

INTERNATIONAL ATOMIC ENERGY AGENCY

**Scientific Forum on
"Atoms in Industry – Radiation Technology for Development"**

Vienna, Austria

**RADIATION PROCESSING APPLICATIONS IN INDUSTRY:
PROSPECTS IN LATIN AMERICA AND THE CARIBBEAN**

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National Nuclear Energy Commission - Brazil (CNEN)
Radiation Technology Center**

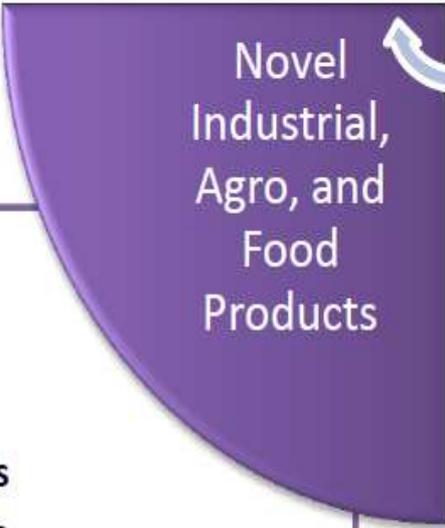
15th - 16th September, 2015

GAMMA RAYS AND ELECTRON BEAM TECHNOLOGY APPLICATIONS

- Vaccines
- Blood sterilization
- Pediatric Cancer diets
- Tissue transplantation
- Artificial Tissues
- Novel Biotherapeutics



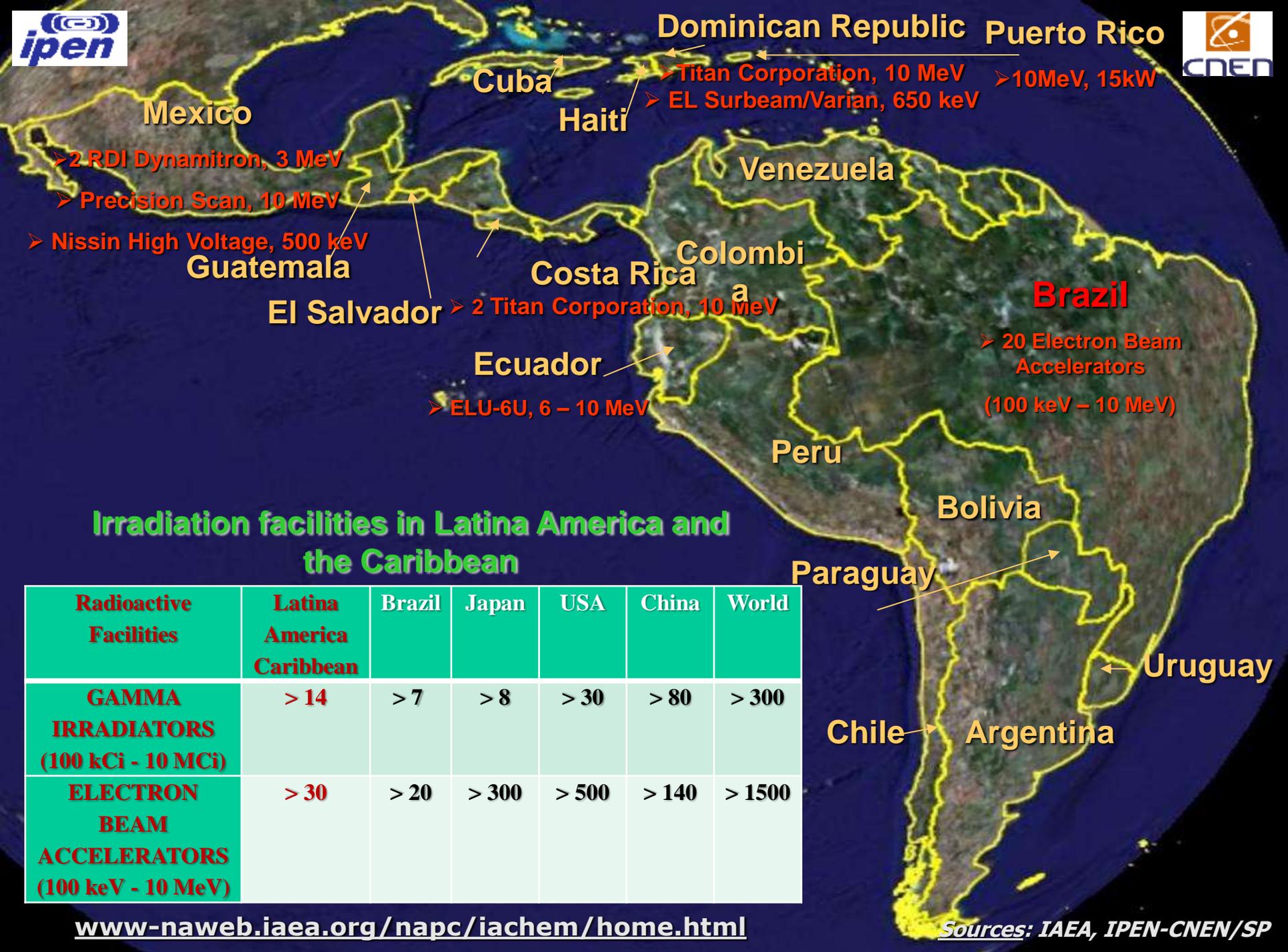
- Food Pasteurization
- Protection against insects/pests –Global trade
- Shelf-life extension
- Reducing food waste
- Global Food Security



- Bioplastics
- Seed Enhancement
- Functionalized polymers
- Immobilized biofactories



- Water Reuse
- Sludge disinfection
- Industrial waste treatment
- Agriculture waste treatment



Irradiation facilities in Latina America and the Caribbean

Radioactive Facilities	Latina America Caribbean	Brazil	Japan	USA	China	World
GAMMA IRRADIATORS (100 kCi - 10 MCi)	> 14	> 7	> 8	> 30	> 80	> 300
ELECTRON BEAM ACCELERATORS (100 keV - 10 MeV)	> 30	> 20	> 300	> 500	> 140	> 1500

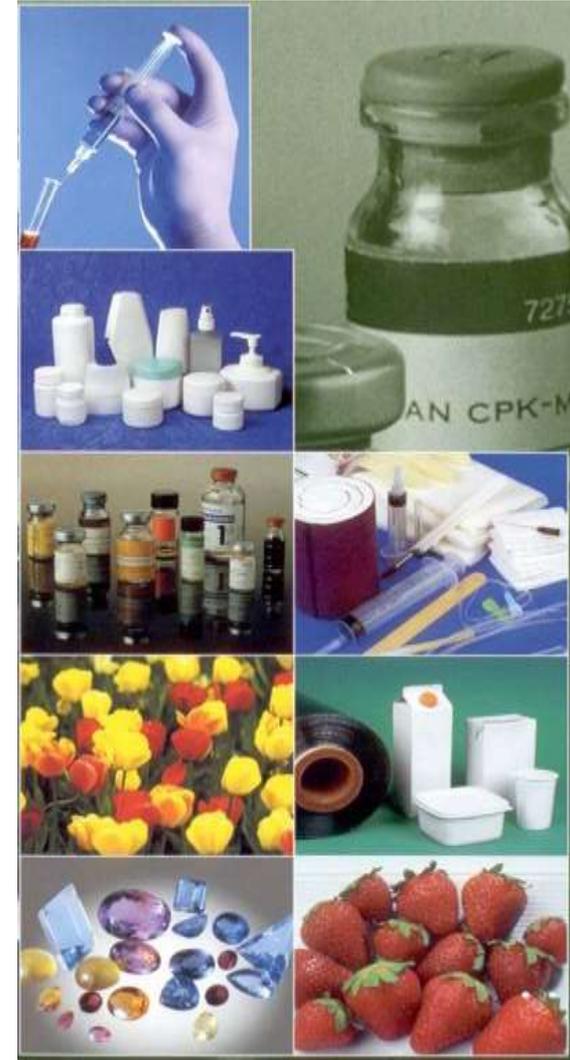
Country	Organization	City	Units	Products	Additional Information
Brazil	Nuclear and Energy Research Institute (IPEN-CNEN/SP)	Sao Paulo	2	<u>R&D</u> : wastewater treatment, polymer modification, shrink tube and film, surface curing, food irradiation	Radiation Dynamics, Inc. (RDI), JOB 188, 37.5 kW, 1.5MeV, roller bed conveyor (batch), pilot plant for wastewater treatment (30 L/min)
				<u>Commercial</u> : wire and electric cables, semiconductors, sterilization of medical and pharmaceutical devices, PE foam	RDI, JOB 307, 97.5 kW, 1.5 MeV, continuous treatment system (300 m/min)
Ecuador	Escuela Politecnica Nacional	Quito	1	<u>R&D</u> : food irradiation, wires and electric cables	ELU-6U, 6-10 MeV
Mexico	Comision Nacional de Seguridad Nuclear y Salvaguardias	Tijuana	2	Polymer modifications (plastics and rubber)	RDI Dynamitron 300/46/1220, 3MeV
	ICU Medical S.A.	Ensenada	1	Sterilization of medical devices, polymer modifications	Precision Scan, SB108, 10MeV, 15kW
	Cryovac	Mexico City	1	Fresh food packaging	Nissin High Voltage, 2SP500, 500keV
Costa Rica	BeamOne SRL	Alajuela	2	Sterilization of medical and pharmaceutical devices	Titan Corporation, 18kW, 10MeV
Dominican Republic	FENWAL International Inc. (BAXTER)	Haina	2	Sterilization of medical and pharmaceutical devices	Titan Corporation, TB-10/15, 10MeV, 1.44mA, 15kW EL Surbeam/Varian, SB-1/5, 650keV, 0.094mA
Puerto Rico	STERIS Isomedix Services	Vega Alta	1	Sterilization of medical and pharmaceutical devices	10MeV, 15kW

Sources: IAEA, IPEN-CNEN/SP

Company	Manufacturer	Energy (keV)	Applications
IPEN-CNEN/SP and Cofibam	Radiation Dynamics, Inc.	1,500	R&D and crosslinking
Bridgestone - Firestone	Energy Scineces, Inc.	300	Crosslinking of tires
Cryovac Brasil	Cryovac	500	Crosslinking
Unipac Embalagens	Energy Scineces, Inc.	210	Curing
Itap Bemis	RPC Industries	300	Curing
Acome do Brasil	Acome/Radiation Dynamics, Inc.	550	Crosslinking of wire and electric cables
Prysmian	Radiation Dynamics Inc.	1,500	Crosslinking of wire and electric cables
Aceletrica Comercio e Representações	Titan Corporation/ EL Surebeam	10,000	Food irradiation, gemstone enhancement, radiosterilization of medical disables, cosmetics, polymer modification
CBE - Sterigenics International	Ion Beam Applications	10,000	Food irradiation, gemstone enhancement, radiosterilization of medical disables, cosmetics, polymer modification
Michelin do Brasil	Radiation Dynamics Inc.	600	Crosslinking of tires
Sumitomo Rubber do Brasil	NHV Corporation	500	Crosslinking of tires
Antilhas	Energy Scineces, Inc.	110	Curing

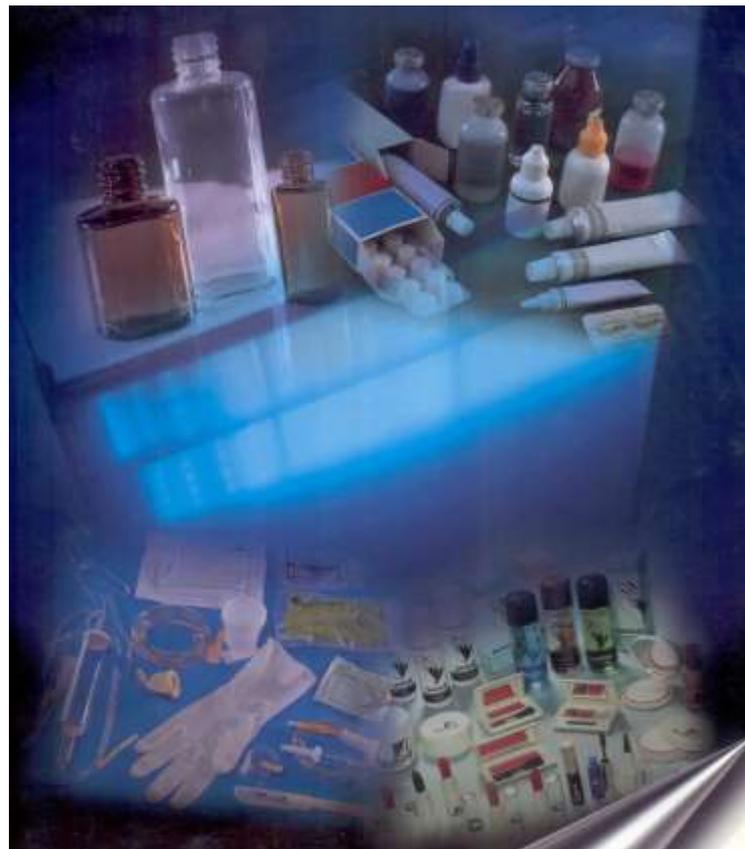


Brazilian Technology (3MCi)





**MDS Nordion Gamma Irradiators/Canada
(Category IV – AIEA)**



White Quartz → Green Gold

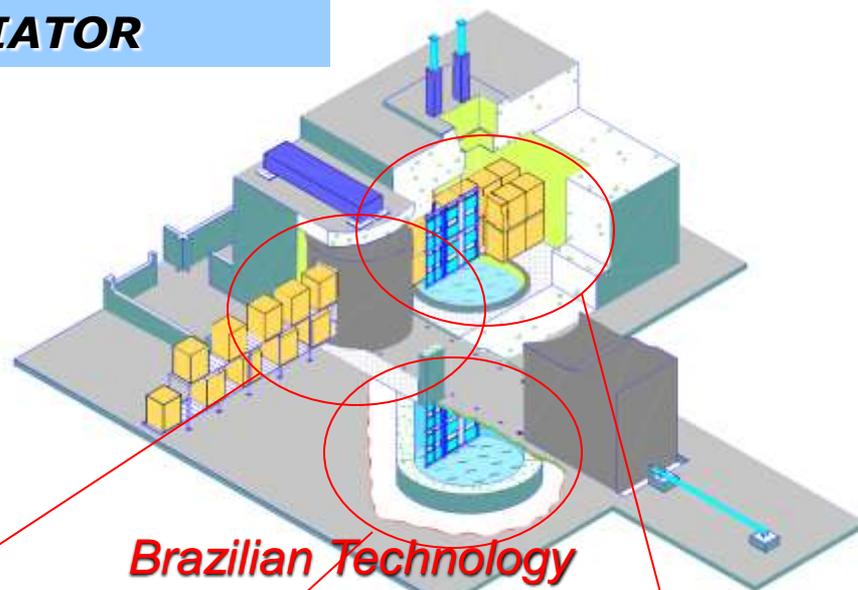


Topaz



Blue Beryllium

MULTIPURPOSE GAMMA IRRADIATOR



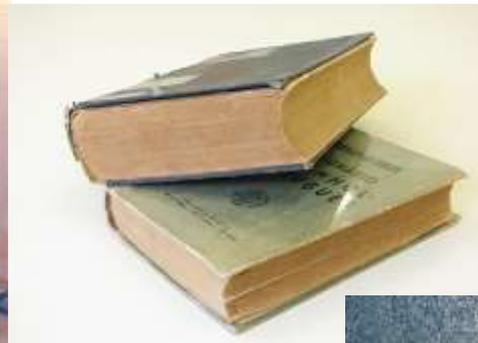
**Brazilian Technology
(2MCi, Category IV – IAEA)**



DUR / Efficiency:
1,33 / 11,6% (0,09g/cm³)
2,08 / 36,6% (0,49g/cm³)



Source: IPEN-CNEN/SP

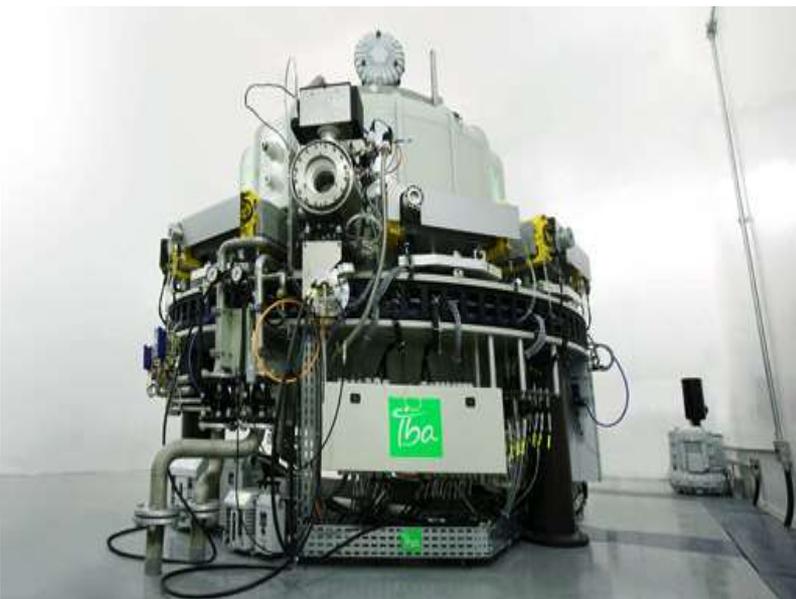


**MDS Nordion/Canada
(Category II – AIEA)**

Source: CDTN-CNEN/MG



**Sterigenics
International**
Science Driven + Healthcare Focused + Globally Trusted



**Sterilized
Medical
Devices:
135.000
m³/year**





18 kW (10 MeV)



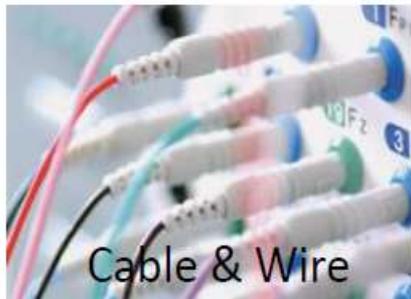
Trends of Gamma Rays and EB- Technology Applications in Industry

(Latin America and the Caribbean Region)



Food Packaging

no Peroxides
less energy



Cable & Wire

better properties
less / no additives



Inks /Curing/ Adhesives

no UV-Initiators
less energy



Heat shrinkable

better properties



Sterilization

no chemicals
less energy



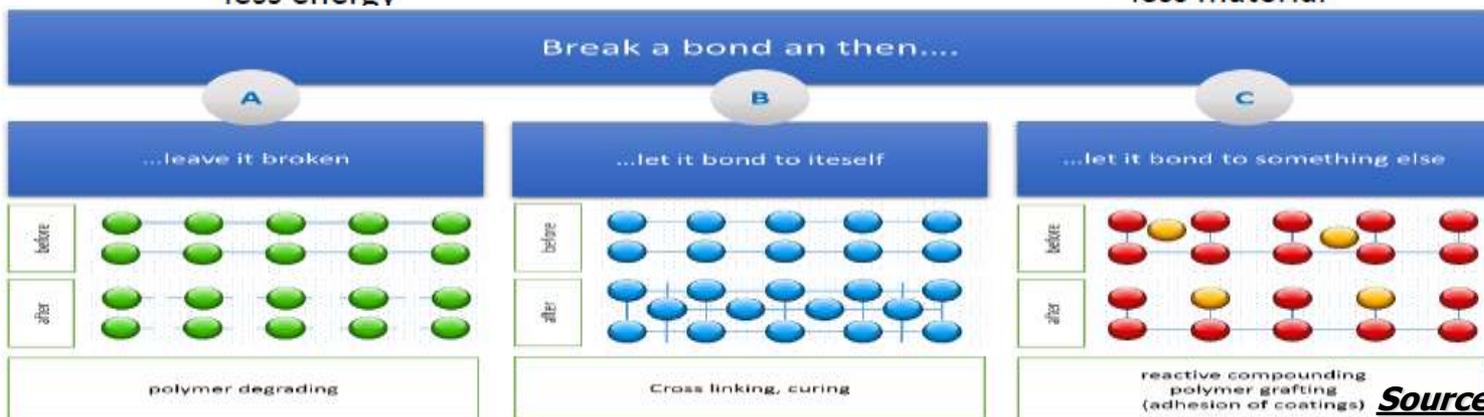
Spice & Seed processing

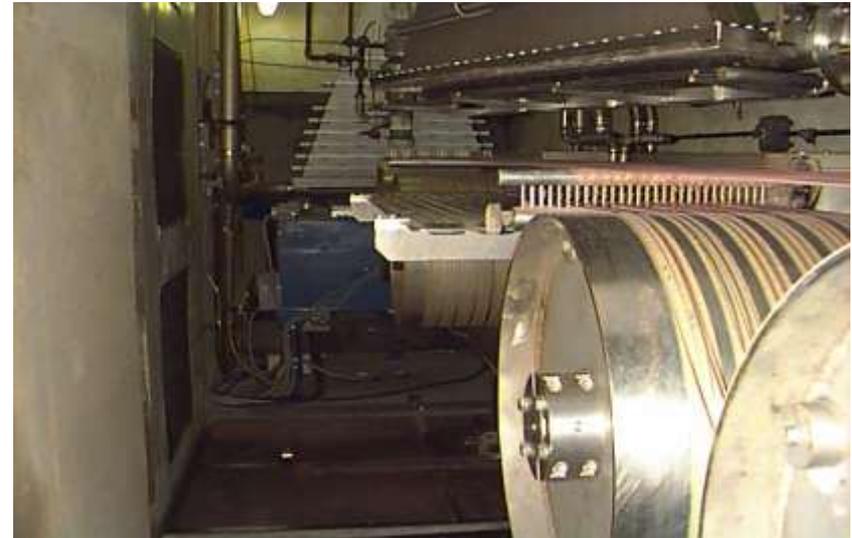
no chemicals



Tires

processability
less material







SEMICONDUCTORS IRRADIATION and POLYMER DEGRADATION



Powered Diodes

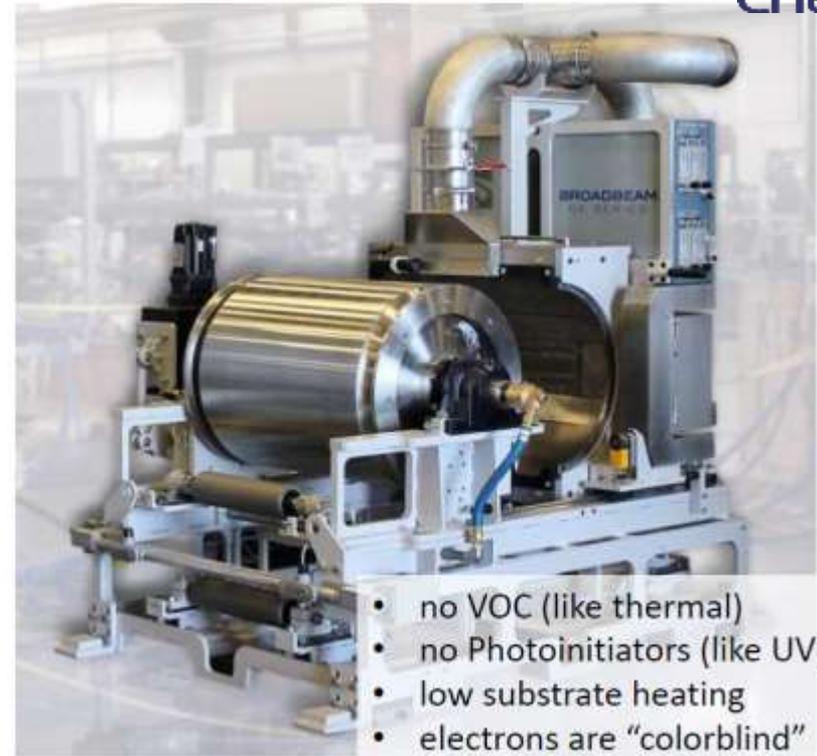


PTFE (Teflon™)

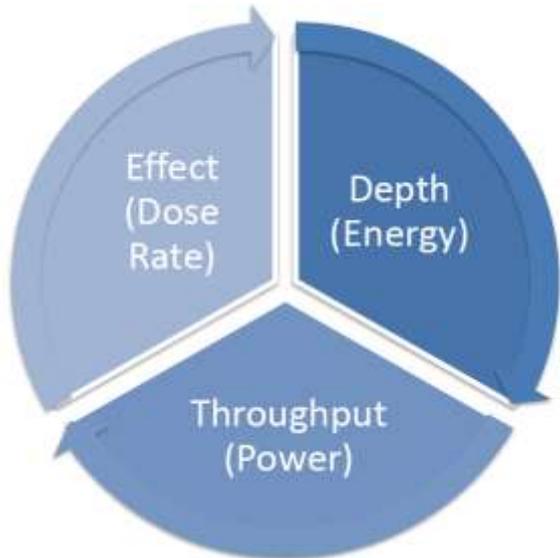


e⁵
efficient
enabling
economical
energy savings
environmental friendly

- **Integrated shield roll design**
 - With sealed e-beam Emitter
- **Features**
 - Energy: **80kV to 180kV**
 - Web width: **360mm**
 - Web speed **90m/min at 25kGy**
- **Applications**
 - Pilot / development lines
 - Narrow web printing presses
 - Presses for shrink sleeve labels



- no VOC (like thermal)
- no Photoinitiators (like UV)
- low substrate heating
- electrons are “colorblind”
- higher speed



⇒ **IAEA/CRP: Application of Radiation Technology in the Development of Advanced Packaging Materials for Food Products: Development of Advanced Food Packaging Materials Based on Polymer Petroleum-Derived for Pre-Packaged Irradiated Foods and Based on Biobased and Compostable Materials for Dry Food Packaging**



Composite materials based on:

- Copolyester/starch blend
- Copolyester/PLA blend



Reinforced with filler from natural resources:

- Vegetal fibers
- Nanoparticles: bio-CaCO₃, green silica, metal, natural clay

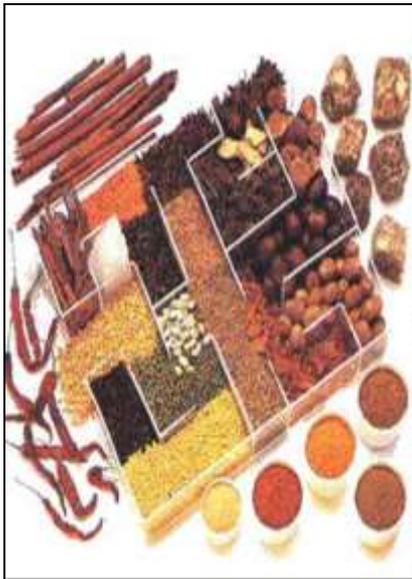
Current Production Volumes of Irradiated Food Stuffs

Region	Volumes (Metric tons)	Market Condition
USA	175,000	Flat
EU	198,000	Declining
Asia	450,000	Increasing



92% of food stuffs are treated with Cobalt-60. Only 8% is represented by E-beam

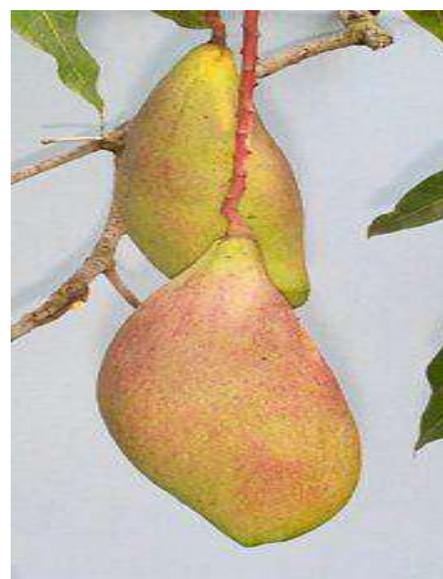
Latina America Caribbean > 100,000 tons



Spices



Medicinal herbs



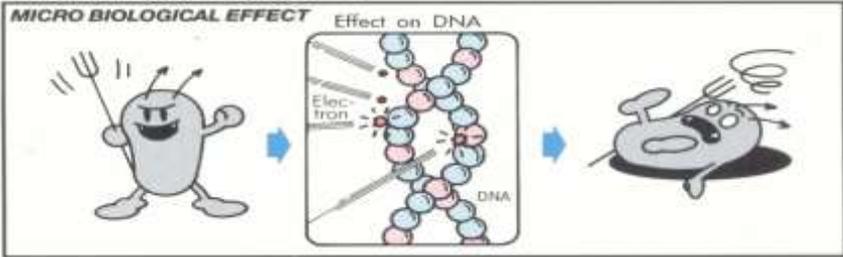
Mango (Mexico)

Food industry are looking for EB or X-ray machines:

- Lower capital cost
- Reliable
- Simple enough to operate
- Lower cost of operation
- Compact enough to integrate in existing
- Production in-line or a packing house space

STERILIZATION OF MEDICAL, PHARMACEUTICAL AND BIOLOGICAL PRODUCTS

World: ~ 50% (> 1,500 EBA)



STERILIZATION PROCESSES						
NECESSARY CONTROLS	Gases	Liquids	Vapor	Filtration	Radiation	
Time	■	■	■	■	■	■
Temperature	■	■	■			
Package	■	■	■			
Pressure	■		■	■		
Humidity	■		■			
Concentration	■	■				
pH		■				

Routine operations (semi-industrial scale)

- **Disinfestation and disinfection of cultural objects (books, furniture, sculptures and paintings)**



Extraordinary cultural objects irradiations



Floods and natural disasters recovery



BEAM TECHNOLOGY FOR POLLUTION CONTROL



Flue gas Purification



Wastewater Treatment



Sludge Hygienization



	Flue Gas Purification	Wastewater Treatment	Sludge Hygienization
Contaminants to clear	SO ₂ , NO _x , (Dioxin)	Complex COD, BOD, other	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	Laboratory to pilot scale	Laboratory to pilot scale
Economies	Proved through pilot & commercial plant	Complicate to analyze	Complicate to analyze
By-product	Useful for fertilizer	Wastewater (less toxic) Reuse	Useful for fertilizer or soil treatment

WASTEWATER TREATMENT PLANT BY E-BEAM Dyeing Industrial Complex/KOREA (10,000 m³/day)



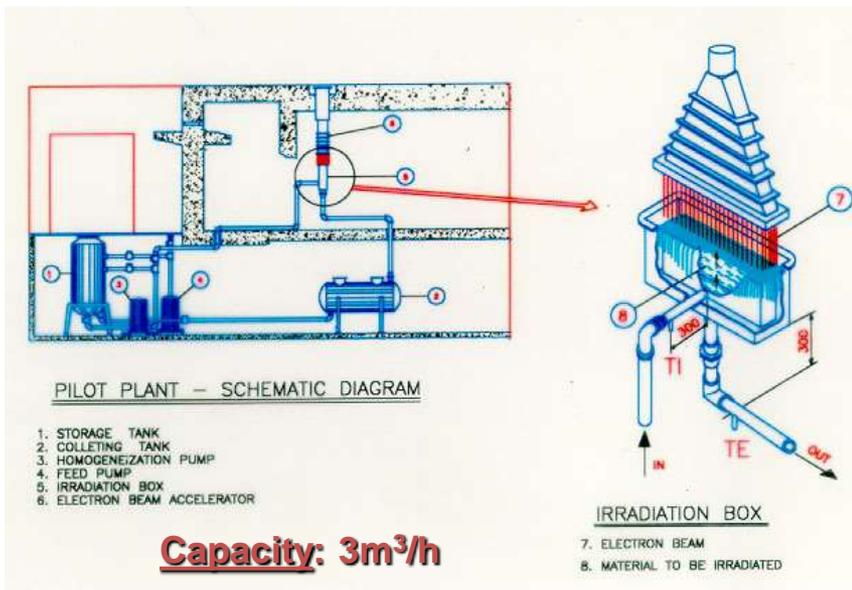
⇒ Electron Beam: **1MeV, 400kW**

E-BEAM TREATMENT FOR WASTEWATER
MAKING THE TEXTILE INDUSTRY CLEANER



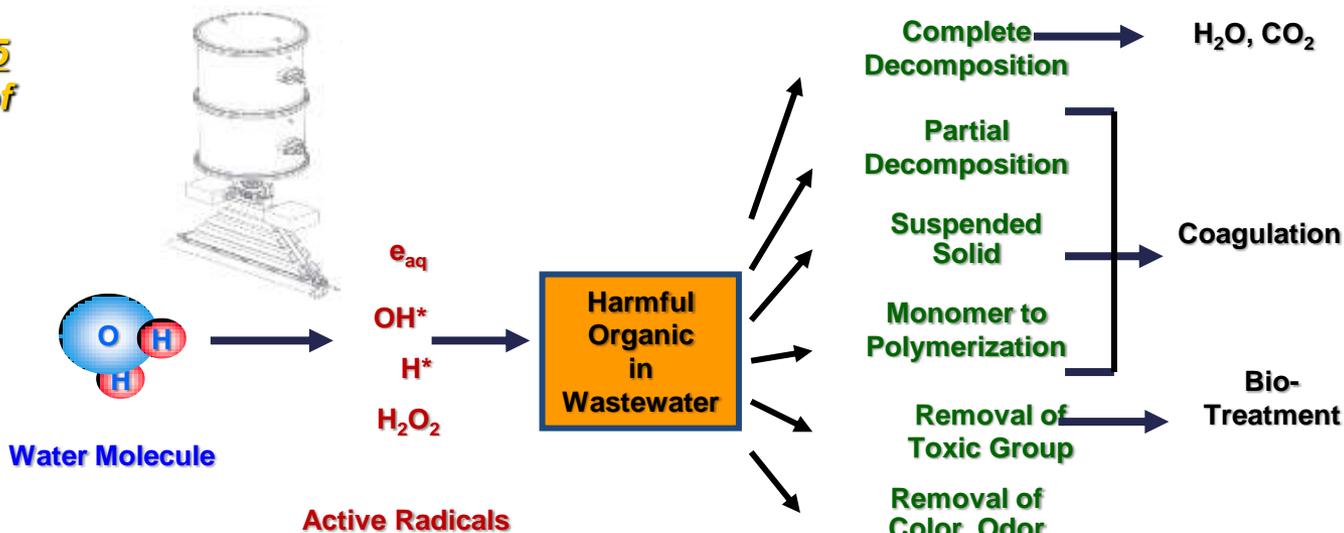
www.iaea.org/newscenter/multimedia/photoes/says/e-beam-treatment-wastewater

Source: IAEA and EB-Tech



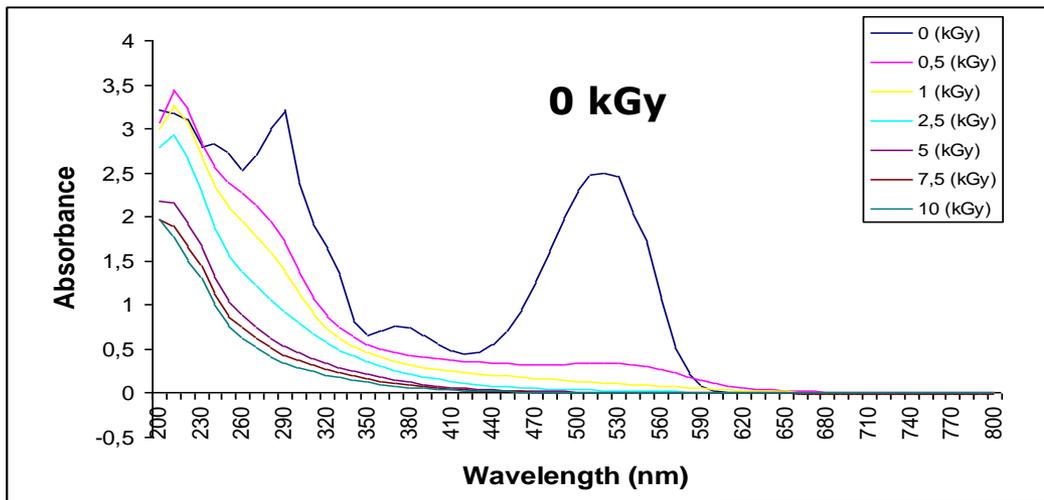
IAEA TC Project BRA/8/025
Electron Beam Treatment of Wastewater
(1993-1997)

➤ **Model Project (1995)**

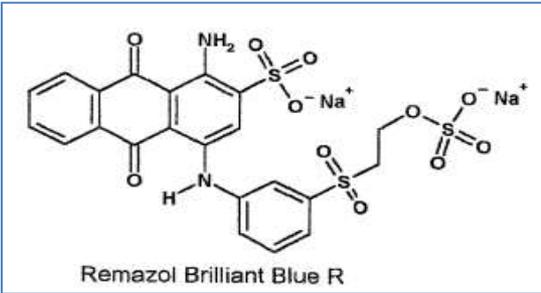


Source: IPEN-CNEN/SP and EB-Tech

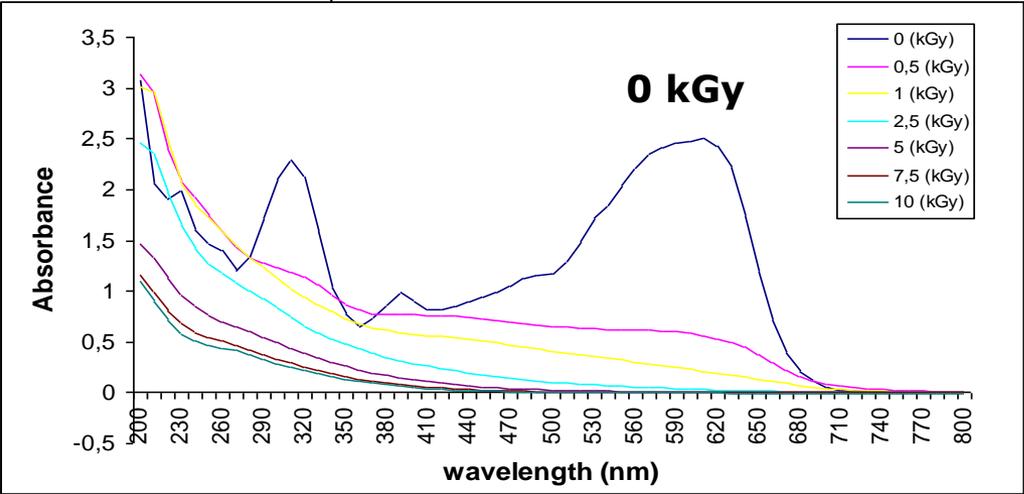
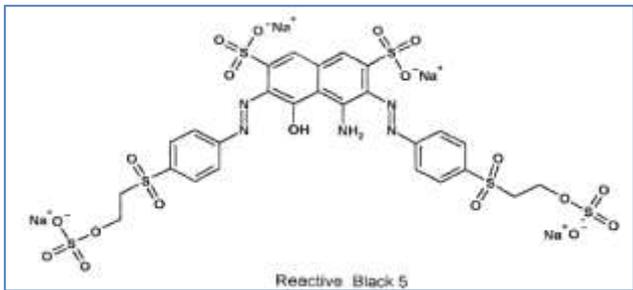
⇒ IAEA/CRP: Radiation Treatment of Wastewater for Reuse with Particular Focus on Wastewaters Containing Organic Pollutants

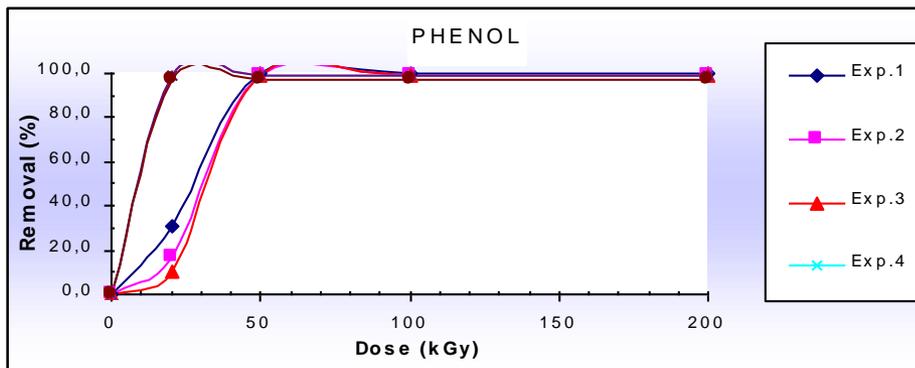
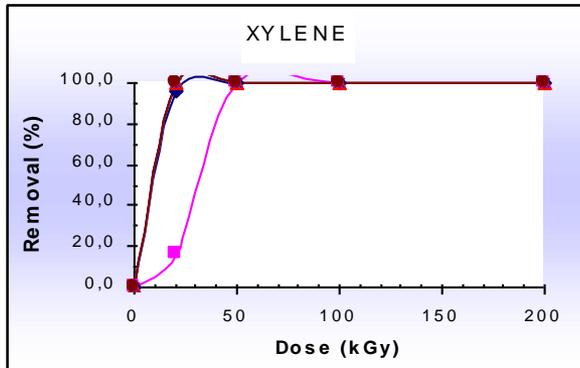
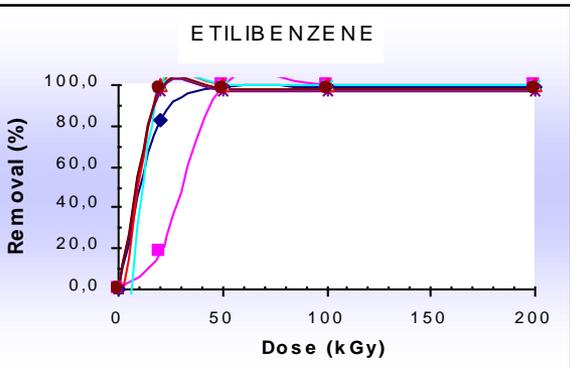
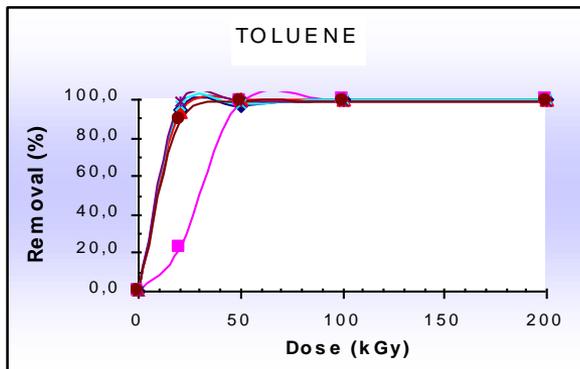
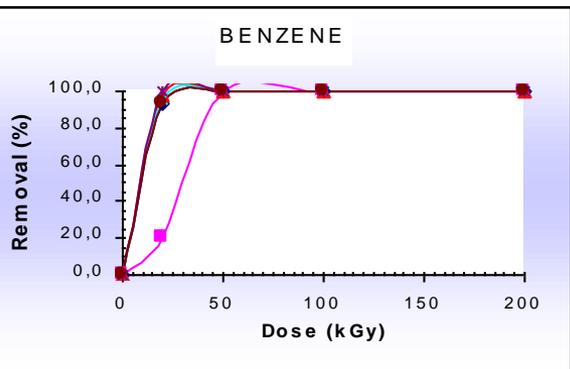


Red Reactive Remazol – RR 198



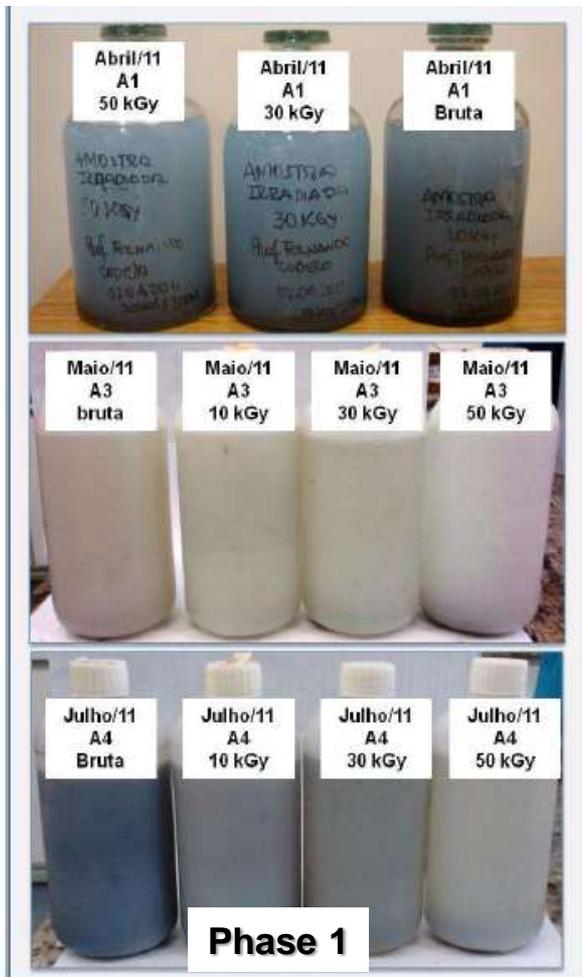
Reactive Black 5 – RB5





Removal of Organic Compounds (EB)





➤ **Efficiency of organic compound and color removal by electron beam irradiation**

Laboratorial scale experiments
(1~50m³/day)



Laboratorial scale experiments
(1~10,000Nm³/h)

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



- **Cost**
- **Space**
- **Operation & Maintenance, other**



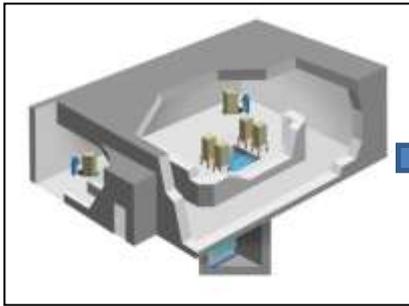
Industrial scale wastewater plant
(10,000m³/day)



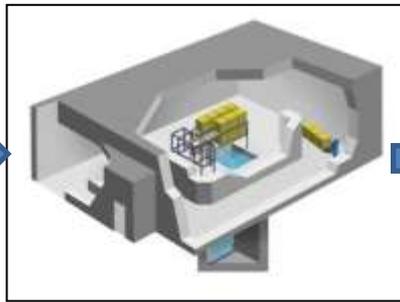
Industrial scale EFBGT Plant
(~600,000Nm³/h)

Final Remarks

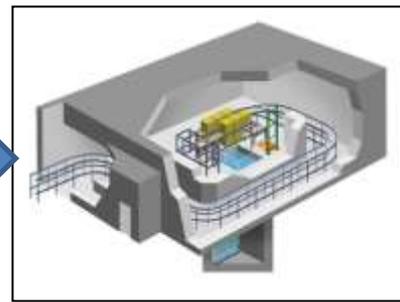
- ✓ **GammaFit Irradiator**
- ✓ **Rhodotron Duo (EB, X-ray)**
- ✓ **Compact Installation (MB5000)**
 - ✓ **EB Engine, LAB System**
- ✓ **Mobiles E-Beam Accelerators**



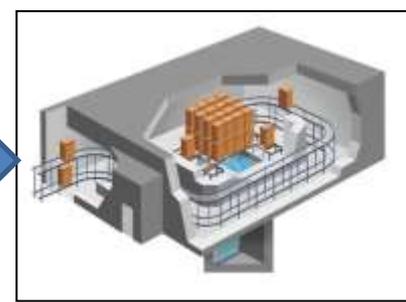
R&D Small Scale



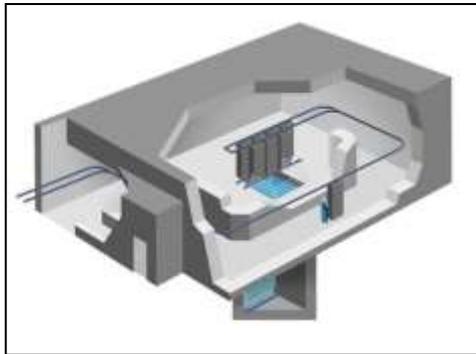
Two-Pass Batch Tote



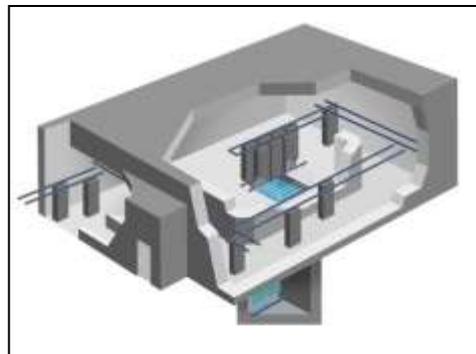
Two-Pass Automatic Tote



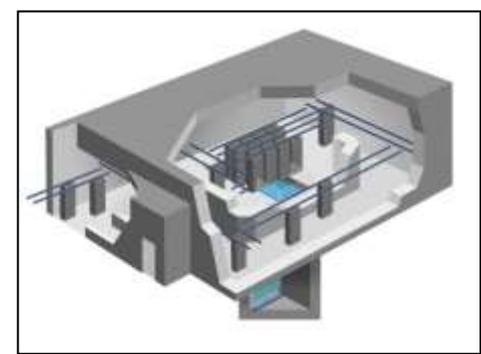
Four-Pass Automatic Tote



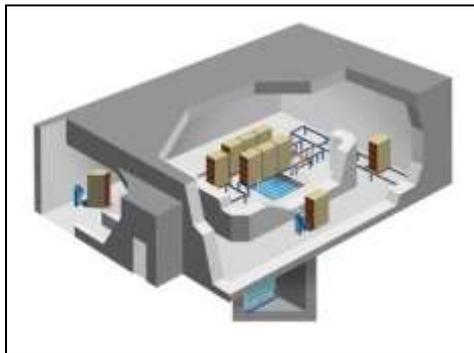
Two-Pass Batch Carrier



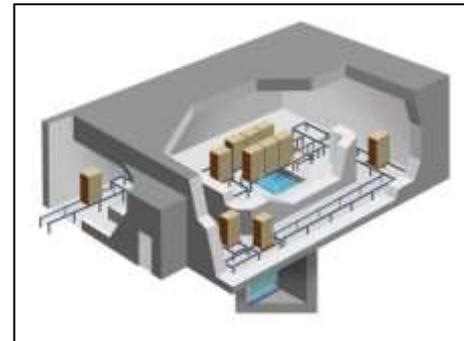
Two-Pass Automatic Carrier



Four-Pass Automatic Carrier



Batch Pallet



Automatic Pallet

Gamma Rays (⁶⁰Co)

**50 cm (1,0 g/cm³)
10 kGy/h**

Electron Beam

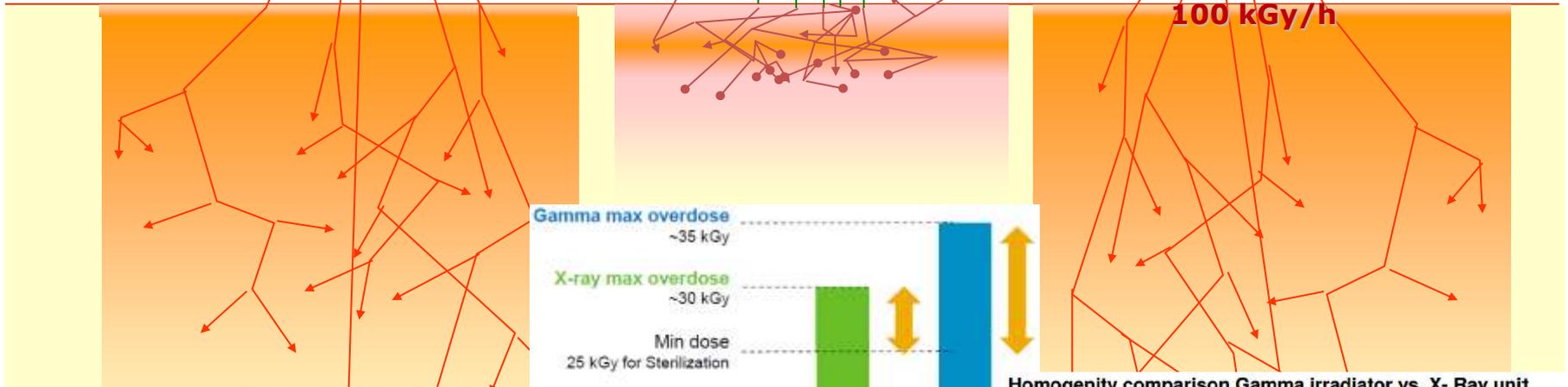
(10 MeV, 50 kW)

**5 cm (1,0 g/cm³)
72 MGy/h**

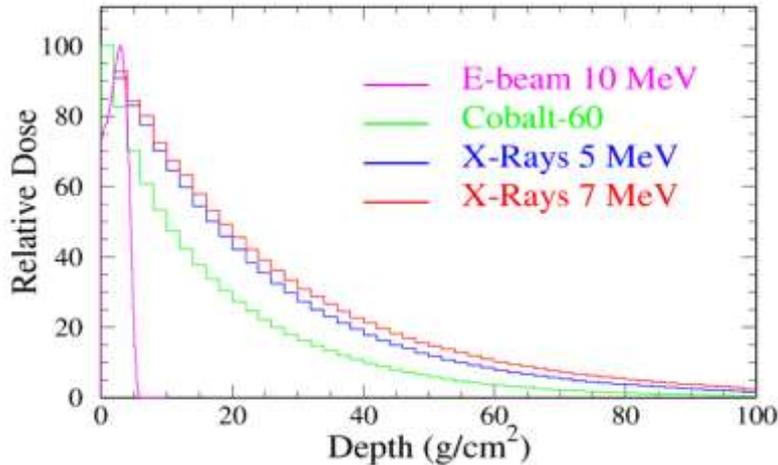
X-Rays

(5–7 MeV)

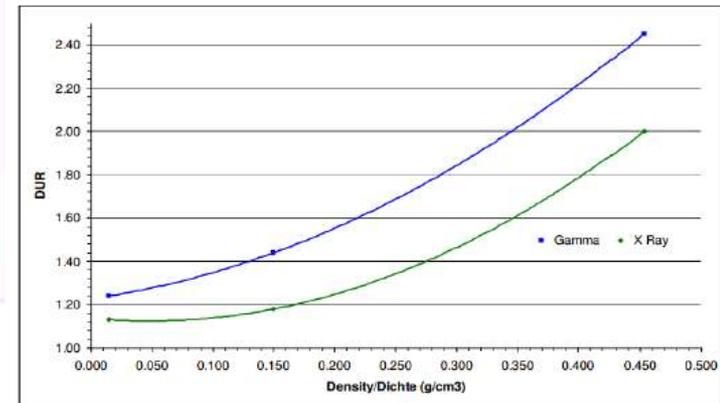
**> 50 cm (1,0 g/cm³)
100 kGy/h**



Dose vs. Depth Profiles



Homogeneity comparison Gamma irradiator vs. X-Ray unit



eXelis X-ray

5 or 7 MeV X-ray
Pallets



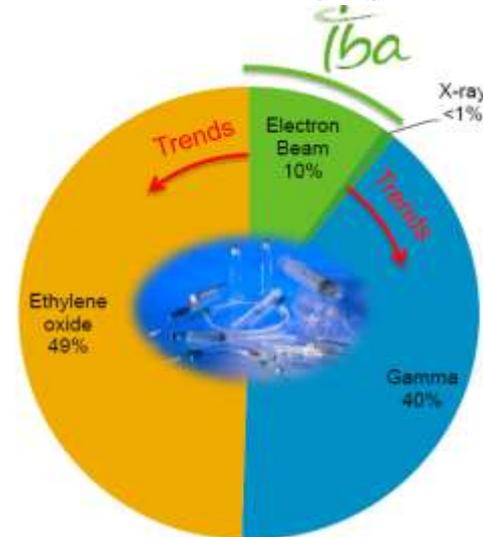
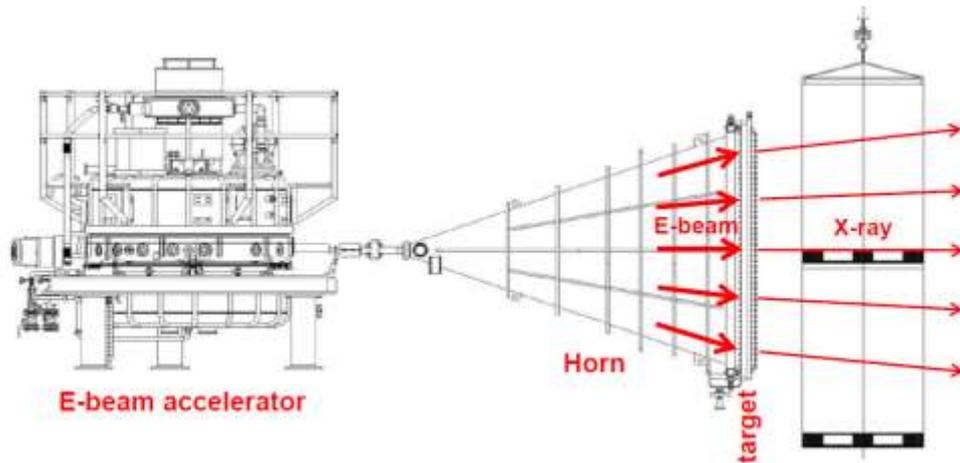
X-ray lateral irradiation

Rhodotron Duo

10 MeV E-beam
+ 5 or 7 MeV X-ray
Boxes

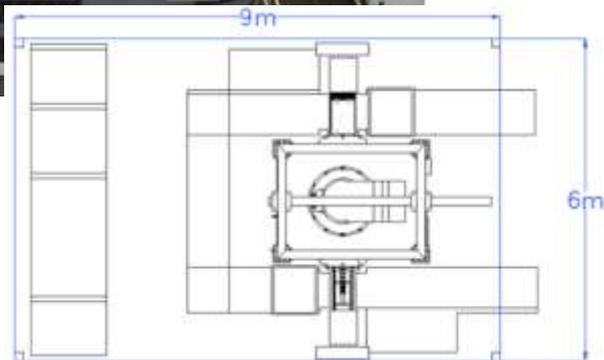


E-beam and X-ray top irradiation

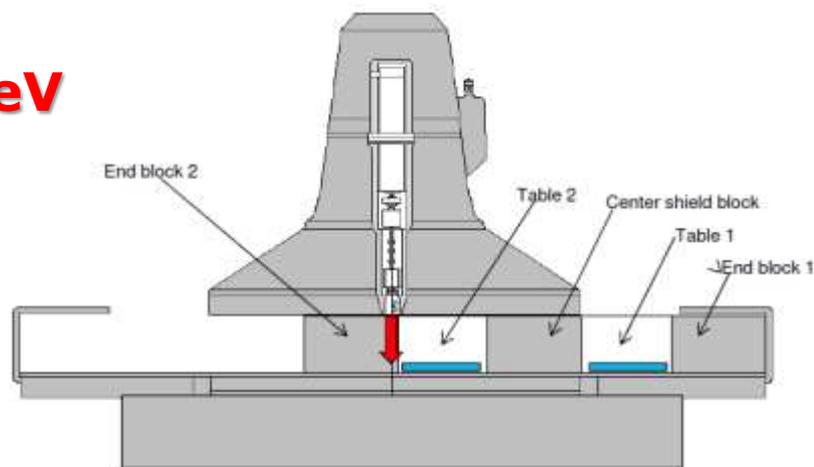


Volume of Sterilized Single Use Medical Devices

E-beam/X-ray market is growing 1.5 to 2 times faster compared with the global sterilization market



5MeV



200 keV ebeam engine



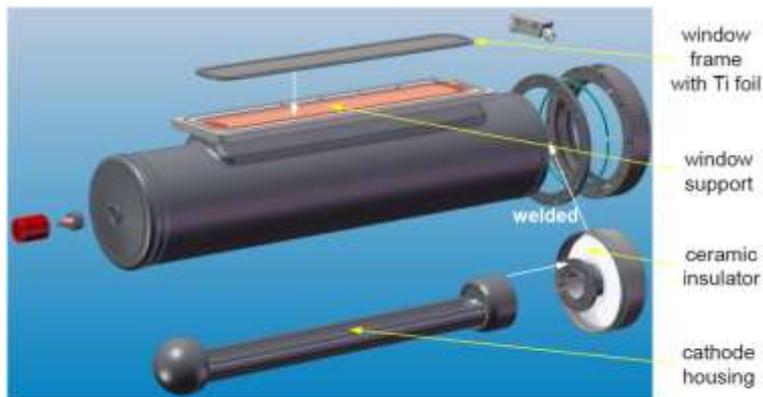
Product	Energy	Window	Power
EBA-200/400	200 keV	400 mm 270mm	4.5 kW

200 keV EBLab System



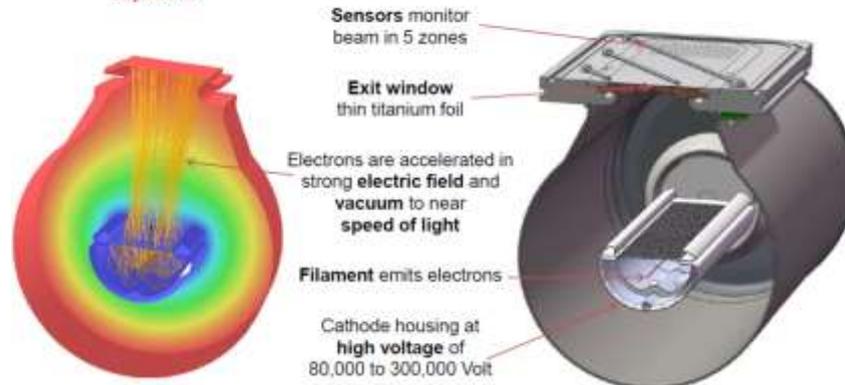
Ideal in-house R&D Tool

Standard Sample up to Letter N₂ / Air atmosphere



- Hermetically sealed by brazing and welding
- Can be refurbished by milling out frame with window foil and welding in new one

Result simulation: electron trajectories



MOBILE E-BEAM IN FLUE GAS PURIFICATION FROM OIL-REFINERY IN SAUDI ARABIA





- **Beam Energy: 0.4 ~ 0.7 MeV**
- **Beam Power: 20 kW**
- **Total weight: 40 tons**



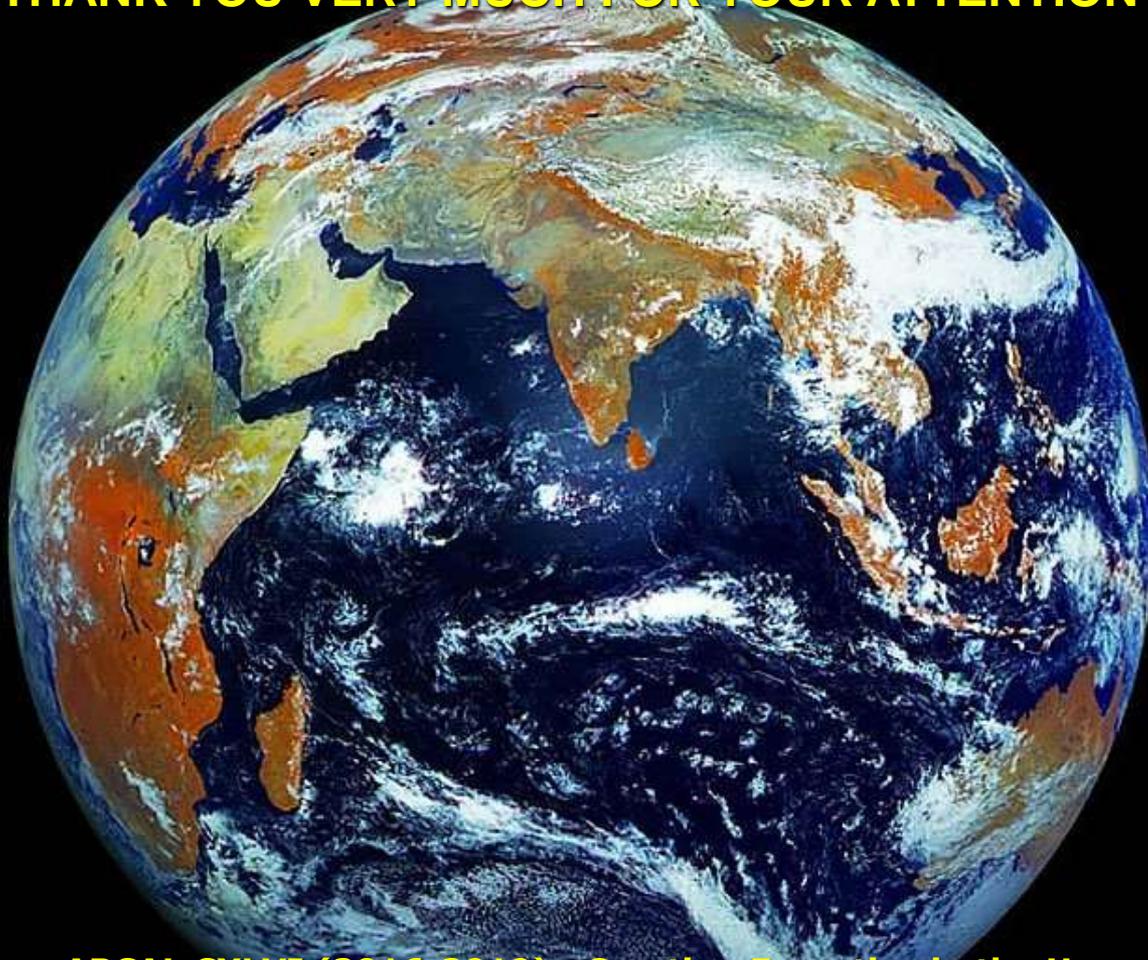
Treatment Costs

Effluent	Dose (kGy)	Amount (m ³ /day)	Power (kW)	Capital cost (Million US\$)	*Variable cost **(Variable and fixed costs) (Million US\$)	Cost/m ³ of effluent treated (US\$)
Removal of geosmine-GEO and methilisoborneol-MIB from drinking water	1	1,000	20	1.5	0.20	0.60
					(0.38)	(1.14)
Removal of industrial textile dyeing from wastewater	2	500	20	1.5	0.20	1.20
					(0.38)	(2.28)
Elimination of coliforms from raw sewage, secondary and chlorinated effluents	3	340	20	1.5	0.20	1.77
					(0.38)	(3.36)
Removal of organic compounds from petroleum production water	20	50	20	1.5	0.20	12.0
					(0.38)	(22.8)
Removal of PCB from transformers oils	50	20	20	1,5	0.20	30.1
					(0.38)	(57.1)

* Variable cost only (maintenance, electricity and labor)

** Both variable and fixed costs (depreciation, bank interest and management)

THANK YOU VERY MUCH FOR YOUR ATTENTION !



ARCAL CXLVI (2016-2019) - Creating Expertise in the Use of Radiation Technology for Improving Industrial Performance, Developing New Materials and Products, and Reducing the Environmental Impact of the Industry