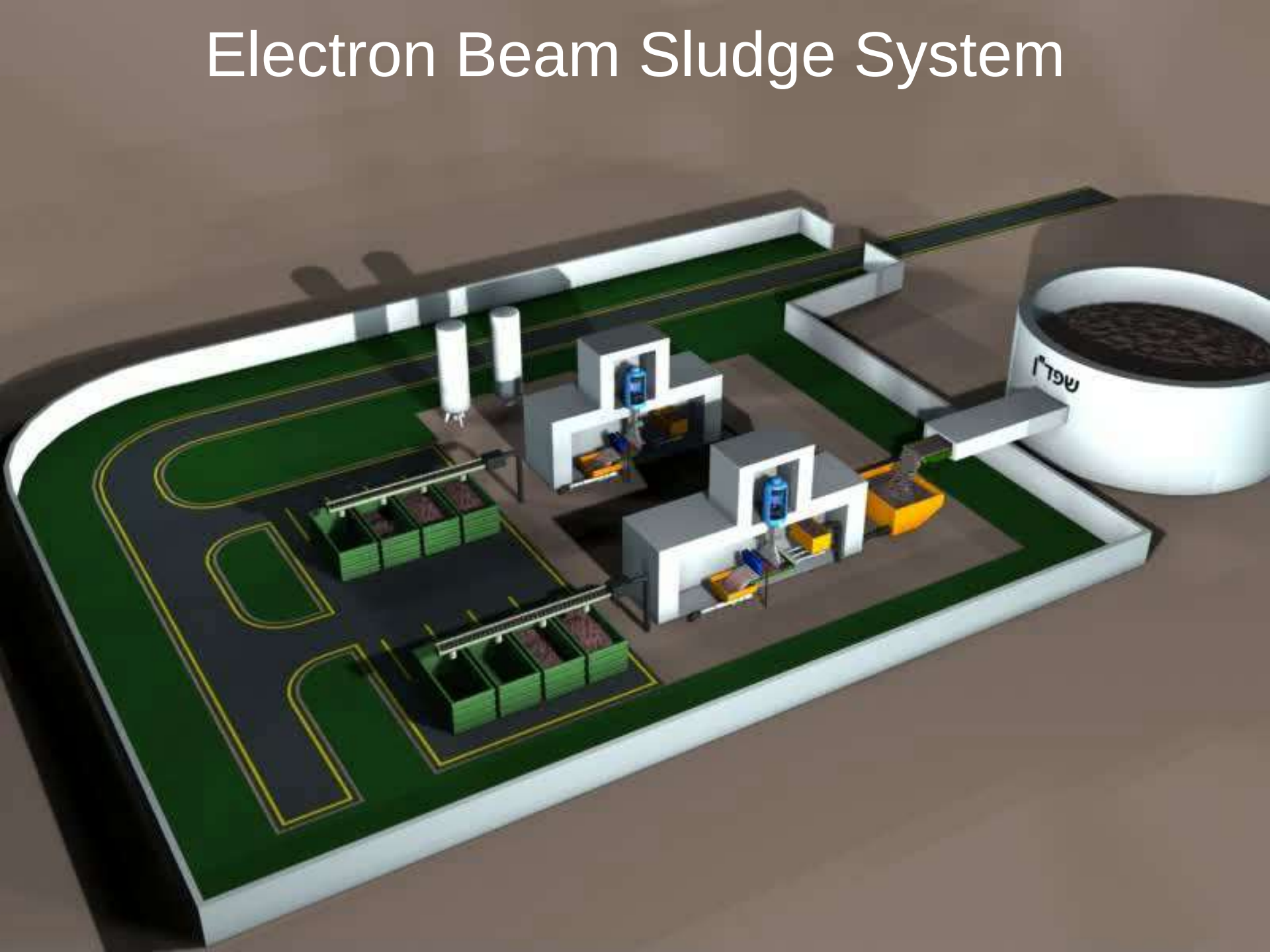
-. Disinfection Sludge Hygienation for re-use (2005~2009)

Sewage Sludge Treatment (ISRAEL)


Shafdan Wastewater Treatment Plant


Sludge feeder
M
EB
Accelerator
Injection nozzle
M
Sludge cake feeding
pump
Conveyor
Storage tank

Electron Beam Sludge System



Sludge Treatment

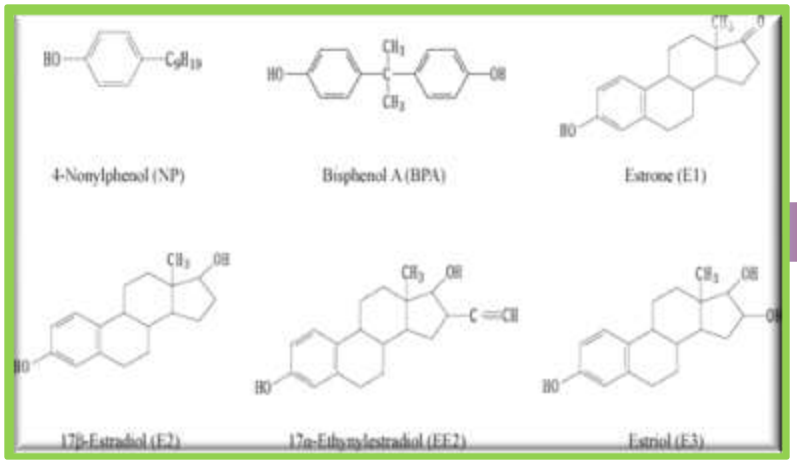
What was done

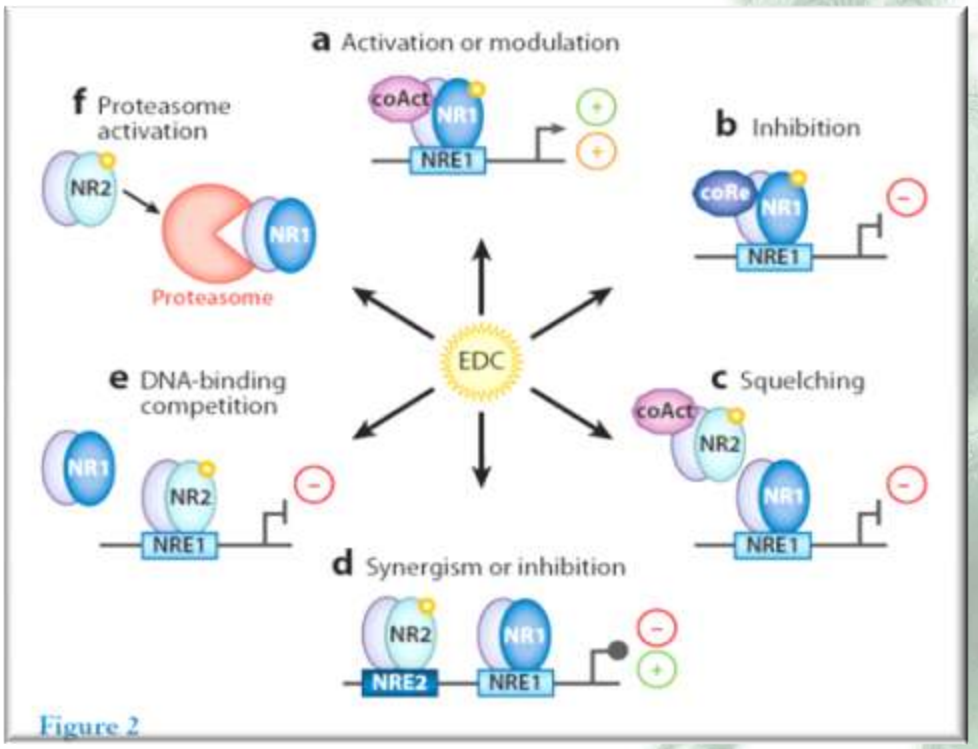
-. Improving dewatering efficiency of Sludge (1996~2000)
-. Disinfection Sludge Hygienation for re-use (2005~2009)

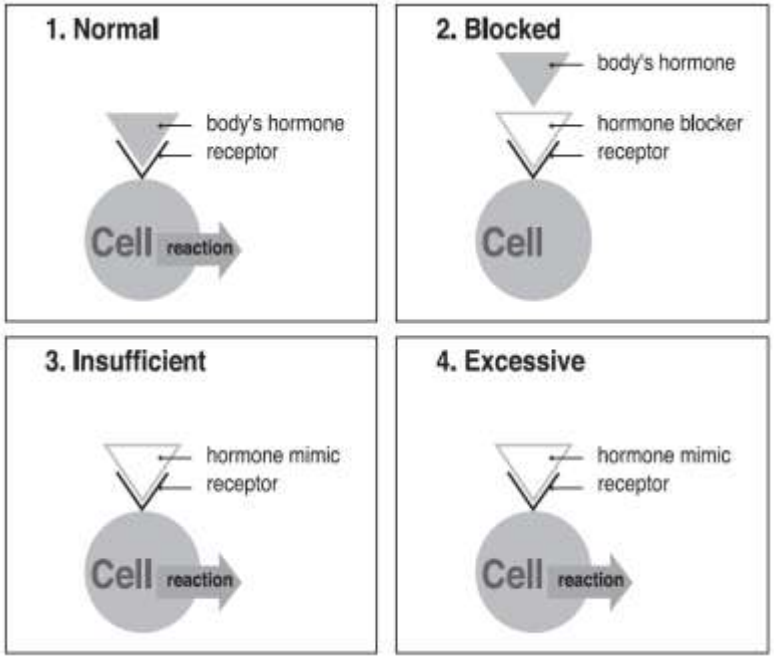
What is going on

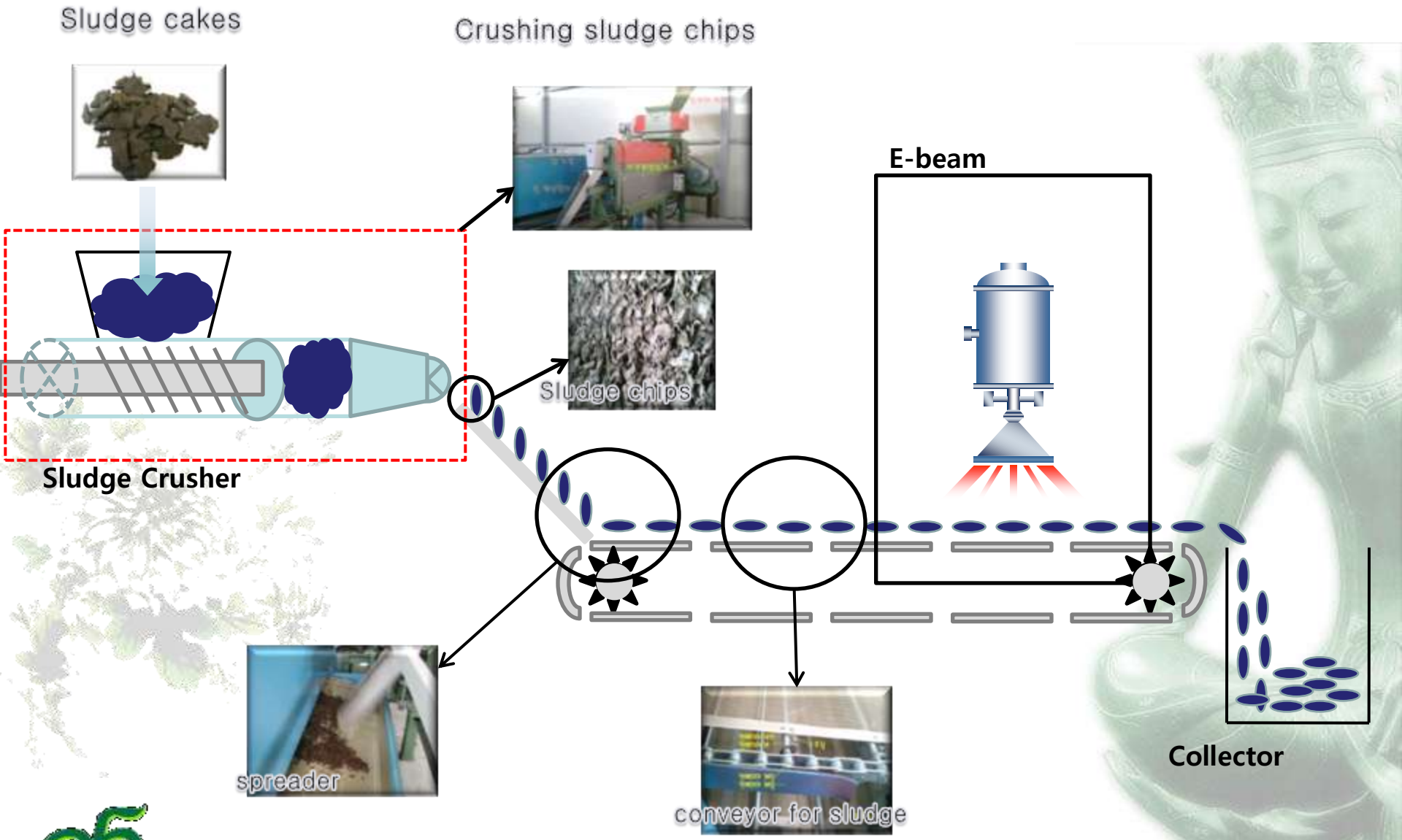
-. Removal of EDs for sanitary land-filling (2012 ~)

Endocrine Desrupters (EDCs)








Sludge cakes
Crushing sludge chips
E-beam
Sludge chips
Sludge Crusher
spreader
conveyor for sludge
Collector

Sludge Treatment

What was done

-. Improving dewatering efficiency of Sludge (1996~2000)
-. Disinfection Sludge Hygienation for re-use (2005~2009)

What is going on

-. Removal of EDs for sanitary land-filling (2012 ~)
-. Commercial plant (with Israel 2008~)

What will be

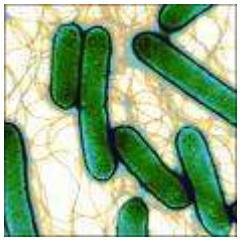
-. Soil treatment (?)

Panax Ginseng pathology

- **Fungal infection can readily destroy ginseng crops. One of the major diseases for *Panax ginseng* is the root rot caused by the fungus,**
- **Cylindrocarpon destructans, Fusarium solani, Erwinia- Carotovora and Pseduomonas Fluorescens .**
- **The exact causes of ginseng rusty root in which brown areas develop are unknown. It was reported that a rust spot formation could result from physiological stresses infection by fungal pathogens or enrichment of iron.**

Cylindrocarpon destructans

Fusarium solani



Erwinia Carotovora

Pseduomonas Fluorescens .

Rot Ginseng (Total Lost price : 0.6 billion $/year)

One month growth after electron beam sterilization

2007
Irradiated planted field for sterilization(1)
Irradiated replanted field for sterilization(2)
Non-irradiated replanted field (3)
Non-irradiated first planted field (4)

(1)

(2)

2008
Irradiated replanted field (1)
Non-irradiated replanted field (2)

Years	Flue Gas	Wastewater	Sludge
1970			Munich, Germany (1973~1984) Commercial Plant
	Pilot Plant		New Maxico, USA(1978)
1980	Indianapolis,USA(1984) Badenwerk,Germany(1985) Novosibirsk, Russia (1989)	Boston, U.S.A. (1980) Ontario, Canada Miami, U.S.A. (1985) Voronezh, Russia (1985)	Weldel, Germany (1980) Verginia Key Florida, USA(1984)
1990	Kawęczyn, Poland (1992) Nagoya, Japan (1992) Daejeon, Korea (1995) Chengdu, China (1997) Pomorzany, Poland (1999) Nisi-Nagoya,Japan(1999)	Seibersdorf, Austria (1990) Daejeon, Korea (1993) Sao Paulo, Brazil (1995) Budapest, Hungary (1998) Angarsk, Russia (1998)	Vadodara, India (1989) Commercial Plant Takasaki, Japan (1991) Sao paulo, Brazil (1993) Warsaw, Poland (1994) Tucuman, Argentina (1998)
2000	Hangzhou, China (2002) Beijing, China (2005)	Daejeon, Korea (2005) Commercial Plant	Daejeon, Korea (2005)
	Svishtov, Bulgaria (2008) Commercial Plant		Tel Aviv, Israel (2007)
2010	Jeddah, Saudi Arabia (2012)	Beijing, China (2010)	Texas, U.S.A. (2010)
	Saudi Arabia, Indonesia, Bulgaria, Turkey	Korea, China, Bangladesh, Saudi Arabia, U.S.A. EU	Israel , India, Egypt, U.S.A.

Red colored plants are with Gamma ray

Capital Investment and O&M cost for Typical Wastewater and Sludge Treatment


EBTECH

Treatment cost of typical wastewater and liquids

		Dose (kGy)	Amount (m^3/day)	Required Beam (kW)	Capital cost (M$)	O&M cost		Remark
						M$/y (with fixed cost)	$ per m^3	
1	Pilot plant of effluent from municipal plant	**0.5**	**5,000**	**50**	**1.25**	**0.193*** **(0.318)****	**0.12 (0.19)**	Design basis
2	Industrial Textile dyeing wastewater	**2**	**10,000**	**400**	**3.0**	**0.81 (1.11)**	**0.24 (0.33)**	Data from the commercial plant operation
3	Disinfection of effluent from municipal plant	**0.4**	**100,000**	**800 (400X2)**	**5.7**	**1.62 (2.19)**	**0.049 (0.066)**	Data from the pilot plant operation
4	Removal of PCBs from Transform. oils	**50**	**100**	**100**	**1.5**	**0.26 (0.41)**	**7.9 (12.4)**	Data from the pilot plant operation
5	Removal of PCBs from Transform. oils	**50**	**20**	**20 (Mobile)**	**(1.3)**	**0.17 (0.30)**	**26 (45)**	Data from the pilot plant operation
	Any Liquid	**1**	**5,000**	**100**	**1.5**	**0.26 (0.41)**	**0.16 (0.25)**	**Rule of thumb**

* Variable cost only : labor, electricity, maintenance

** Both variable and fixed cost (Interests and depreciation)

Land Application of Sludge (ISRAEL)

Treatment cost of typical sludge and solid wastes

		Dose (kGy)	Amount	Required Beam (kW)	Capital cost (M$)	O&M cost		Remark
						M$/y (with fixed cost)	$ per m^3	
1	Liquid sludge (0.5~3% solid)	**5**	**1,000 (m^3/day)**	**100**	**1.5**	**0.26* (0.41)****	**0.79 (1.24)**	Design basis 8,000hr/y
2	Dewatered Sludge cake (18% solid)	**10**	**7,000 (m^3/mon)**	**100**	**2.0**	**0.17 (0.37)**	**2.0 (4.4)**	16hr/day, 20days/mon
3	Dewatered Sludge cake (18% solid)	**10**	**7,000 (m^3/mon)**	**50**	**1.75**	**0.19 (0.36)**	**2.2 (4.3)**	8,000hr/y
4	Dewatered Sludge cake (18% solid)	**10**	**15,000 (m^3/mon)**	**100**	**2.0**	**0.26 (0.46)**	**1.5 (2.6)**	8,000hr/y
5	**Any Solids**	**10**	**15,000 (m^3/mon)**	**100**	**2.0**	**0.26 (0.46)**	**1.5 (2.6)**	**Rule of thumb**

* Variable cost only : labor, electricity, maintenance

** Both variable and fixed cost (Interests and depreciation)

Why e-beam processes are not widely used ?

Theories are easy, but practical applications are not easy.

-. Strong competition with conventional technology

-. Hard to move from lab. to commercial scale.

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

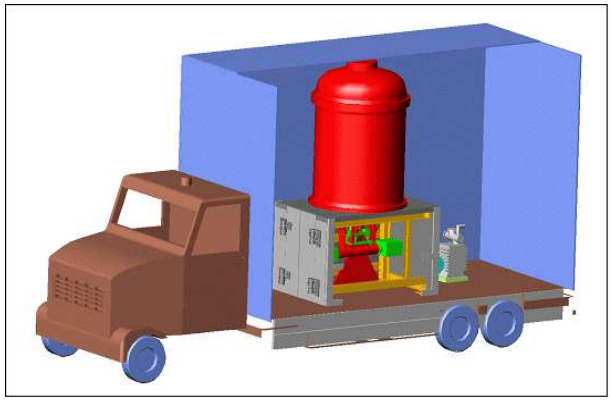
Radiation processing should be

Better & Cheaper

to other processes.

Lab. Scale Experiments (1~50m³/day)

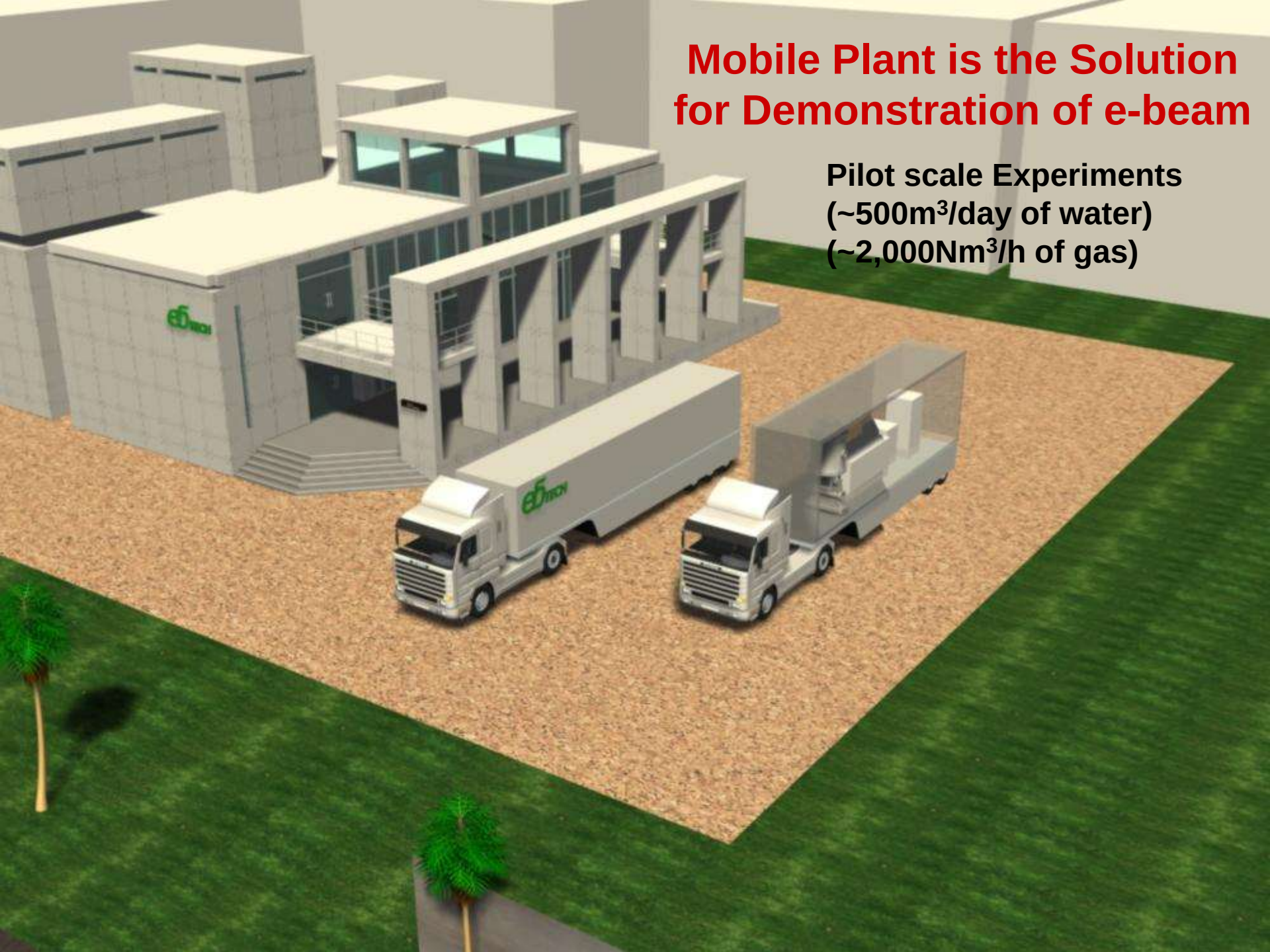
Pilot scale Experiments (500~1,000m³/day)

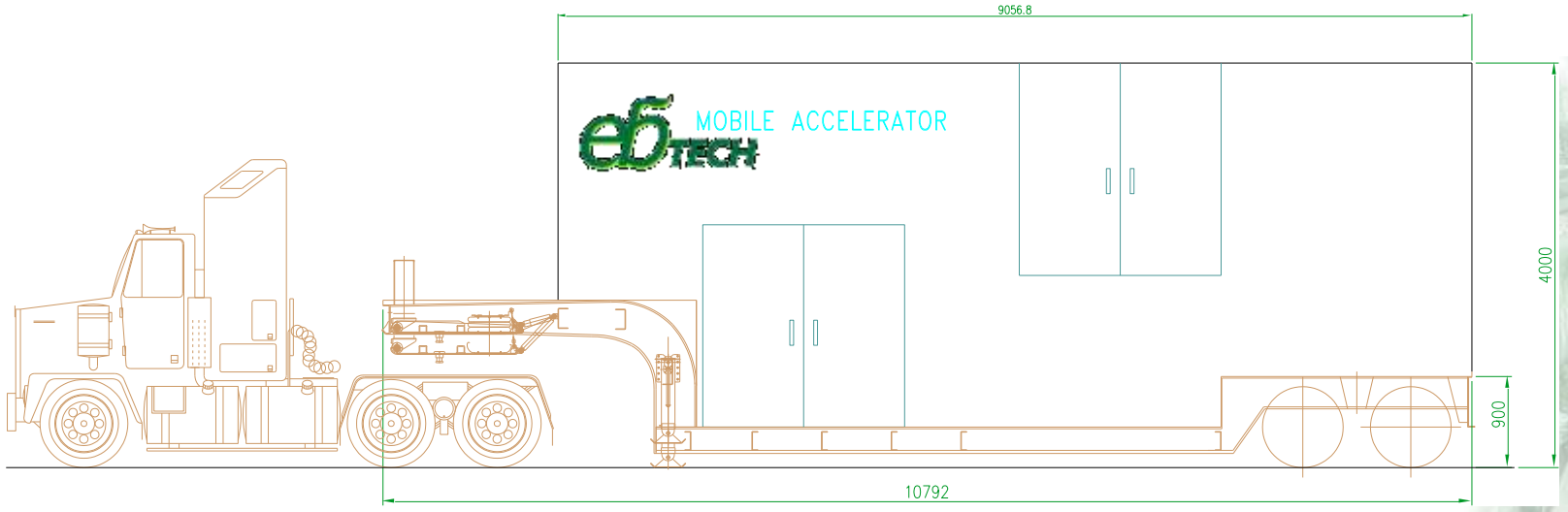


Industrial scale Wastewater Plant (10,000m³/day)

Lab. Scale Experiments (1~10,000Nm³/h)

Industrial scale EBFGT Plant (~600,000Nm³/h)


Mobile Plant is the Solution
for Demonstration of e-beam
Pilot scale Experiments
(~500m3/day of water)
(~2,000Nm3/h of gas)



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

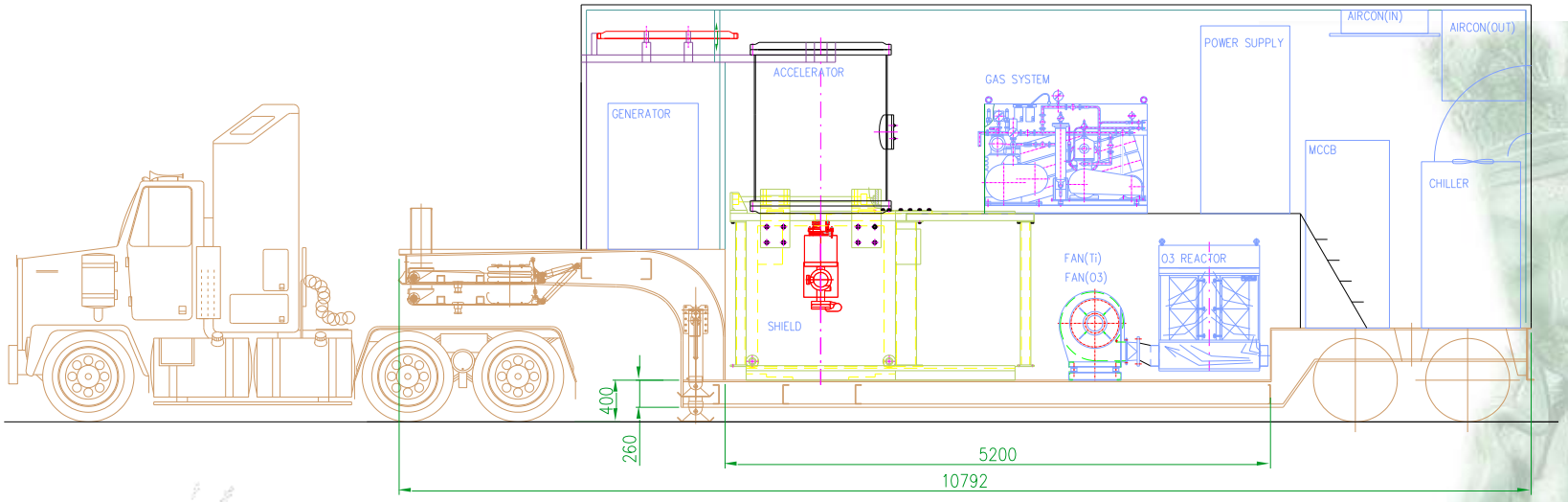
Self-sustaining system : Self-shielded accelerator

Built-in control and monitoring room

Diesel electricity generator (option)

Trailer and Shelter : Fit to U.S. and world standard

Total weight : 40 tons (trailer only 30ton)

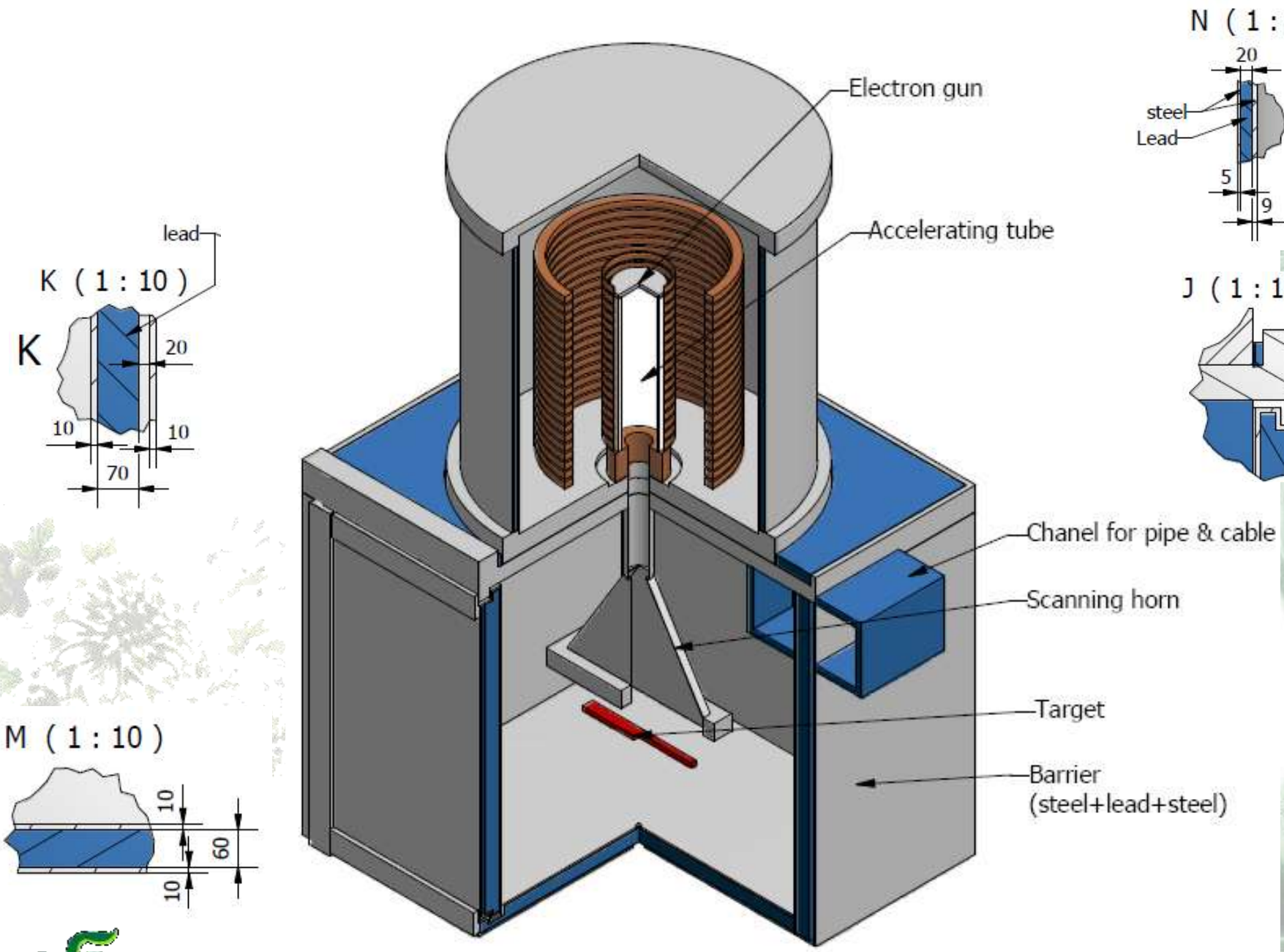


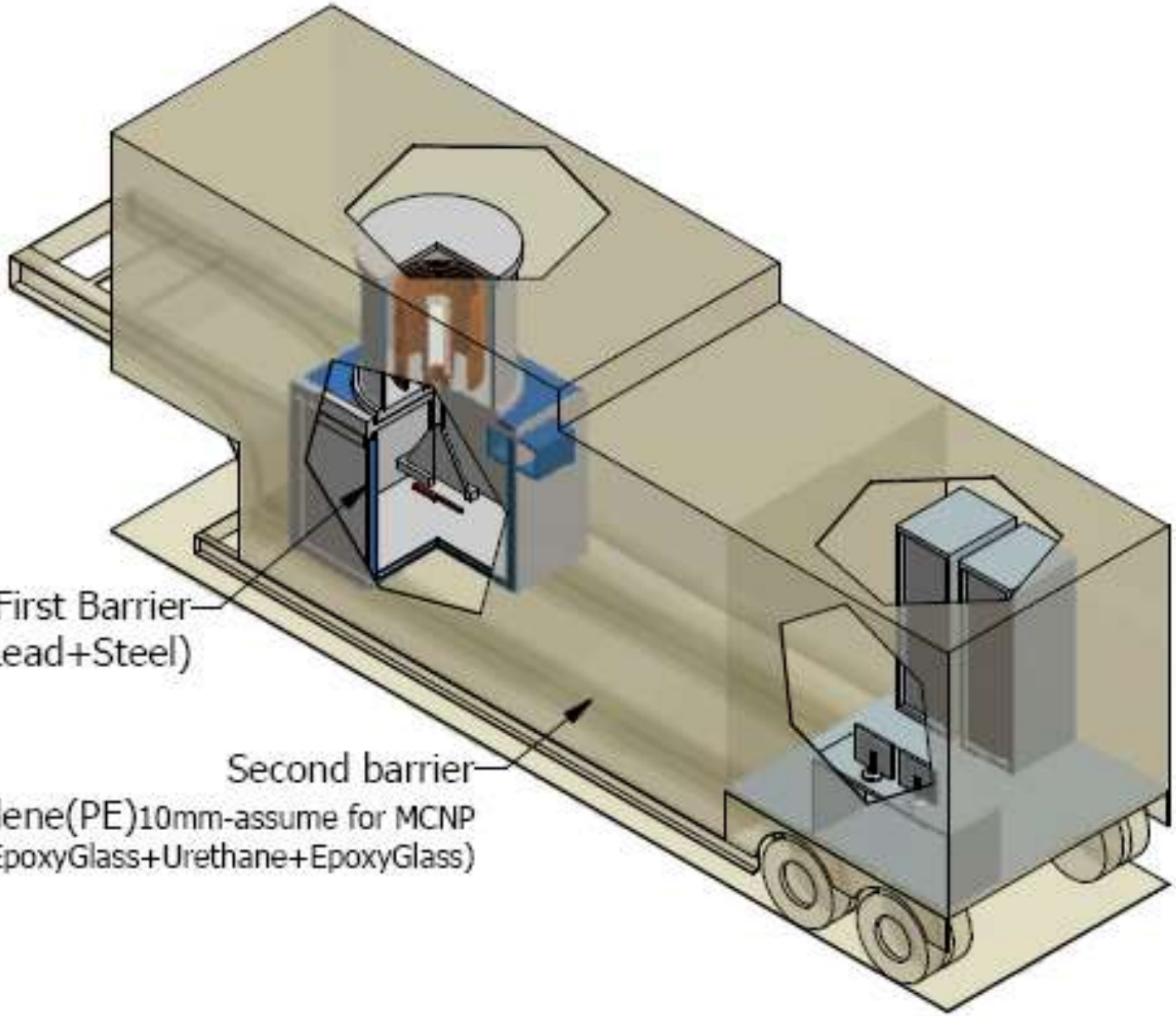
Built-in Computerized Experimental & Monitoring System

Continuous Treatment of Wastewater/Flue gas on site

Treatment Capacity : Liquid waste : 500m^3/day (at max. 2kGy)

Gaseous waste : 2,000Nm^3/h (at max. 15kGy)


N (1 : 10)
20
steel
Lead
5
9
lead
K (1 : 10)
K
20
10
10
70
J (1 : 11)
Electron gun
Accelerating tube
Chanel for pipe & cable
Scanning horn
Target
Barrier
(steel+lead+steel)
M (1 : 10)
10
60
10


First Barrier
(Steel+Lead+Steel)
Second barrier
Polyethylene(PE)10mm-assume for MCNP
(real 50mm: EpoxyGlass+Urethane+EpoxyGlass)



Trailer




Vessel

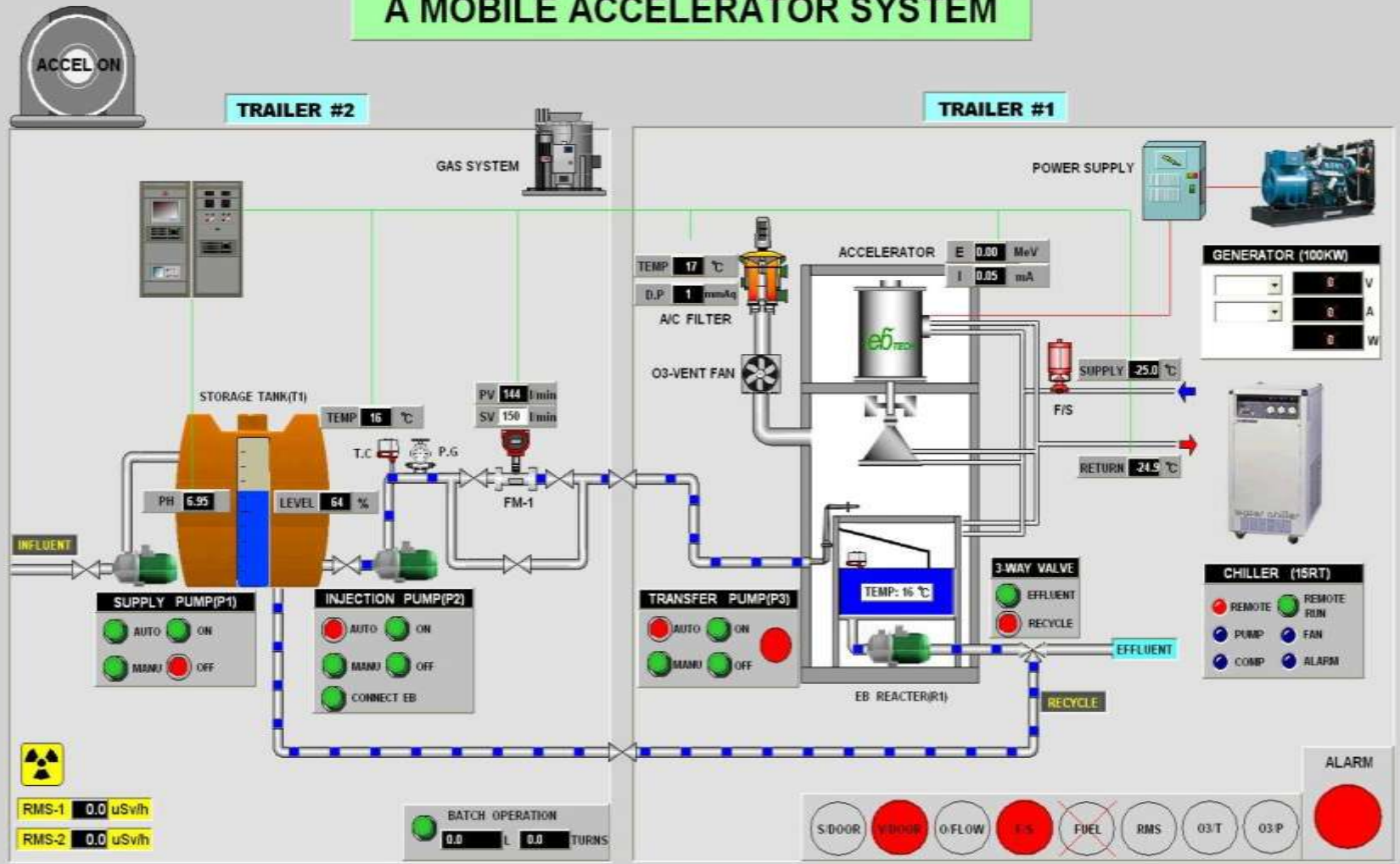


Shield

Shelter


PELE TECHNOLOGY, INC.
Mobile Electron Accelerator

A MOBILE ACCELERATOR SYSTEM



Wastewater under Treatment with Mobile Accelerator

Mobile e-beam in Flue gas Purification from oil-refinery in Saudi Arabia

550 yongsan-dong Yuseong-gu, Daejeon 305-500, Korea WWW.EB-TECH.COM

Future Plan

WastewaterTreatment

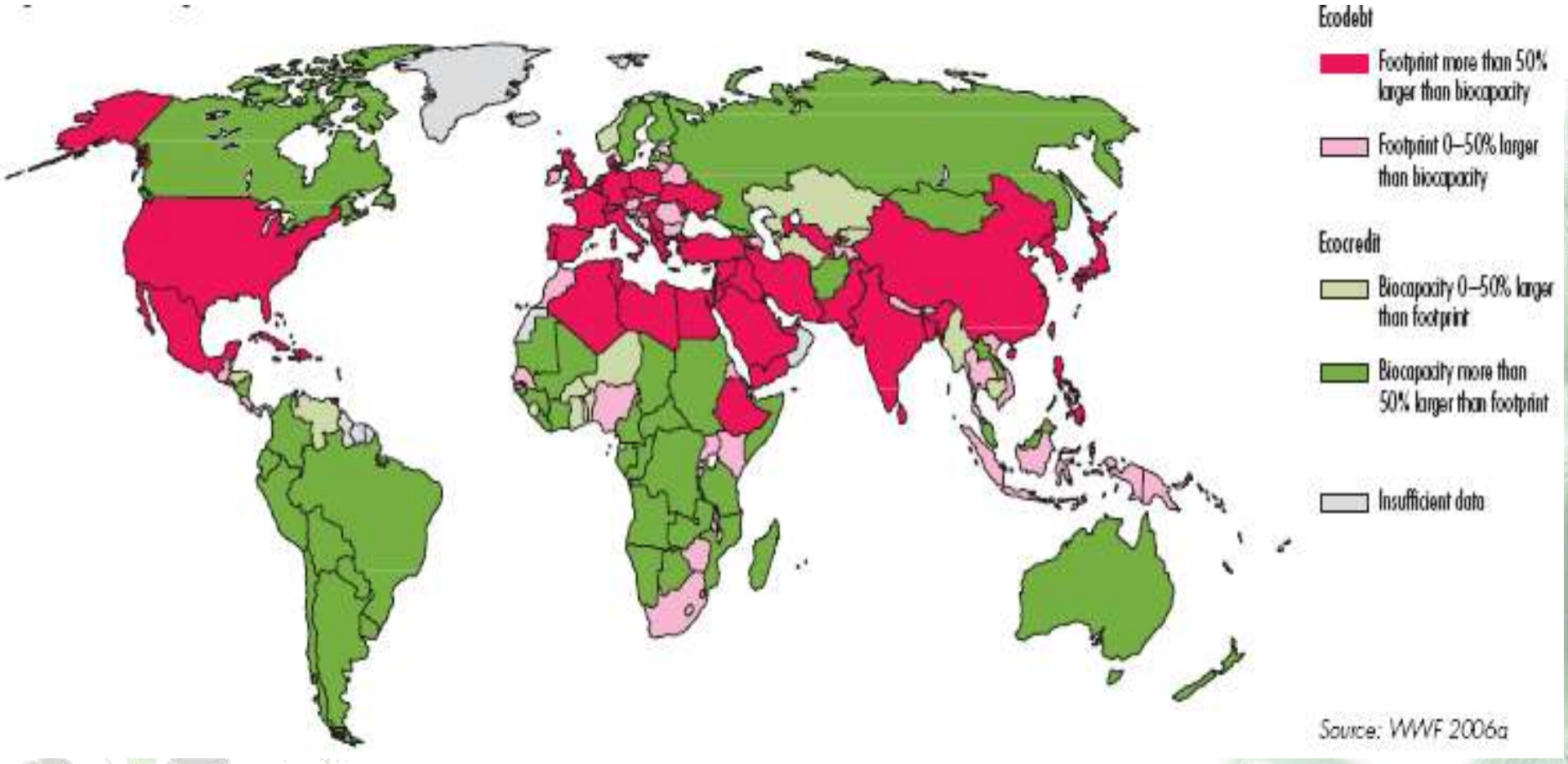
-. Effluent from Municipal plant for re-use (with Pele and HDR, 2008~)
-. Marine Ballast water (with U. Akron, 2010~)
-. Disinfection of Frac water

Gaseous Waste Treatment

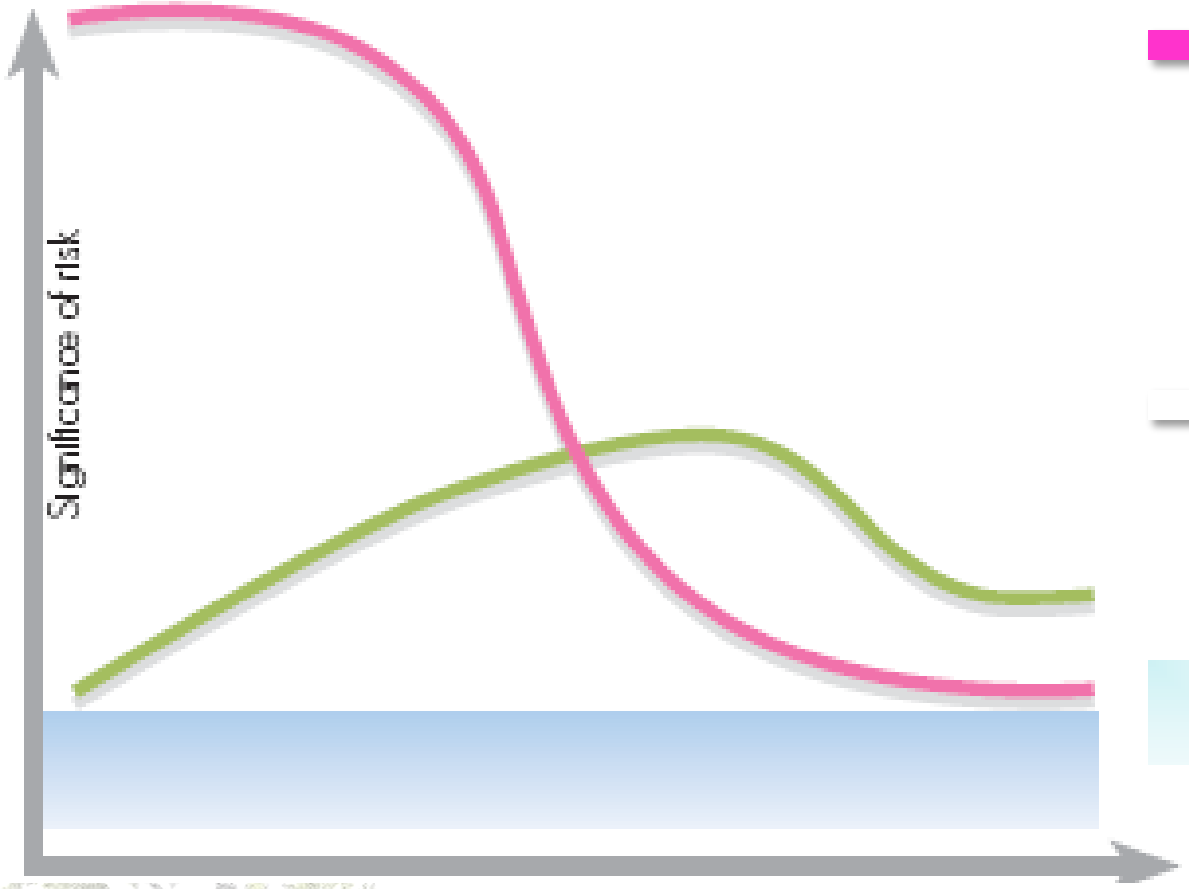
-. Flue gas removal from heavy oil plant (with Saudi Aramco 2011~)
-. VOCs removal from automobile industries (2012 ~)
-. Demo plant in a larger scale (60,000 ~ 200,000Nm3/h)
-. Combined treatment of wastewater and flue gas

Sludge Treatment

-. Removal of EDs for sanitary land-filling (2012 ~)
-. Commercial plant (with Israel 2008~)
-. Mobile plant (?)



Ecological creditors and debtors



Basic risks : Lack of safe water, sanitization and hygiene, indoor air pollution, vector-borne diseases, hazards that cause accidents and injuries

Modern risks : unsafe use of chemicals, environmental degradation

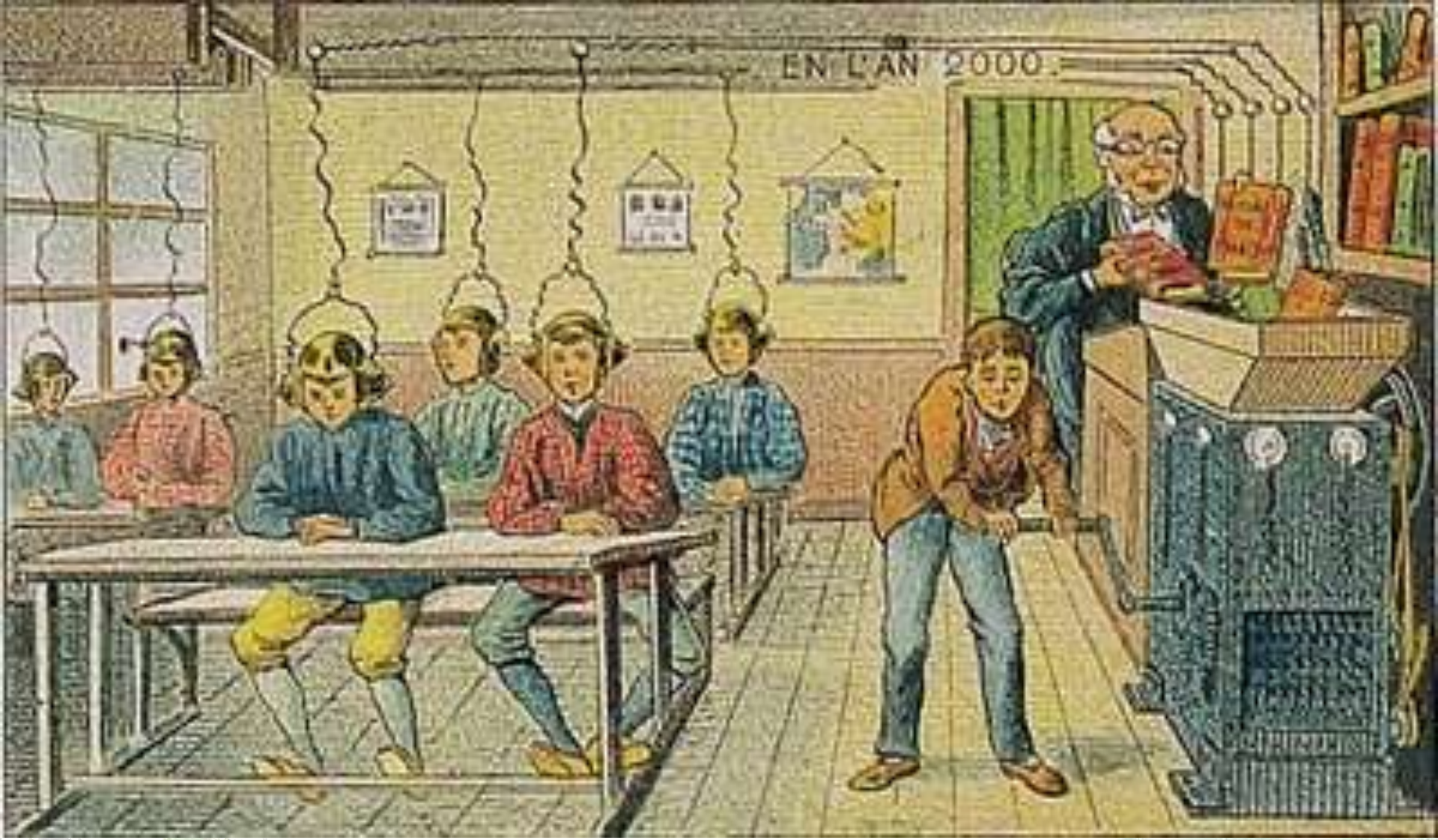
Engineering risks : unsafe use of chemicals, environmental degradation

Low income
Populations
in poverty

Middle income
Populations
in transition

High income
Industrialized
society

Environmental health risk transitions



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


Thank You !