IAEA-CN301-174

Electron Beam Processing to Improve Biodegradable Polymers and for Industrial Wastewater Treatment and Recycling

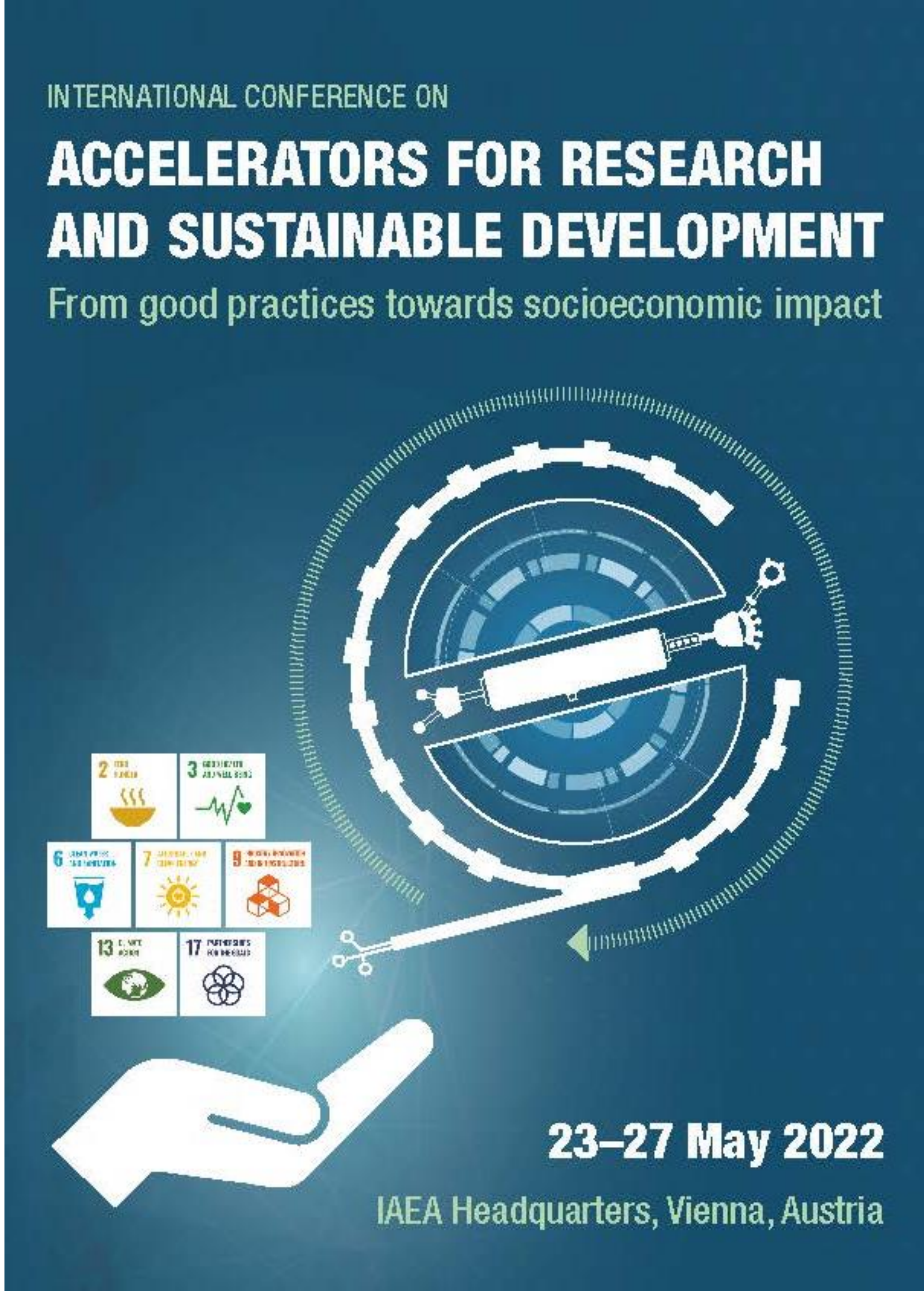
[1]W.A.P. CALVO; [1]P.M. MUNHOZ; S.L. [1]SOMESSARI; [1]C.L. DUARTE; [1]F.E. SPRENGER; [1]A. FEHER; [1]F.F. LAINETTI; [1]R.R. GASPAR; [1]F.C. NASCIMENTO; [1]L.G.A. SILVA; [1]J. HARADA; [2]A. BRAGA; [2]M. RODRIGUES; [1]M.H.O. SAMPA

[1] Nuclear and Energy Research Institute (IPEN-CNEN)

[2] Truckvan Industry

São Paulo/SP, Brazil

wapcalvo@ipen.br

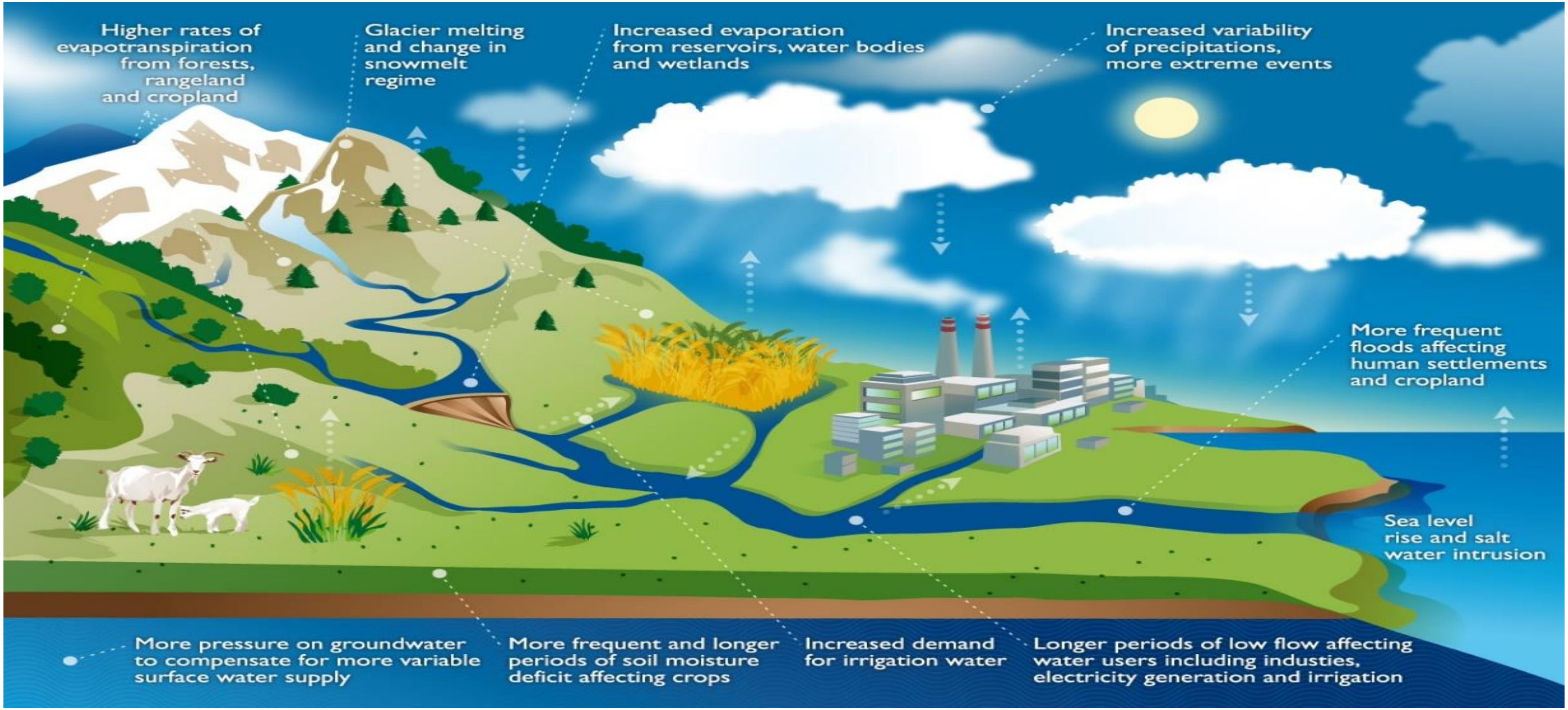


Nuclear applications: peaceful uses addressing global challenges

ENVIRONMENTAL PROTECTION

Wastewater Treatment

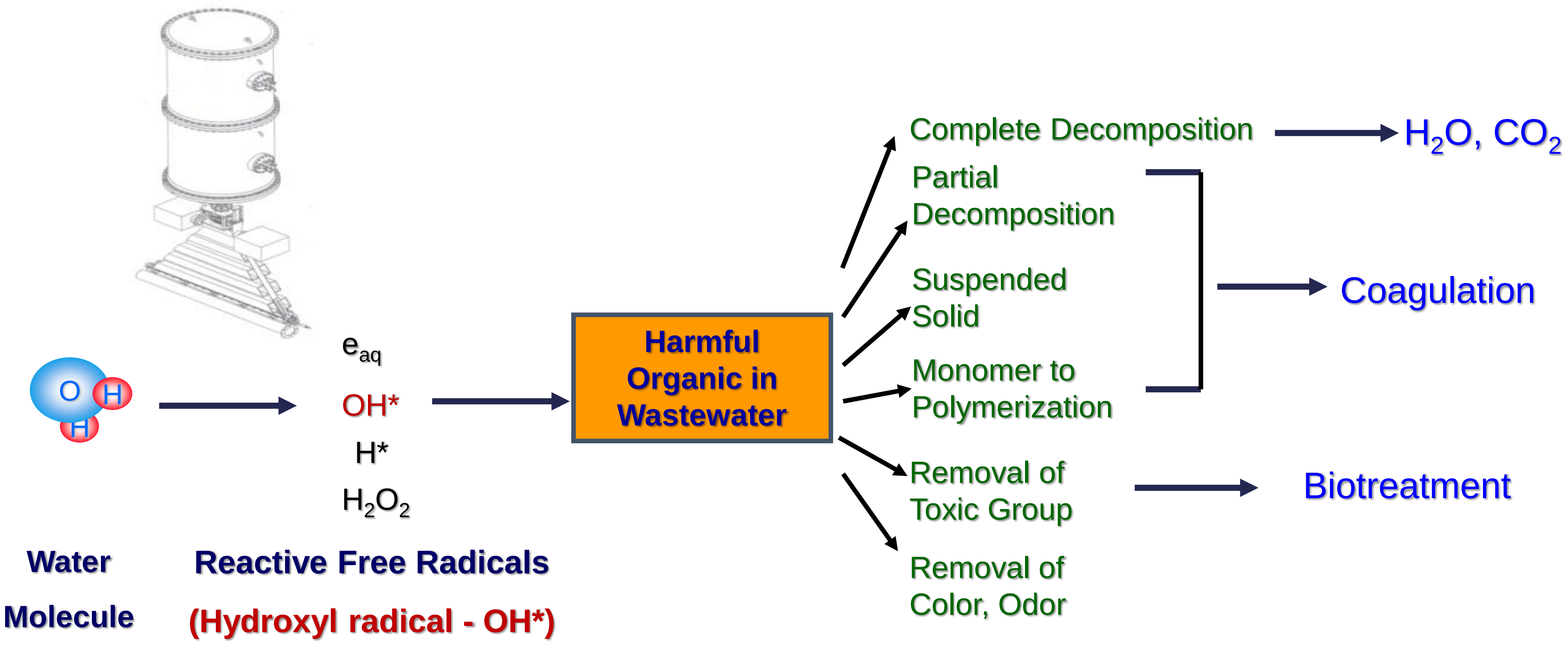
THE TYPICAL ROUTES TO SURFACE AND GROUND WATER ARE TREATED DOMESTIC AND INDUSTRIAL WATER, COMBINED SEWER OVERFLOWS, SEPTIC TANKS AND ANIMAL FEEDING



- **26 millions organic and inorganic substances have been inventoried**

***Source*: Bumsoo Han, IAEA**

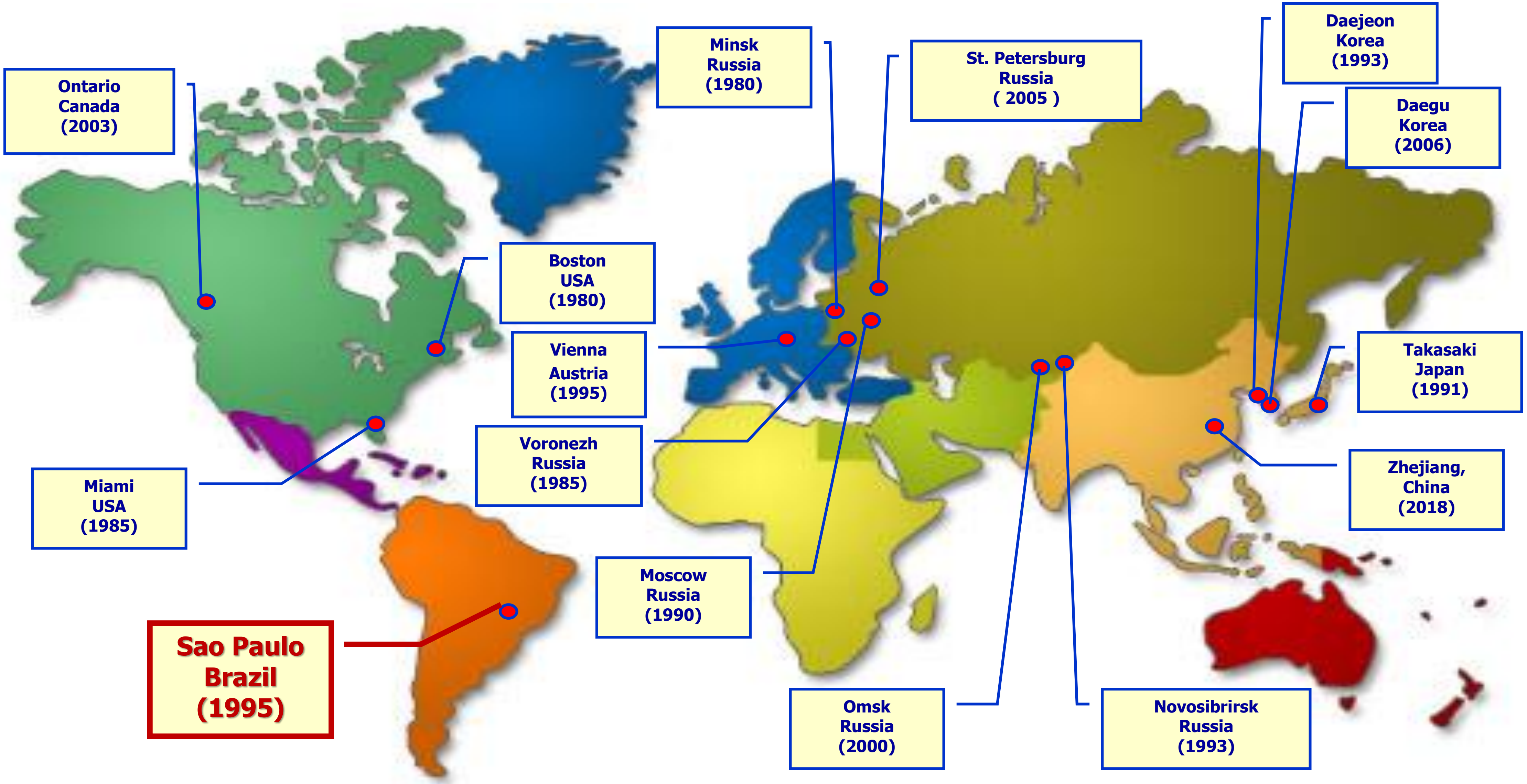
PRINCIPLES OF WASTEWATER TREATMENT WITH ELECTRON BEAM IRRADIATION



- **Removal of harmful impurities** (COD, BOD, S/S)
- **Removal of colour, odour and others**
- **Disinfection of microorganisms** (Coliforms & pathogenic organisms)
- **Destruction of endocrine disrupter and synthetic chemicals**

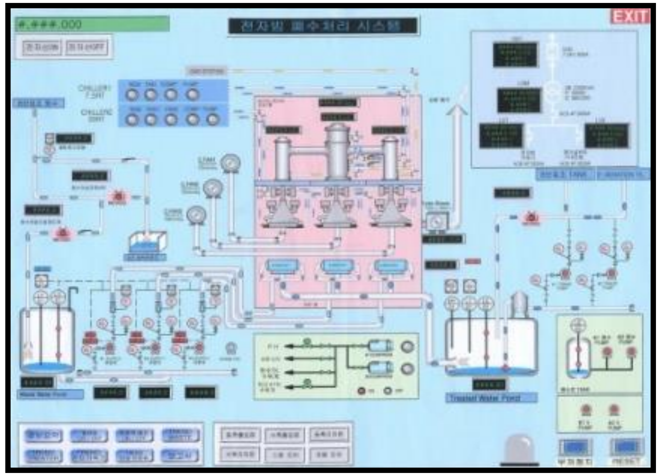
***Source*: IAEA**

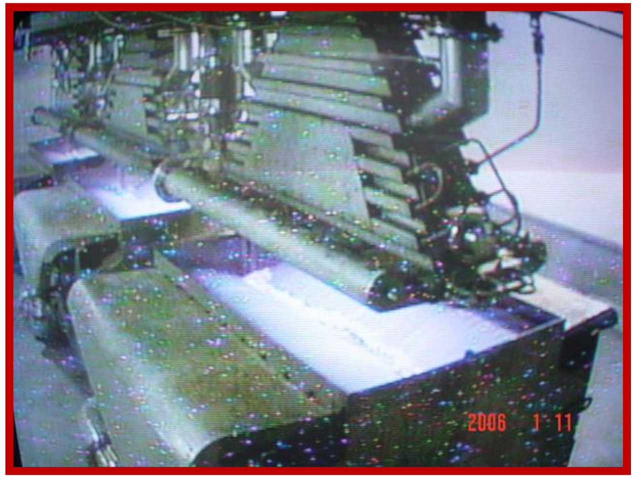
WASTEWATER TREATMENT FACILITIES USING ELECTRON BEAM TECHNOLOGY



Source: Bumsoo Han, IAEA

1ST SUCCESS HISTORY - TEXTILE DYEING WASTEWATER TREATMENT PLANT IN REPUBLIC OF KOREA





- **Full-scale application of electron beam wastewater treatment plant for 10,000 m^3/day of textile dyeing wastewater with 1 MeV, 400 kW accelerator in 2006**

***Source*: Bumsoo Han, IAEA**

2^{ND} SUCCESS HISTORY - CHINA'S ELECTRON BEAM INDUSTRY OPENS WORLD'S LARGEST WASTEWATER TREATMENT FACILITY

- Capacity to treat 30 million liters of industrial wastewater/day
- Largest wastewater treatment facility using EB technology in the world
- Treatment process will save 4.5 billion liters of fresh water/year
- Enough to quench the thirst of 100,000 people/year

Guanhua Knitting Factory in southern China

Nuclear and Energy Technology Institute
Tsinghua University

June 29th, 2020

***Source:* IAEA**

3RD SUCCESS HISTORY - CHINA OPENS ASIA'S FIRST FACILITY TO TREAT MEDICAL WASTEWATER USING ELECTRON BEAM TECHNOLOGY

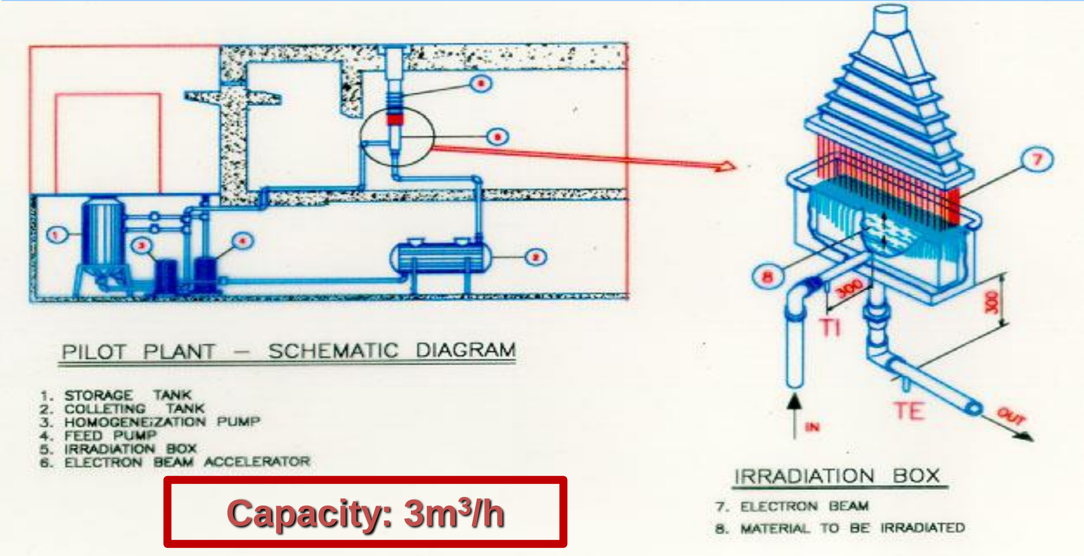
- **Asia's first demonstration facility for medical wastewater treatment using EB technology**
- **Pilot-scale (400 m^3/day) demonstration of EB for medical wastewater treatment**
- **Sterilizes medical wastewater and decomposes antibiotics without additional disinfectant or the production of secondary pollution**

Institute of Nuclear and New Energy Technology (INET) at Tsinghua University

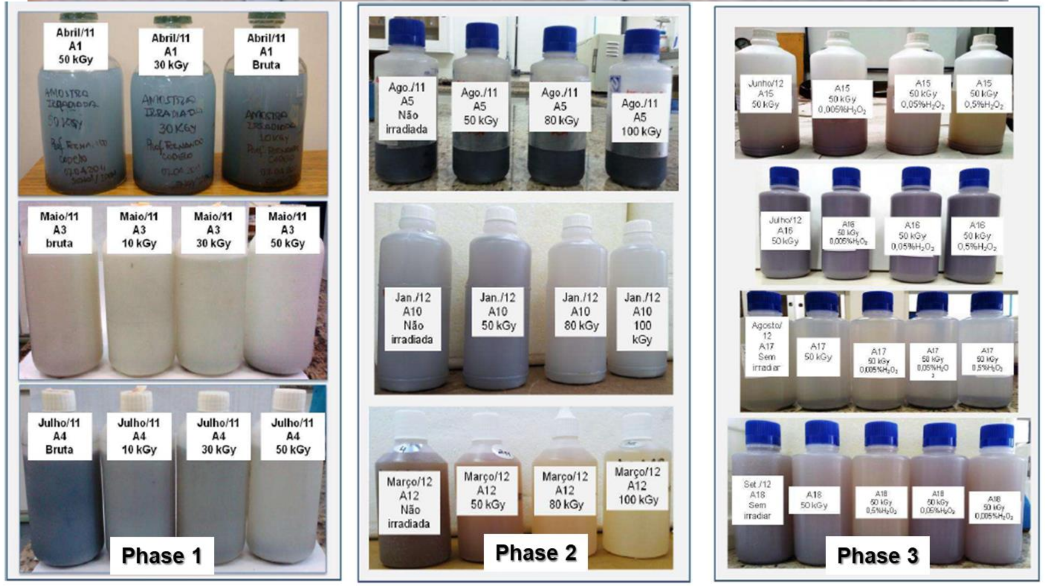
August 11st, 2021

***Source*: IAEA**

1ST CASE STUDY - IAEA TC PROJECT BRA8025 “ELECTRON BEAM TREATMENT OF WATEWATER (1993-1997)”



- **Model Project in 1995**

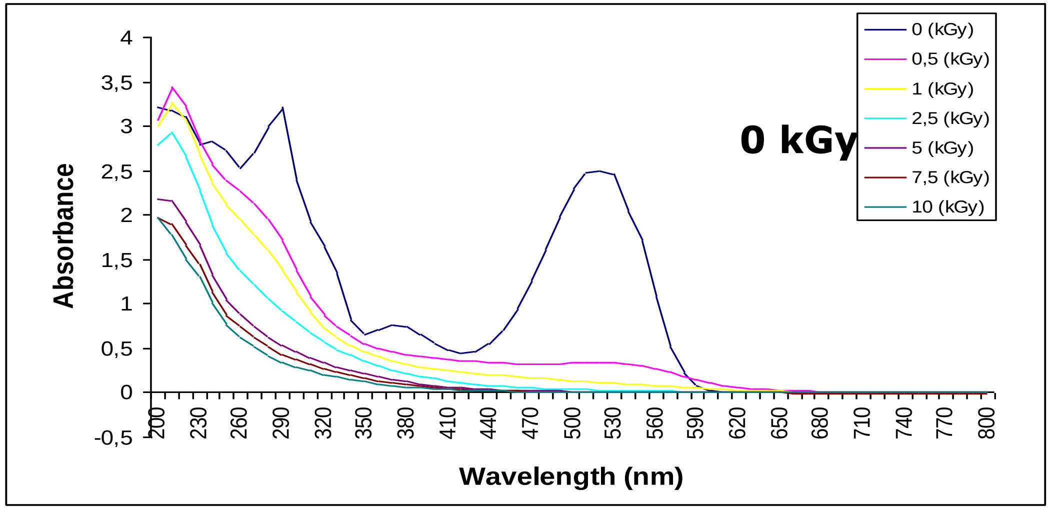


TREATMENT OF INDUSTRIAL WASTEWATER FROM PAINT INDUSTRY BY ELECTRON BEAM IRRADIATION

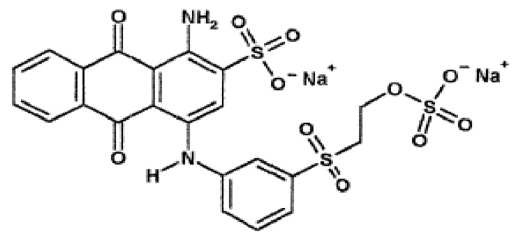
- **Efficiency of organic compound and color removal by electron beam irradiation**

***Source*: IPEN-CNEN**

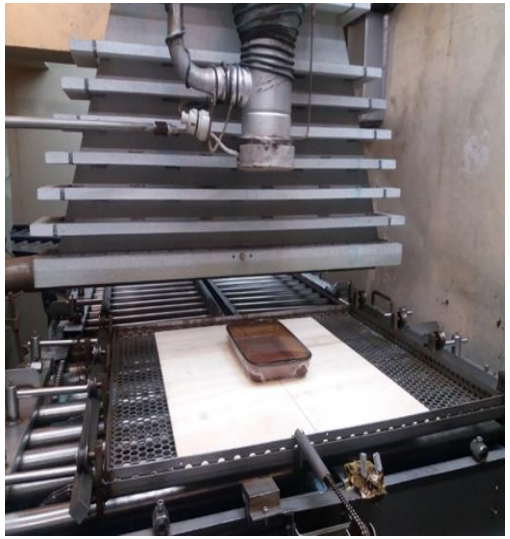
- **Radiation treatment of wastewater for reuse with particular focus on wastewaters containing organic pollutants**



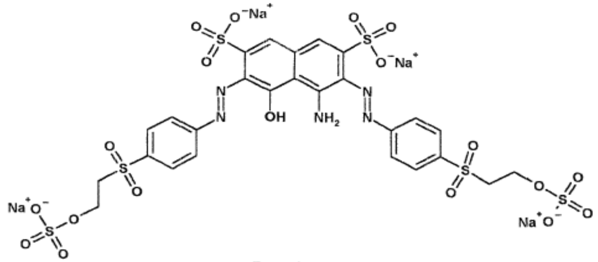
Red Reactive Remazol – RR 198



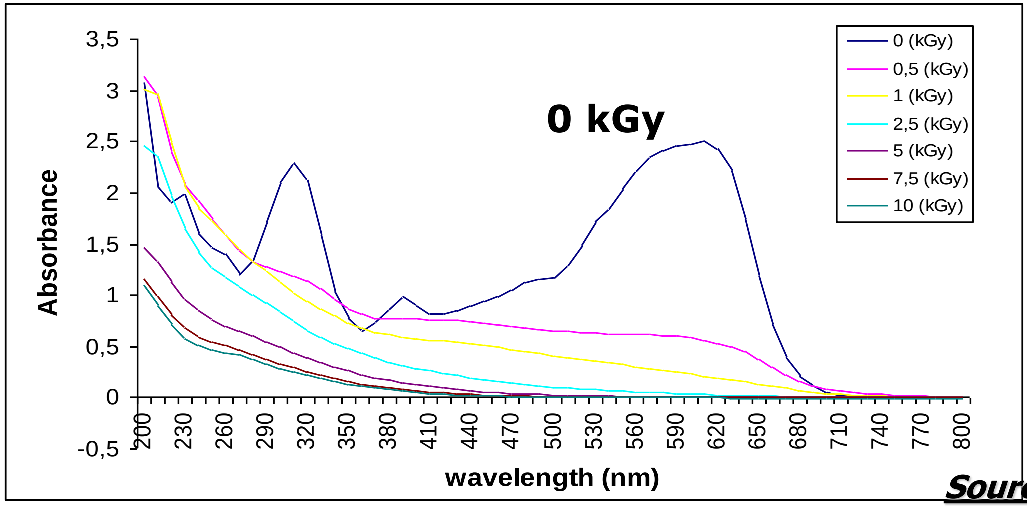
Remazol Brilliant Blue R



Reactive Black 5 – RB5

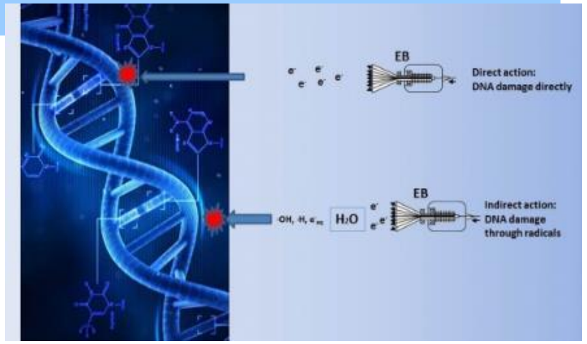


Reactive Black 5



Source: IPEN-CNEN

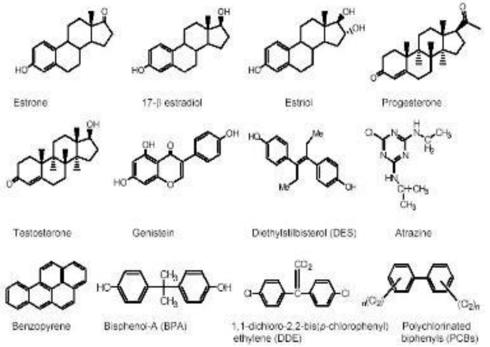
PARTICIPATION IN COORDINATED RESEARCH PROJECTS ON WASTEWATER AND SLUDGE TREATMENT



1) Radiation Inactivation of Bio-hazards Using High Powered Electron Beam Accelerators (2018 - 2022)

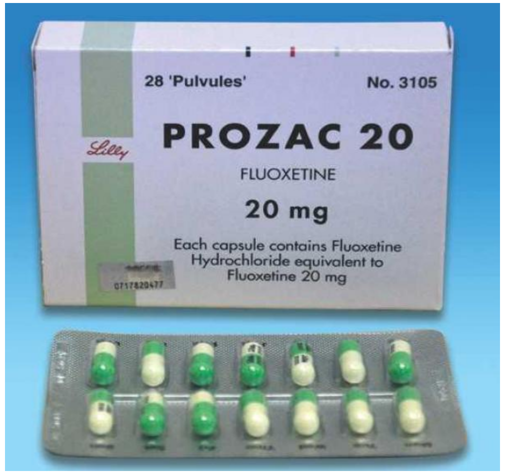
Objective: To enhance and strengthen use of EBA for treatment of biohazards of concern under changing conditions such as at high dose rates, different ambient conditions, and varying substrates in **applications such as radiation sterilization, hygienization of biosolids, sanitizing infectious hospital waste or toxic effluents and eliminating deliberate biohazards**

2) Removal of Emerging Organic Pollutants in the Wastes by Radiation (2019 - 2023)



Objective: To exploit the innovative methodologies and technologies **to remove the emerging pollutants such as endocrine disruptors, pharmaceutical residues, and other toxic pollutants in wastewater and sludge**

***Source*: IAEA, IPEN-CNEN**



➢From humans and animals, pharmaceuticals going to several environmental matrices: water, sewage, soil, plants and food !!!

Green algea

Dafnids

Salmo trutta

➢Pharmaceuticals have been introduced into the food chain !!!

***Source*: IPEN-CNEN**

3RD CASE STUDY - ELECTRON BEAM IRRADIATION OF PHARMACEUTICALS

Environmental Science and Pollution Research
https://doi.org/10.1007/s11356-020-11718-8

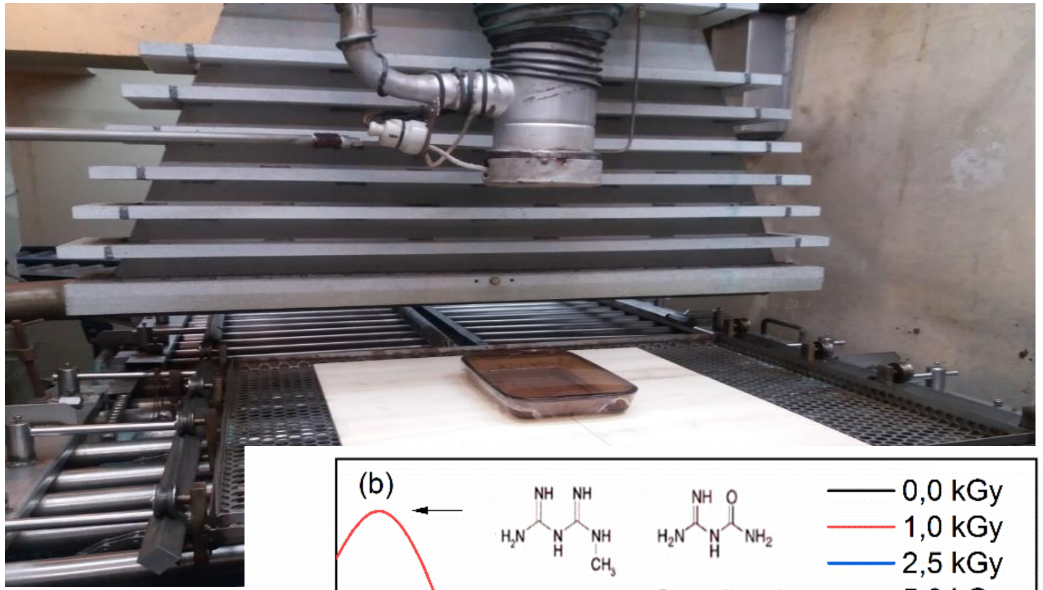
ADVANCED OXIDATION/REDUCTION TECHNOLOGIES: AN PERSPECTIVE FROM IBEROAMERICAN COUNTRIES

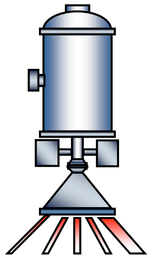
Check for updates

Is ionizing radiation effective in removing pharmaceuticals from wastewater?

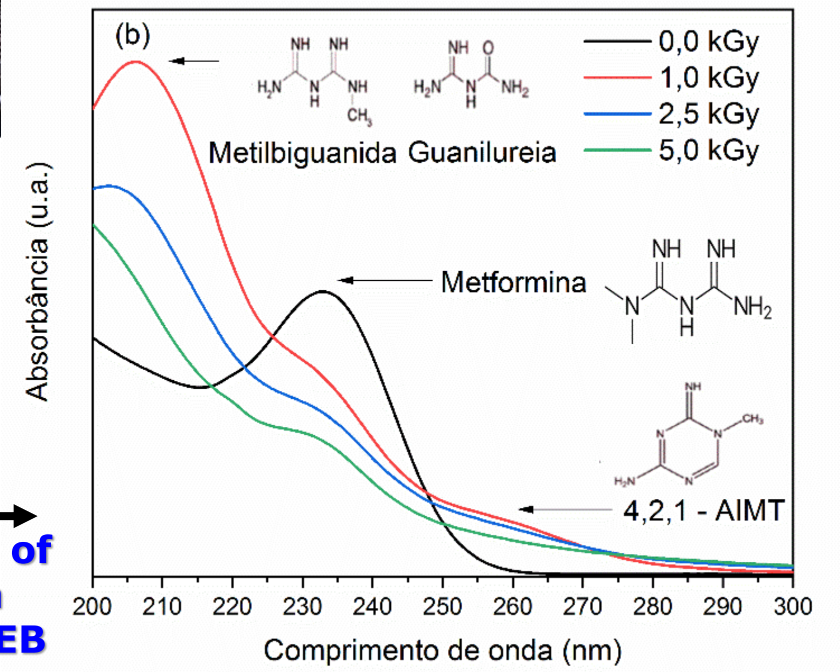
Flávio Kyoshi Tominaga[1] · Thalita Tieko Silva[1] · Nathalia Fonseca Boiani[1] · Juliana Mendonça Silva de Jesus[2] · Antonio Carlos Silva Costa Teixeira[2] · Sueli Ivone Borrely[1]

- **Fluoxetine** – Prozac (depression)
- **Amoxicilin; Ciprofloxacin; Sulfadiazine** (antibiotics)
- **Aspirin and Voltaren** (anti-inflamatory)
- **Propranolol** (blood pressure)
- **Metformin** (diabetics)





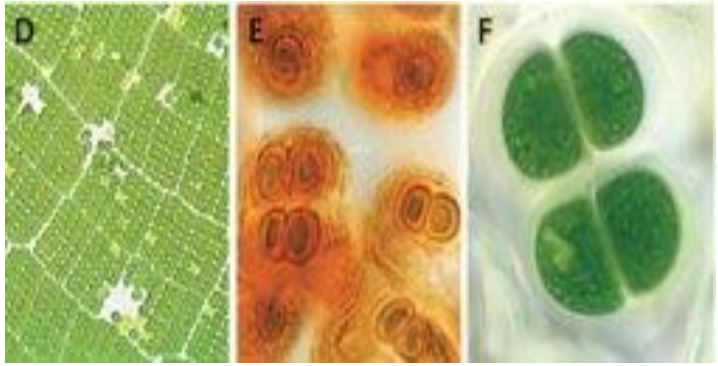
Degradation of Metformin Induced by EB Irradiation



Source: IPEN-CNEN

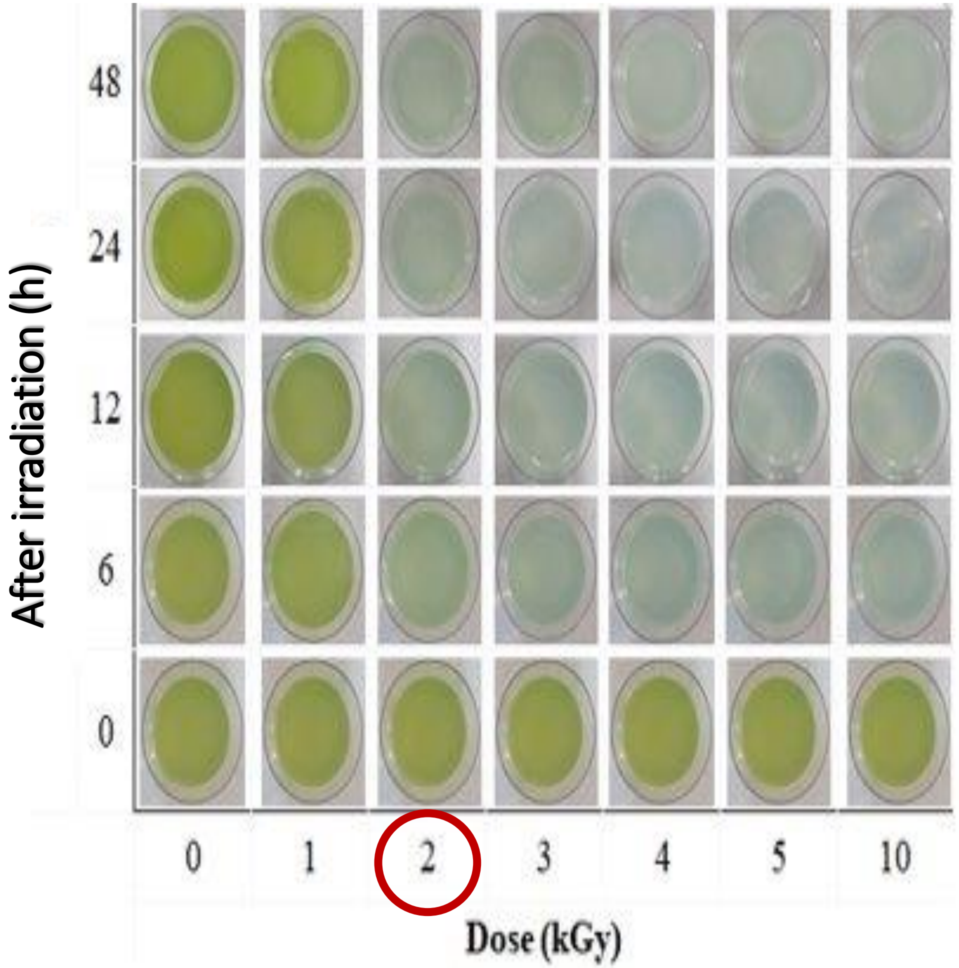
4TH CASE STUDY - IONIZING RADIATION FOR REDUCING TOXICITY INDUCED BY CIANOBACTERIA IN WATERS

- **Positive effect of electron beam irradiation is the detoxification related to algal toxins in drinking water**



Microcystis aeruginosa
(Cianobacteria in drinking water)

E-Beam Accelerator
(1.5 MeV, 25 mA, 37.5 kW)



Source: IPEN-CNEN

- **IAEA TC PROJECT BRA1035 - Establishing a Mobile Unit with an Electron Beam Accelerator to Treat Industrial Effluents for Reuse Purposes (2016 - 2020)**

- **INNOVATION AGREEMENT with Truckvan Industry**

Objective: To enlarge the national capacity to treat industrial effluents using electron beam accelerators, **the mobile unit treating effluents on site from 1 m³/h up to 1,000 m³/day**, **will provide an effective facility between a laboratory-scale plant to a large-scale plant with the objective to demonstrate the efficacy and transfer the technology**

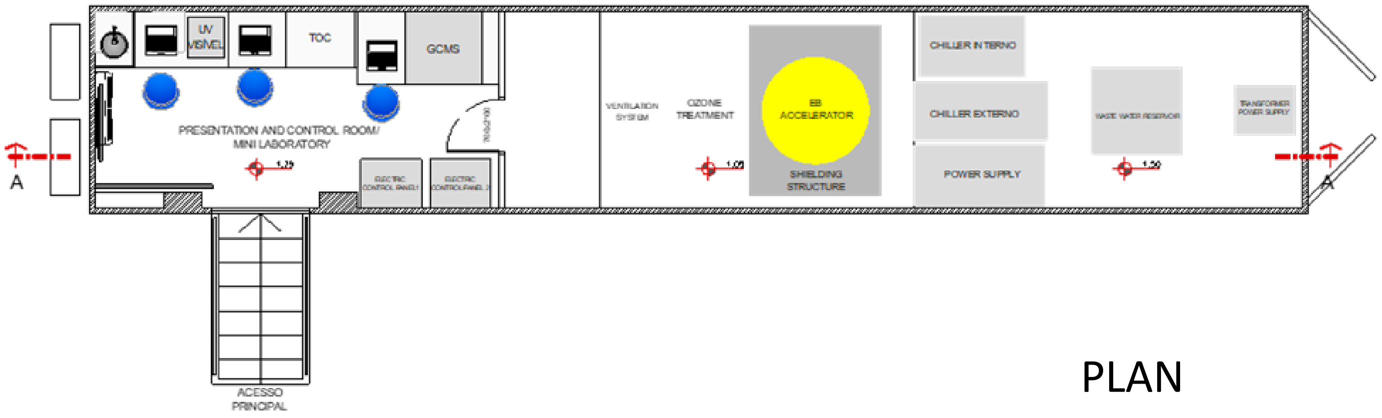
Source: IPEN-CNEN

Radiological shielding built in IPEN-CNEN's Mobile Irradiation Unit, in which the Industrial electron beam accelerator will be installed

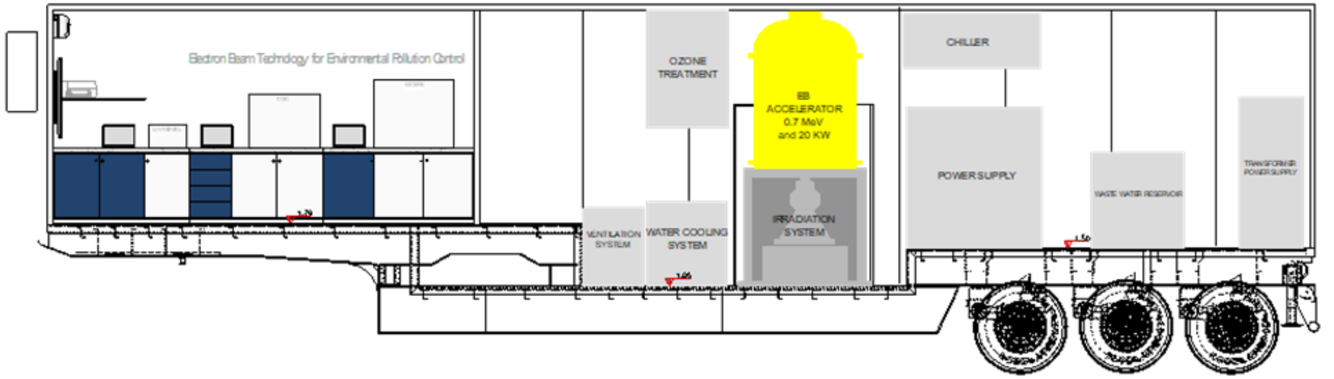
Industrial electron accelerator (700 keV, 28 mA, 20 kW, scan horn 640 mm).

- It is warehoused in the Radiation Technology Center at IPEN-CNEN

Source: IPEN-CNEN



PLAN



SECTION AA

The cart is divided into three separate parts:

a) Control room and laboratory for analyses, technical and scientific dissemination of the technology

b) Industrial electron beam accelerator, hydraulic units, ventilation system, cooler and bunker with irradiation device

c) Transformer and power source supply

- **Mobile Unit dimensions: 15 m length, 2.6 m width and 4.4 m height**

***Source*: IPEN-CNEN**

- ✓ Gas Chromatograph Mass Spectrometer (CG-MS)
- ✓ Ultraviolet Visible Spectrophotometer (UV-Vis)
- ✓ Total Organic Carbon Analyzer (TOC)

Others equipment purchased by the IAEA:

- ✓ Radiation monitoring device and survey meters
- ✓ Ultra purification water system (HPLC grade)
- ✓ Biological Incubator Chamber (BOD type)

➢ **There are materials and instruments purchased by the IAEA to be set up in the mobile unit**

Source*: *IPEN-CNEN

➢ Quantities of energy, treatment capacity and costs by type of effluent treated in the Mobile Unit

EFFLUENTS	Dose (kGy)	Amount (m^3/day)	Power (kW)	Capital cost (Million US$)	*Variable cost **(Variable and fixed costs) (US$)	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 (0.38)	0.60 (1.14)
Removal of industrial textile dyeing from wastewater	2	500	20	1.5	0.20 (0.38)	1.20 (2.28)
Elimination of coliforms from raw sewage, secondary and chlorinated effluents	3	340	20	1.5	0.20 (0.38)	1.77 (3.36)
Removal of organic compounds from petroleum production water	20	50	20	1.5	0.20 (0.38)	12.0 (22.8)
Removal of PCB from transformers oils	50	20	20	1.5	0.20 (0.38)	30.1 (57.1)

* Variable cost only (maintenance, electricity and labor)

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

Business Plan for the IAEA TC Project BRA1035:

a) Project Costs

➢ **Capital Cost (Investment)**

Initial investment costs of the Mobile Electron Accelerator: **US$1,500,000.00**

➢ **Operating Costs**

Operating costs (fixed and variable) of the Mobile Electron Accelerator: **US$380,500.00/year**

➢ **Rental Price of the Mobile Facility**

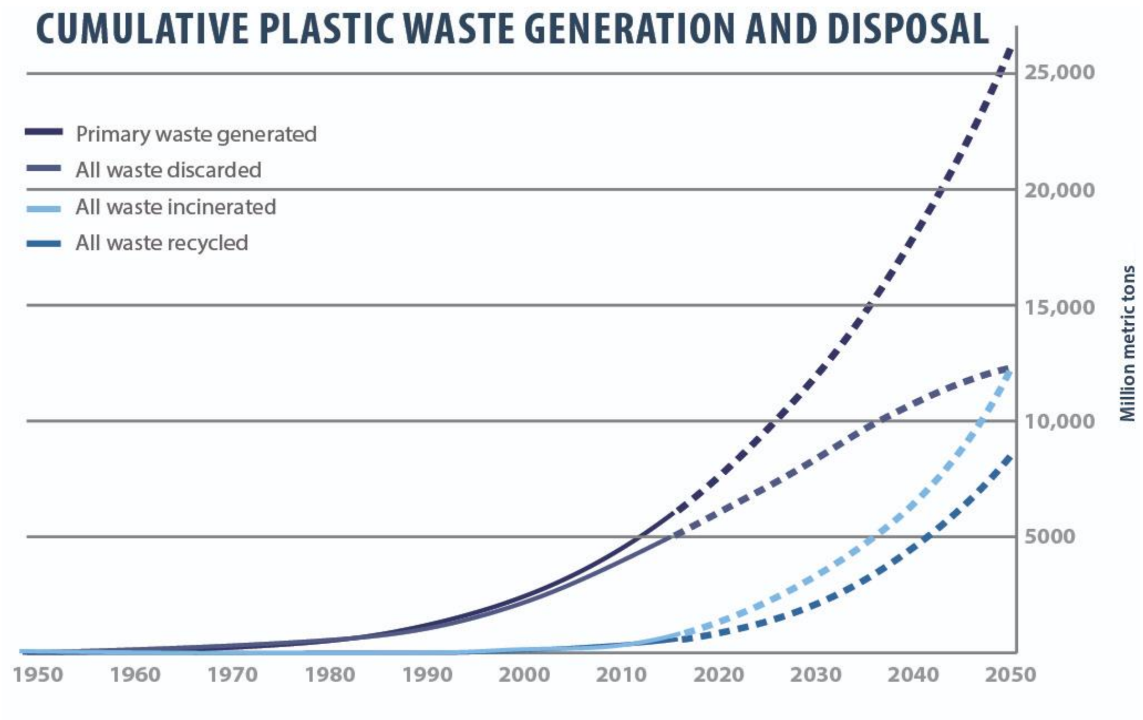
Rental price calculation of the Mobile Electron Accelerator: **US$31,708.00/month** or **US$380,496.00/year**

***Source*: IPEN-CNEN**

Nuclear applications: peaceful uses addressing global challenges

ENVIRONMENTAL PROTECTION

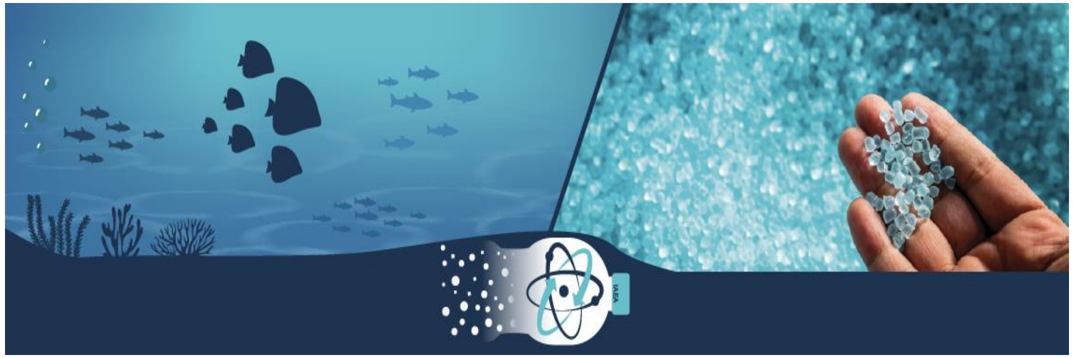
NUTEC Plastics



Geyer, R., Jambeck, J. R., & Law, K. L. (2017). Production, use, and fate of all plastics ever made. Science advances, 3(7), e1700782.

- **IAEA's efforts to deal with plastic pollution through recycling using radiation technology and marine monitoring using isotopic tracing techniques**

It provides science-based evidence to characterize and assess marine microplastic pollution, while also demonstrating the use of ionizing radiation in plastic recycling, transforming plastic waste into reusable resources



Recycling with irradiation

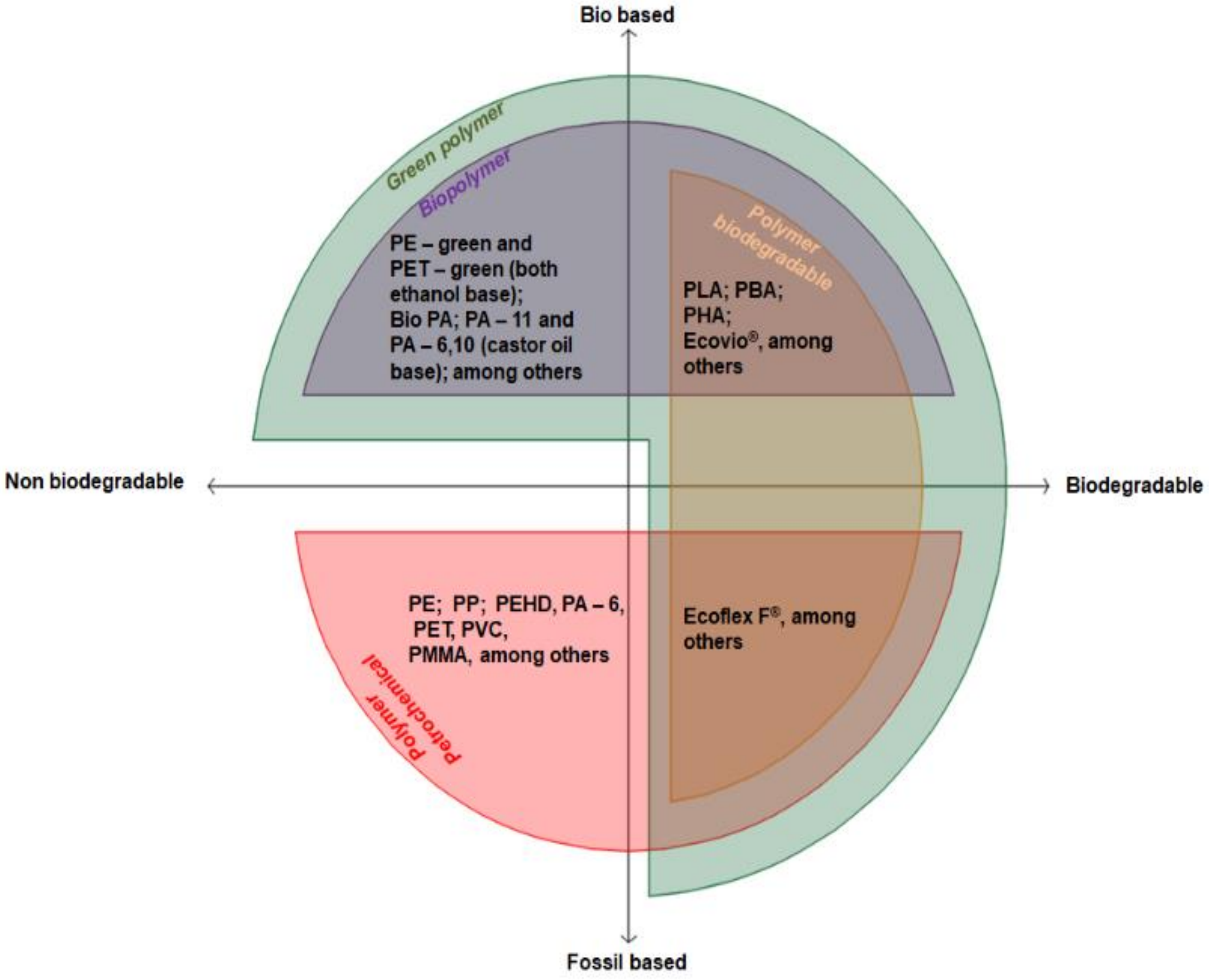
Using gamma and electron beam radiation technologies as a complement to traditional mechanical and chemical recycling methods, certain types of plastic waste can be modified and therefore reused or recycled. These technologies can complement existing recycling methods to:

- **Sort mechanically treated plastic waste according to polymer type.**
- **Breakdown plastic polymers into smaller components to be used as raw materials for new plastic products.**
- **Treat plastic so that it can be amalgamated with other material to make more durable products.**
- **Convert plastic into fuel and feedstock through radiolysis (irradiation + chemical recycling).1**

- **Precise scientific data to inform plastic pollution policies**
- **Strengthened methodology to track plastics**
- **Effective and efficient technologies**
- **Scalable technology**

Source: Celina Horak, IAEA

6TH CASE STUDY - INFLUENCE OF ELECTRON BEAM IRRADIATION ON THE MECHANICAL AND THERMAL PROPERTIES OF PBAT/PLA POLYMERIC BLEND ECOVIO®

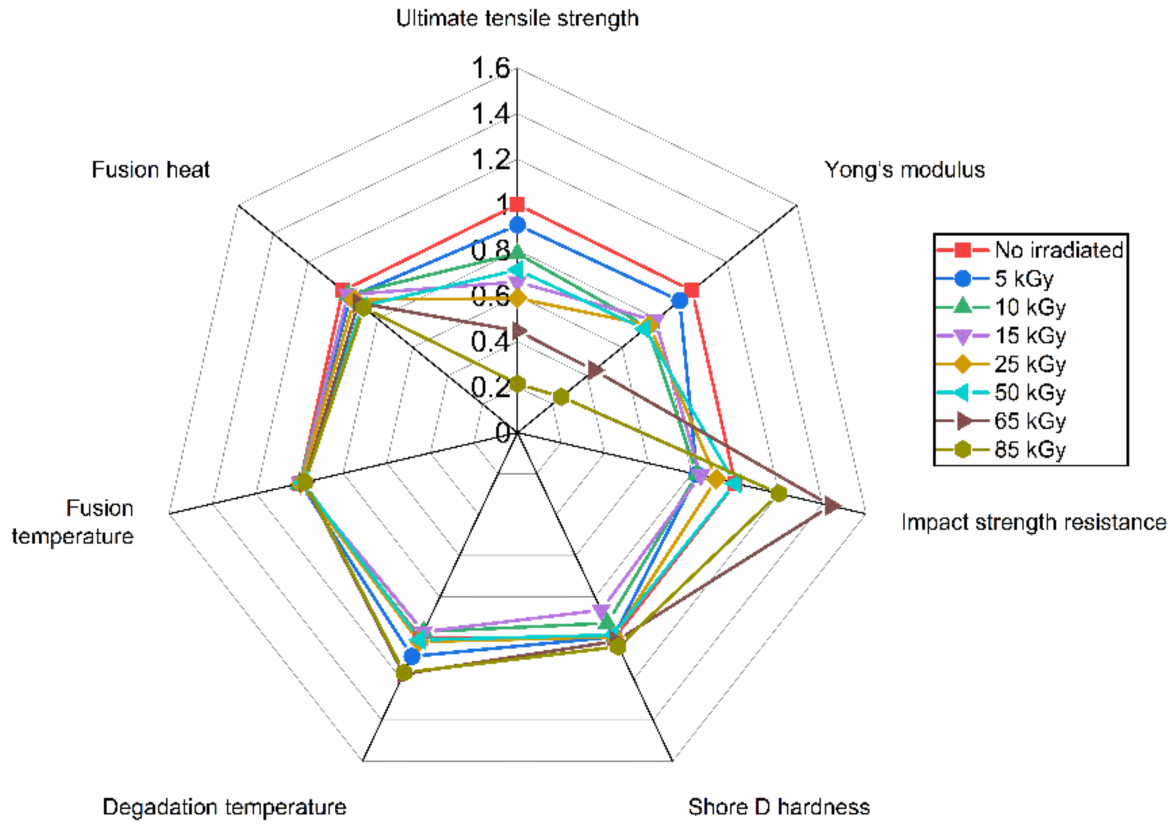


- **GREEN POLYMER - BIODEGRADABLE POLYMERIC BLEND ECOVIO® needs to be resistant to cross sectional demands, impact and thermal stability and should have an average lifetime of 1 to 5 years**
- **Then, for INJECTED PACKAGING, FILMS FOR TUBE PRODUCTION, PLASTIC BAGS, PACKAGING FOR COSMETICS AND FOOD, it is recommended to use the PBAT/PLA polymeric blend Ecovio® irradiated by EB with 65 kGy**

- **Industrial EBA (1.5 MeV, 25 mA, 37.5 kW) application on the PBAT/PLA polymeric blend Ecovio® was studied.**

***Source*: IPEN-CNEN**

6TH CASE STUDY - RESULTS OF MECHANICAL AND THERMAL ANALYZES OF THE PBAT/PLA POLYMERIC BLEND ECOVIO® AS A FUNCTION OF RADIATION DOSE



- EB irradiation reduce only 2.4% the melting temperature of the PBAT/PLA polymeric blend with an absorbed dose of 80 kGy.
- A reduction of 78.6% was observed in relation to tensile strength at the highest radiation dose of 80 kGy.
- There was also a reduction of 80% in Yong's modulus at 80 kGy absorbed dose.
- A significant change in hardness was not observed at a dose of 65 kGy in relation to the non-irradiated material.
- **With absorbed dose of 65 kGy , there was an increase of 43% in impact strength resistance and an increase of 17.4% in thermal stability of the polymeric blend**

***Source*: IPEN-CNEN**

Thank you very much for your attention!

Acknowledgements

- ✓ International Atomic Energy Agency
- ✓ Funding Authority for Studies and Projects
- ✓ National Council for Scientific and Technological Development
- ✓ Truckvan Industry
- ✓ Nuclebras Heavy Equipment
- ✓ National Industrial Apprenticeship Service