ELECTRON ACCELERATORS: RESEARCH OPPORTUNITIES AND INDUSTRIAL APPLICATIONS

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KRAKÓW

INCT EXPERIENCE IN DEVELOPMENT OF EB APPLICATIONS

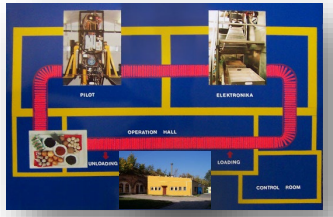
1971

LAE 13/9



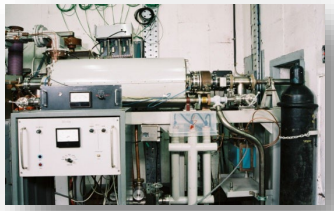
1988

ILU-6 pilot installation for polymers modification



1993

Sterilization plant – Elektronika accelerator



2002

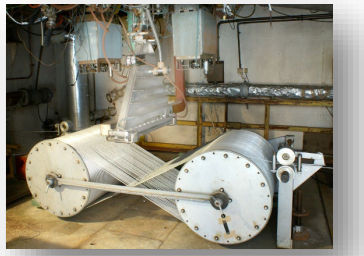
Pomorzany – flue gas treatment plant





1987

AS 2000 electrostatic



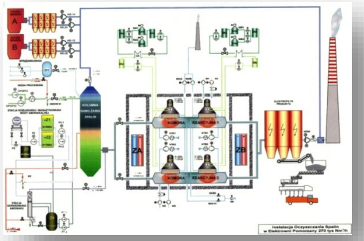
1990

Food irradiation (Pilot 10MeV, 1 kW; in 1993 – Elektronika accelerator)



2000

LAE 10 – basic research, pulse radiolysis

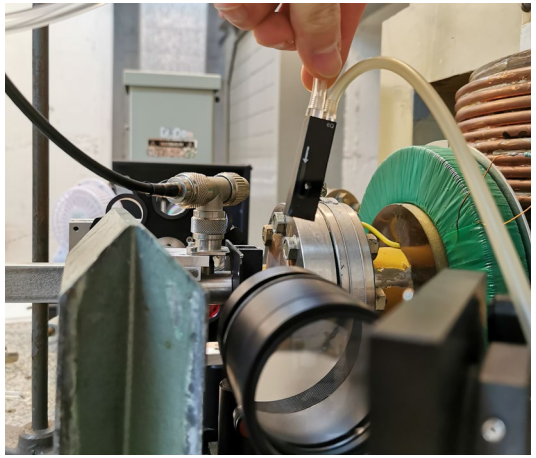


2025

DZ 10/20 accelerator

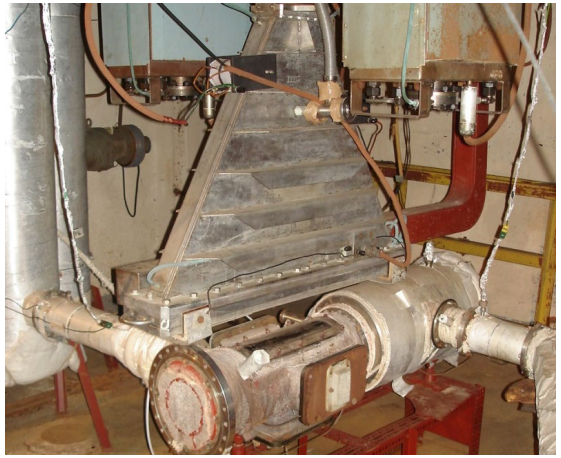
ELECTRON ACCELERATORS: FROM FUNDAMENTAL RESEARCH TO INDUSTRIAL APPLICATIONS

1. Fundamental Research



- Understanding radiation–matter interactions
- Radiation chemistry and reaction kinetics
- Transient species and ultrafast processes
- Radiation-induced changes in materials
- Mechanisms of degradation and modification

2. Technology Development



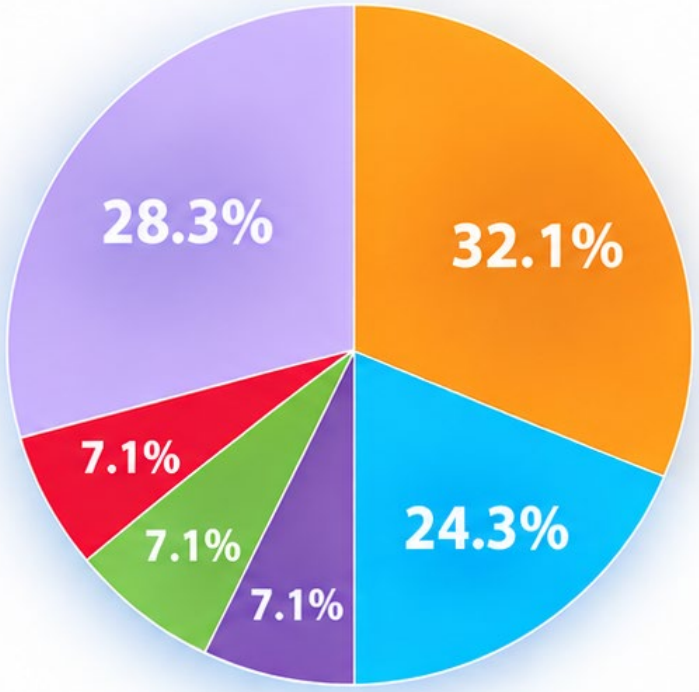
- Turning scientific knowledge into solutions
- Process optimisation and dosimetry
- Polymer crosslinking and grafting
- Functional materials and coatings
- Dose mapping and computational modelling

3. Industrial Applications



- Scalable, non-contact processing
- Sterilisation of medical products
- Food irradiation and phytosanitary treatment
- Wire, cable and polymer processing
- Environmental treatment and pollutant removal

INDUSTRIAL APPLICATIONS OF ELECTRON ACCELERATORS



- Surface curing (32.1%)
- Shrink film (24.3%)
- Tires (7.1%)
- Other (7.1%)
- Service (7.1%)
- Wire cable tubing (28.3%)



Advanced materials

- radiation-induced functionalization
- modification of natural polymers
- recycled materils



Healthcare

- sterilization of medical devices
- synthesis of hydrogel wound dressings
- production of vaccines



Food safety and quality

- microbial decontamination
- shelf-life extension
- PI irradiation



Environment protection

- removal of NO_x and SO_2 from flue gas
- decomposition of chemical contamimants
- inactivation of biological hazards



Cultural heritage

- microbial decontamination
- consolidation
- EB plasma cleaning

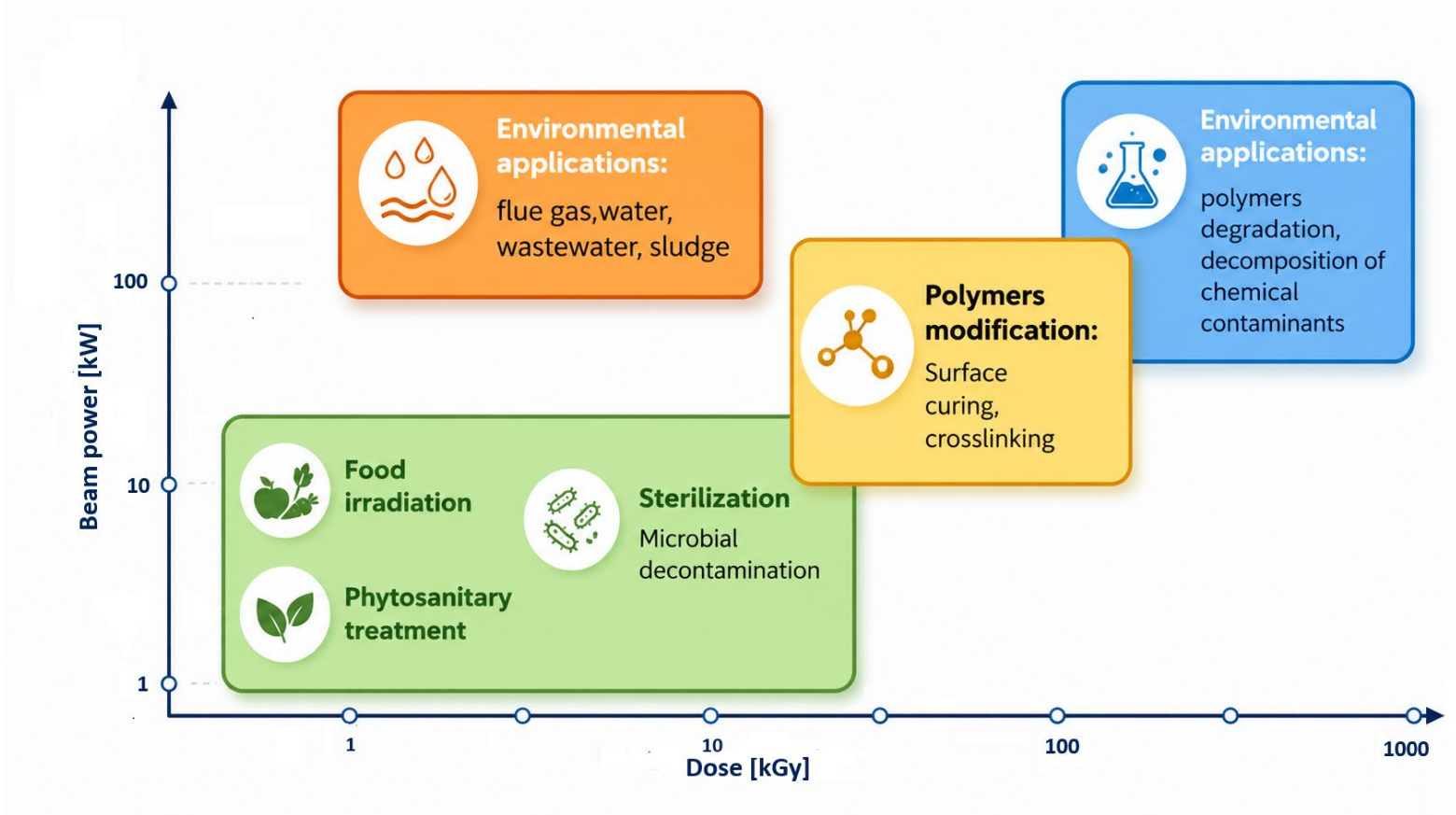
EB ACCELERATORS FOR RADIATION TECHNOLOGIES

ENERGY RANGE OF ELECTRON BEAM ACCELERATOS

LOW-ENERGY
80–800 keV
- Thin films
- Surface treatments

MID-ENERGY
800 keV – 5 MeV
- Polymer processing
- Environmental applications

HIGH-ENERGY
5–11 MeV
- Sterilization
- Food irradiation



Environmental applications of electron beam



Air contaminants

- removal of NO_X and SO_2
- decomposition of chemical contaminants

e.g Volatile Organic Compound (VOC)



Water, wastewater, sludge, soil

- decomposition of chemical contaminants
- inactivation of biological hazards



Greenhouse effect

- elimination of contaminants
- reduction of fossil fuels usage
- disintegration of biomass

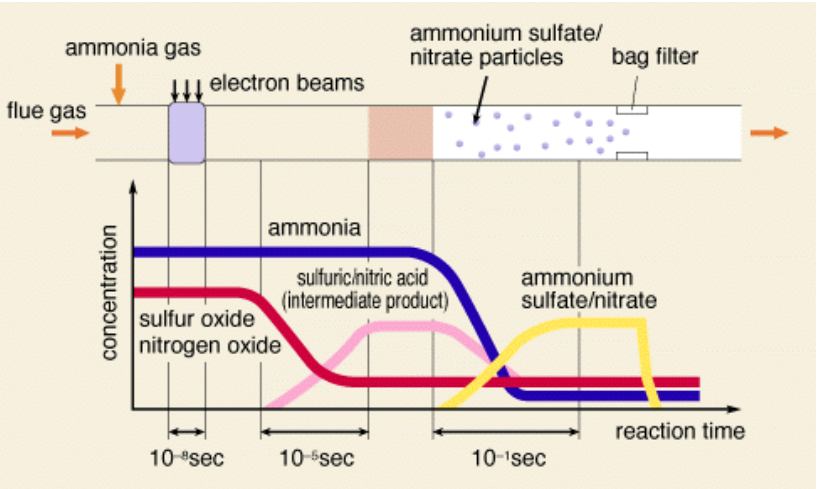


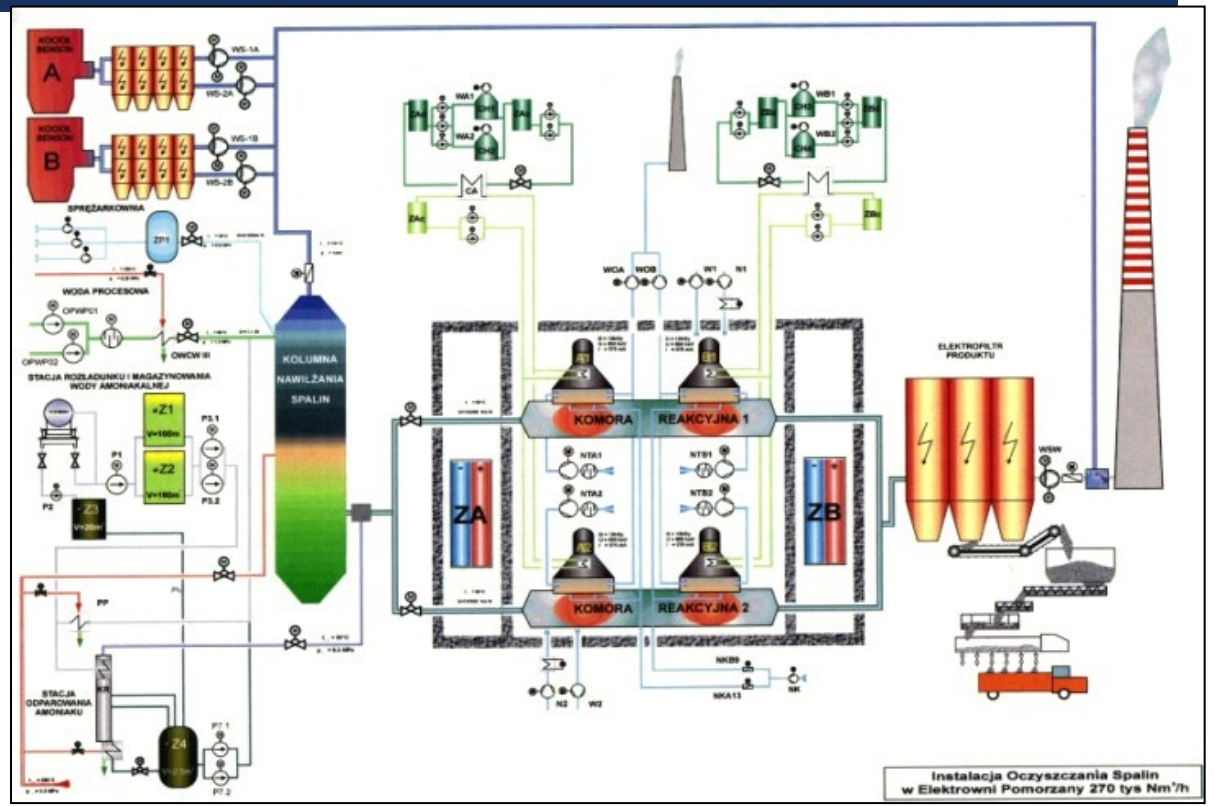
Advanced materials

- radiation induced functionalization of polymers
- modification of natural polymers

FLUE GAS TREATMENT INSTALLATION AT POMORZANY

- Flue gas conditioning unit (60-75 ^{0}C and 12-14%) humidity)
- Ammonia storage and feeding system
- Process vessel (2 vessels, 4 accelerators, 260 kW, 0.7 MeV each)for max. flow rate 270 000 Nm^3/h
- By-products collection

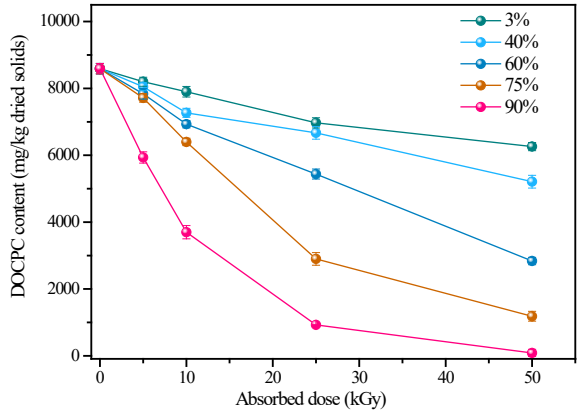




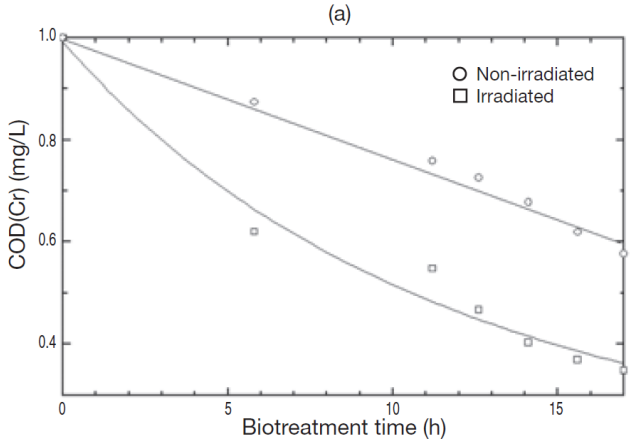
Air ionization - mixture consists of nitrogen, oxygen, water and carbon dioxide. Mostly dissociation and ionization of molecules. Water molecules in air – formation of reactive •OH

WATER, WASTEWATER, SLUDGE TREATMENT

- Water contaminants: **MPs, antibiotics, pesticides, hormones, cosmetics and personal care products, bisphenols, polychlorinated biphenyls, textile dyes**
- **Advanced oxidation processes (AOPs)** –decomposition of organic compounds
- Additive free process that uses **short lived reactive species formed during radiolysis of water** to decompose pollutants
- **Combined radiation and biological treatment** - increased biodegrability of pollutants, reduces chemical reagents consumption, treatment time and increases flow capacity.



Effects of water content in fermentation residues on DOCPC degradation during ionizing irradiation

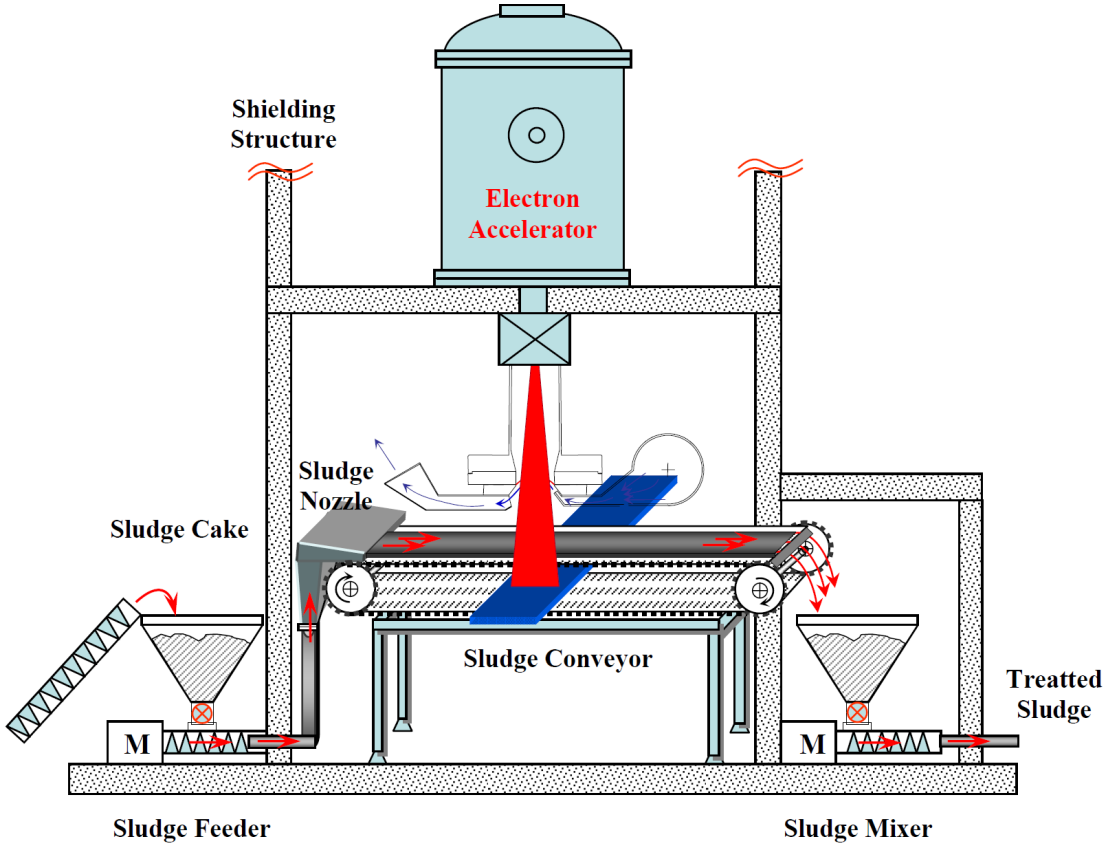


Kinetic of biotreatment of nonirradiated and irradiated watewater

Dewatered sludge irradiation

In Korea accelerator of electron energy **2.5 MeV and** maximum power **100 kW** was used. The nozzle type sludge feeder and stainless steel belt conveyor was constructed to fit a penetration range on electron beam. The rate of moving sludge was controlled in the range 10 - 4 m/min, which allowed to treat **up to 500 kg of sludge cake per hour**.





Cultural heritage



Disinfection

- Paper-based objects
- Photographic and cinematographic films of cellulose triacetate
- Wooden statues and altar wings, leathers, pigments other objects



Consolidation

- Terracotta army, preservation of the polychromic layer by hydroxy-ethyl methacrylate (HEMA),
- e-beam curing (40 kGy)



Cleaning

- Eb plasma

CH objects made of silver which went black,

- Treatment without use of the wet chemistry or abrasive minimize the strain usually fragile objects.

ELECTRON BEAM DISSINFECTION

- Biocorrosion of CH objects
- Effective dose – to inactiveate biodegradation agent
- Effects induced in treated objects

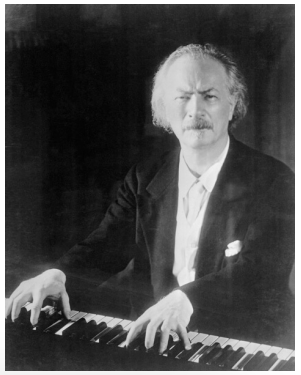
Biodegradation agents	Recommended doses	Effect
Insects	0.5-2 kGy	A dose of 2 kGy is considered to be sufficient for the eradication of any insect morph (egg, larva, pupa or adults)
Microorganisms: fungi and bacteria	6-10 kGy	Considered a safe maximum dose for the most sensitive materials (cellulosic). A dose > 10 kGy may be considered in special situations

PAPER-BASED OBJECTS

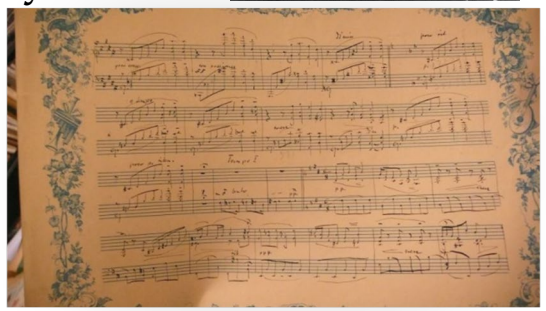


INCT, Poland, Elektronika 10/10 EB accelerator, energy 10 MeV,
Dose 6-10 kGy

University of Warsaw Library
Faculty of Modern Languages Library
The Fryderyk Chopin University of Music Library
The Sejm (Polish Parliament) Library
The Office for Registration of Medicinal Products, Medical Devices and Biocidal Products
Diocesan Library in Sandomierz



Original music notation composed by Ignacy Paderewski

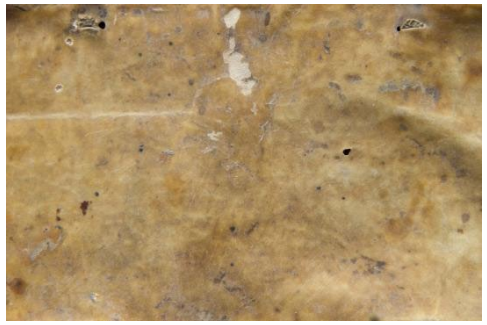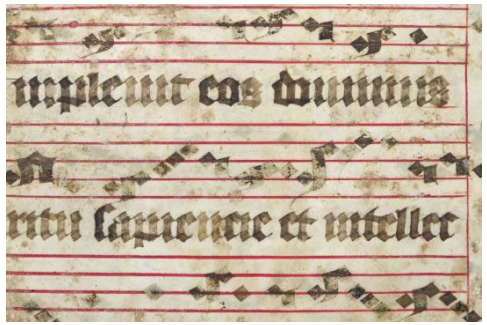






LETHER OBJECTS

Leather cover(manuscripts from the beginning of the XIX century) from the Diocesan Library in Sandomierz)



Parchment



State Archaeological Museum in Warsaw (collection of leather shoes and documents)



INCT, Poland
Accelerator Elektronika 10/10, energy 10 MeV, power 10 kW
Doses 2-25 kGy

EASTER EGGS

State Museum of Ethnography in Warsaw

Elektronika 10/10, energy 10 MeV, power 10 kW, Dose 2 kGy









COLLECTION OF VARIOUS ARTIFACTS



Uniforms, coins, atrefacts,
The Katyń Museum, Warsaw

For the first time, an electron beam was used to sterilize a large number of artifacts in the Institute of Nuclear Chemistry and Technology in Warsaw while sterilizing the artifacts for the **Museum of the Polish Army.**

INCT, Poland
Elektronika 10/10 EB accelerator, energy 10 Mev, power 10 kW
Dose 25 kGy









THANK YOU FOR YOUR ATTENTION

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