ELECTRON ACCELERATOR BASED SYSTEMS FOR AIR, WATER AND SOIL POLUTION CONTROL

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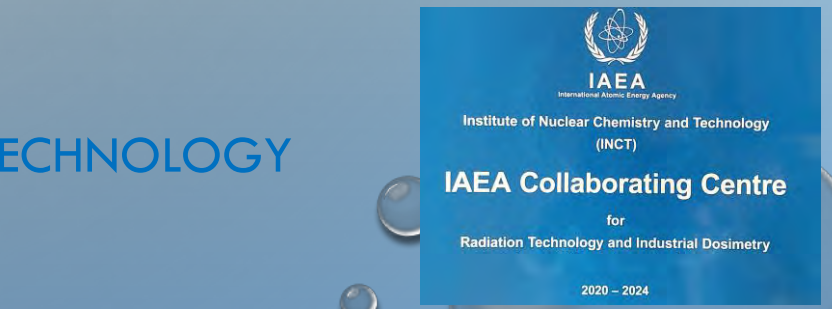
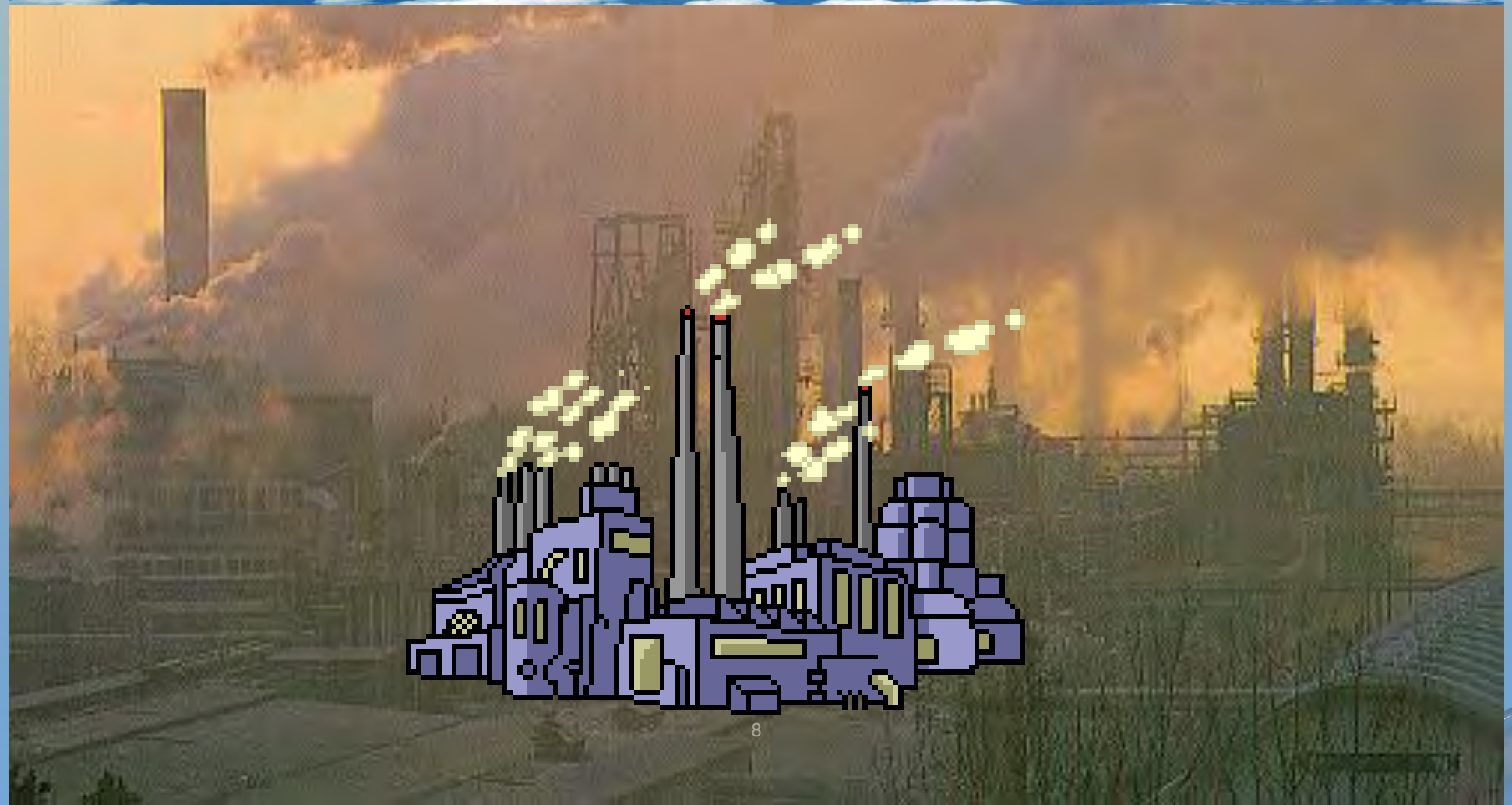
WARSAW, POLAND



AIR



GAS ELECTRON BEAM IRRADIATION

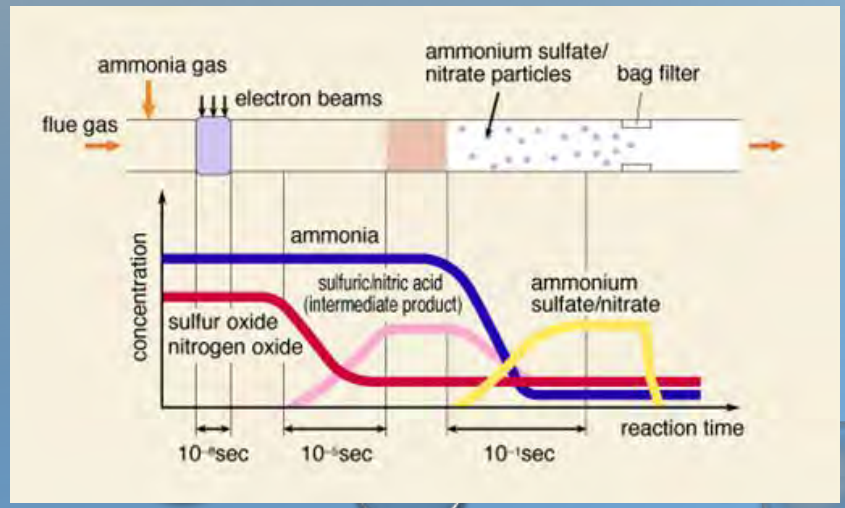
$$4.43N_2 \xrightarrow{100\ eV} 0.29N_2^* + 0.885N(^2D) + 0.295N(^2P) + 1.87N(^4S) + 2.27N_2^+ + 0.69N^+ + 2.96e^- \quad (1)$$

$$5.377O_2 \xrightarrow{100\ eV} 0.077O_2^* + 2.25O(^1D) + 2.8O(^3P) + 0.18\,O^* + 2.07O_2^+ + 1.23O^+ + 3.3e^- \quad (2)$$

$$7.33H_2O \xrightarrow{100\ eV} 0.51H_2 + 0.46O(^3P) + 4.25OH + 4.15H + 1.99H_2O^+ + 0.01H_2^+ + 0.57OH^+ + 0.67H^+ + 0.06O^+ + 3.3e^- \quad (3)$$

$$7.54CO_2 \xrightarrow{100\ eV} 4.72CO + 5.16O(^3P) + 2.24CO_2^+ + 0.51CO^+ + 0.07C^+ + 0.21O^+ + 3.03e^- \quad (4)$$

Process	Energy Dissipation (% of Input Power)
N_2 Vibrational	5.3
N_2 ($A^3\Sigma_u^+$)	1.1
N_2 ($B^3\Pi_g$)	1.8
N_2 Dissociation	24.0
N_2 Dissociative Ionization	13.9
N_2 Molecular Ionization	28.3
O_2 Vibrational	0.6
$O_2(a^1\Delta_g)$	0.7
O_2 Dissociation	8.3
O_2 Dissociative Ionization	2.9
O_2 Molecular Ionization	2.8
Others	10.3



$$OH + CH_3CH_2OH = H_2O + CH_3CHOH, \quad k = 2.9 \times 10^{-12}, \quad (21)$$

$$CH_3CHOH + O_2 = CH_3CHO + HO, \quad k = 1.9 \times 10^{-11}, \quad (22)$$

$$OH + CH_3CHO = H_2O + CH_3CO, \quad k = 1.6 \times 10^{-11}, \quad (23)$$

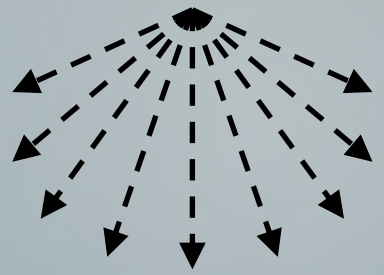
$$CH_3CO + O_2 = CH_3CO_3, \quad k = 5.0 \times 10^{-12}, \quad (24)$$

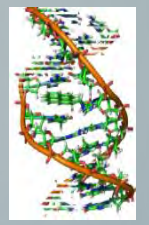
$$CH_3CO_3 + HO_2 = O_3 + CH_3COOH, \quad k = 1.0 \times 10^{-11}, \quad (25)$$

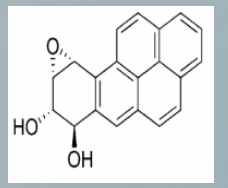
$$CH_3CO_3 + NO = CH_3 + CO_2 + NO_2, \quad k = 2.0 \times 10^{-11}, \quad (26)$$

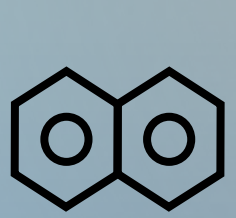
$$CH_3CO_3 + NO_2 = CH_3CO_3NO_2, \quad k = 1.2 \times 10^{-11}, \quad (27)$$

$$CH_3CHO + NO_3 = HNO_3 + CH_3CO, \quad k = 2.7 \times 10^{-15}. \quad (28)$$



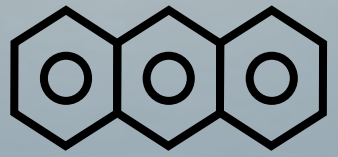




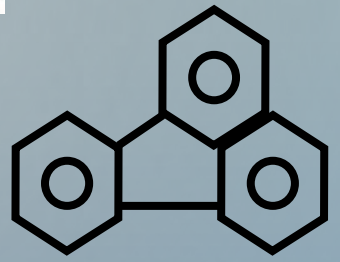


naphtalene

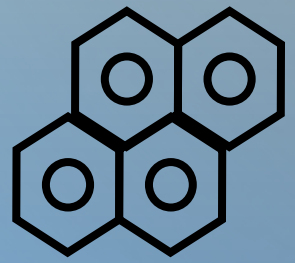
acenaphtene



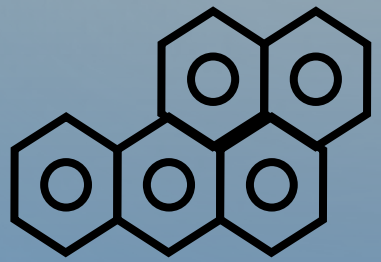
anthracene



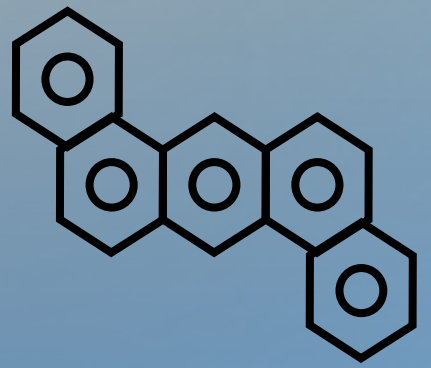
fluoranthene



pyrene



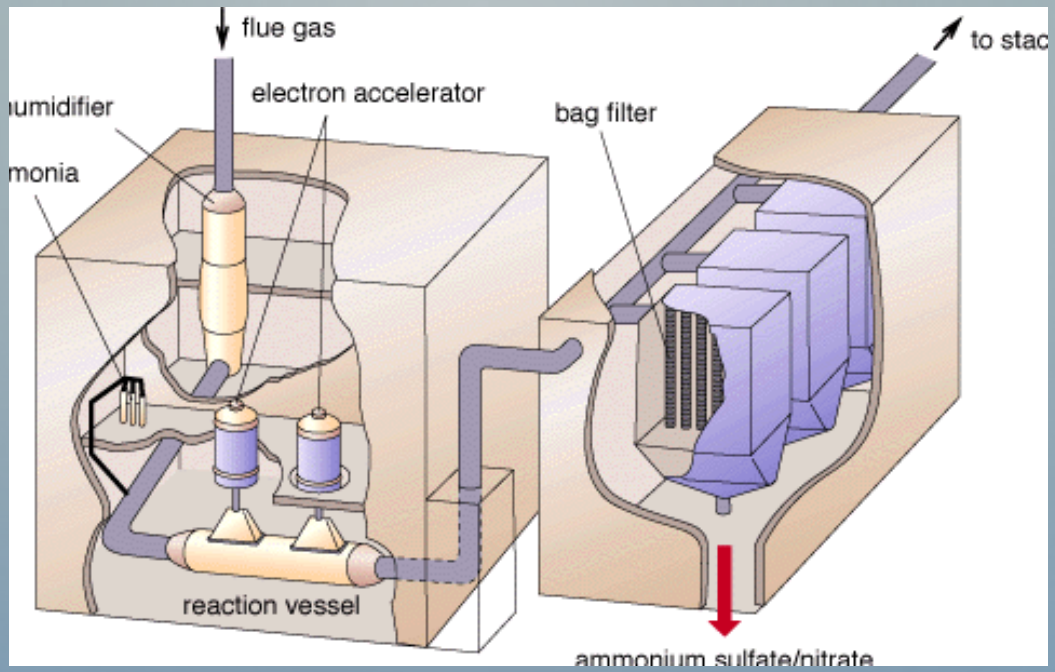
benzo(a)pyrene

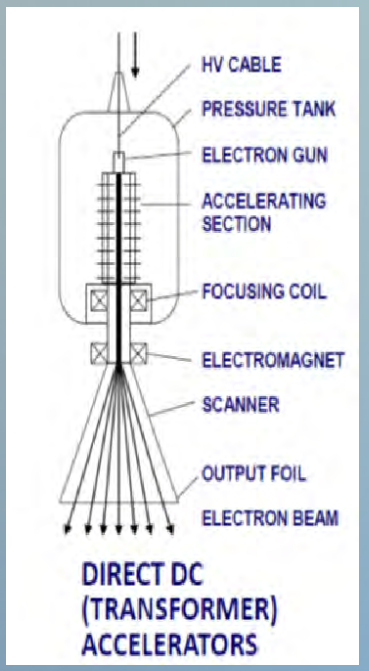


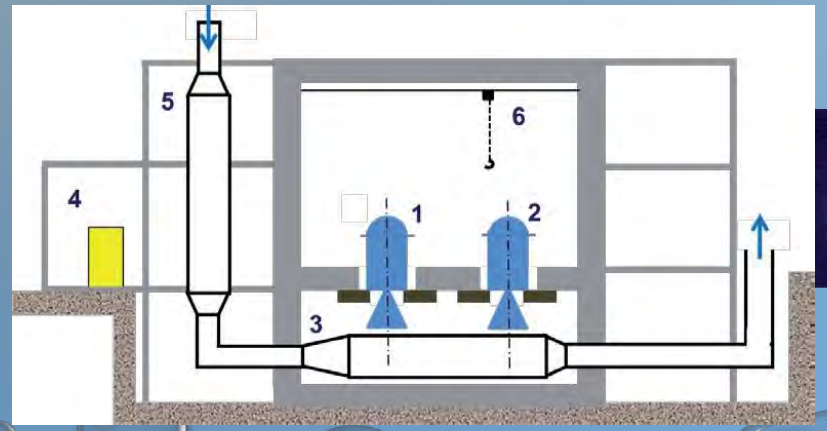
dibenzo(a,h) anthracene

PAH treatment

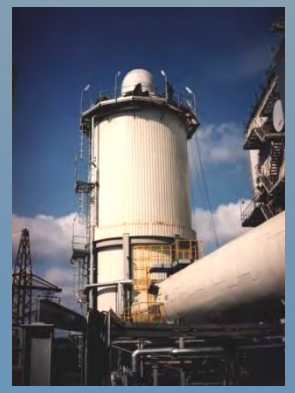
EPS KAWĘCZYN

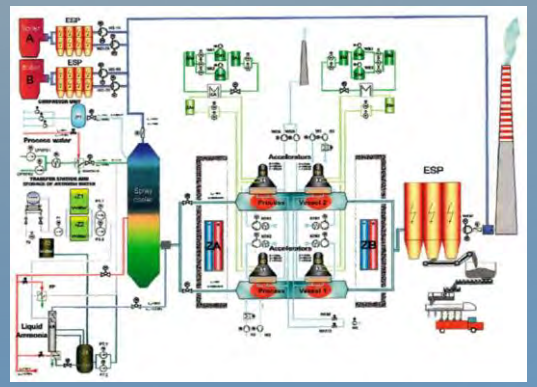


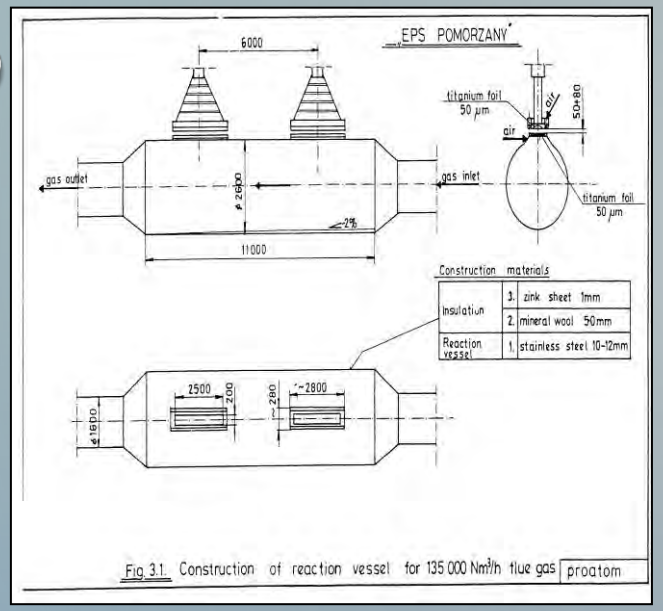


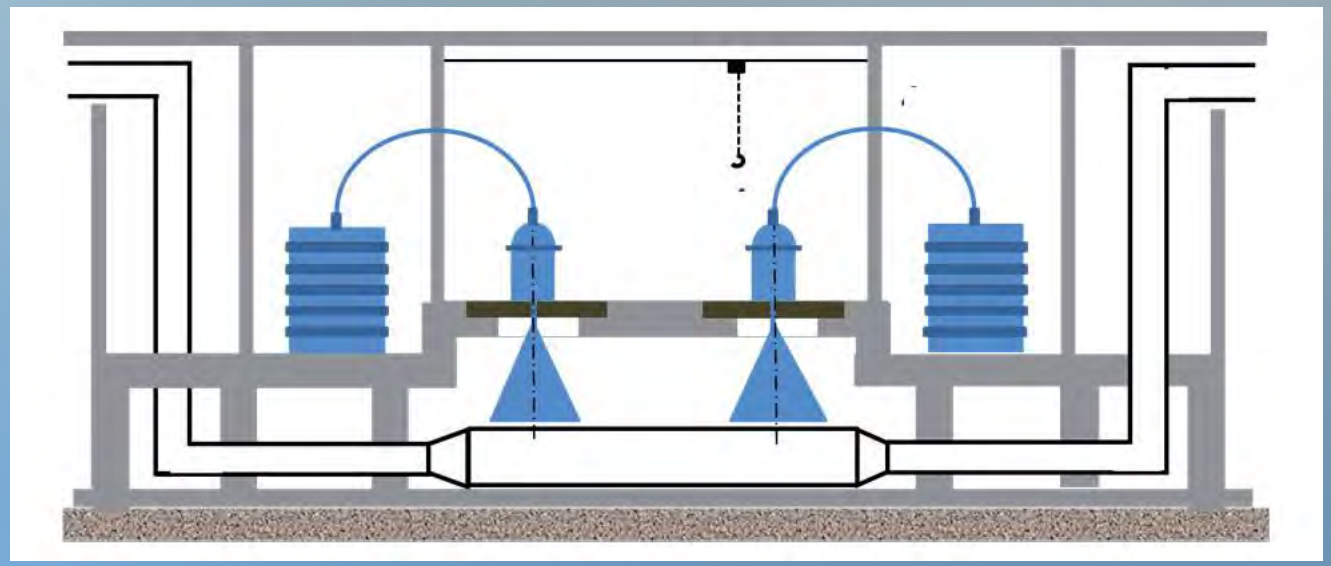


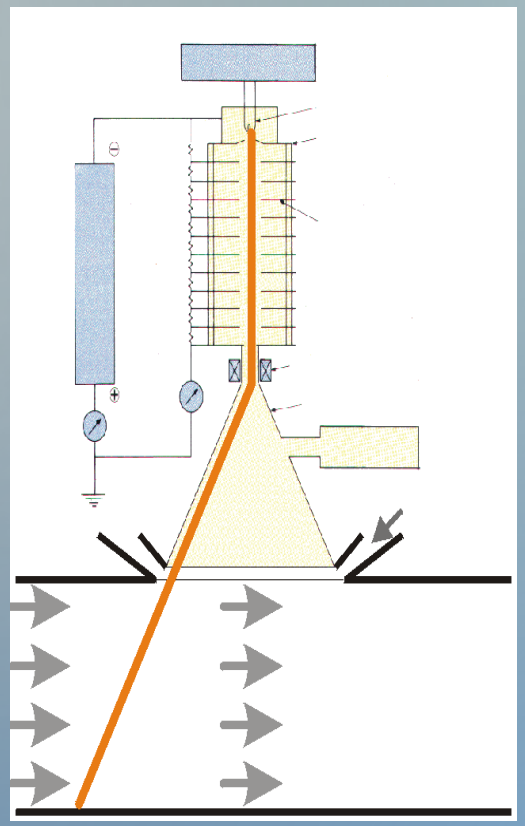
EPS POMORZANY









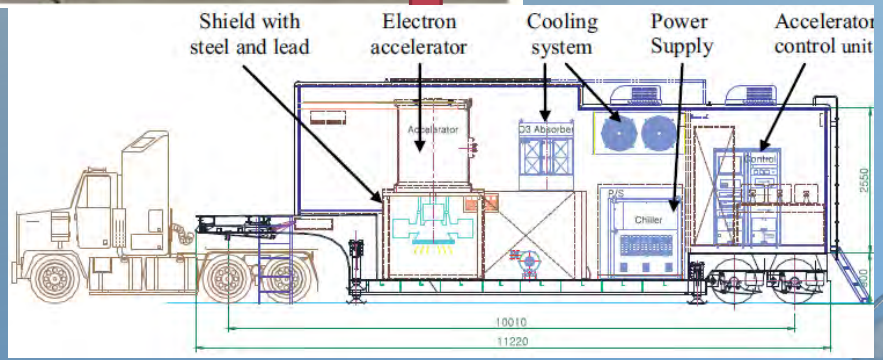


PROCESS VESSEL AND ELECTRON BEAM SCANNING

OIL FIRED BOILER

GENERAL VIEW OF THE PILOT PLANT

1- stack of F 1001 boiler
2- boiler F1001
3-flue gas duct
4-control room
5-humidification unit
6-pilot plant stack
7 - bag filter
8 - insulated duct part
9 - cyclone
10 - ammonia storage and injection unit
11 - EB mobile unit



Andrzej G. Chmielewski, Bumsoo Han: Electron Beam Technology for Environmental Pollution Control, Top Curr Chem (Z) (2016) 374:68

EMISSIONS FROM DIESEL ENGINES MOUNTED ON SHIPS

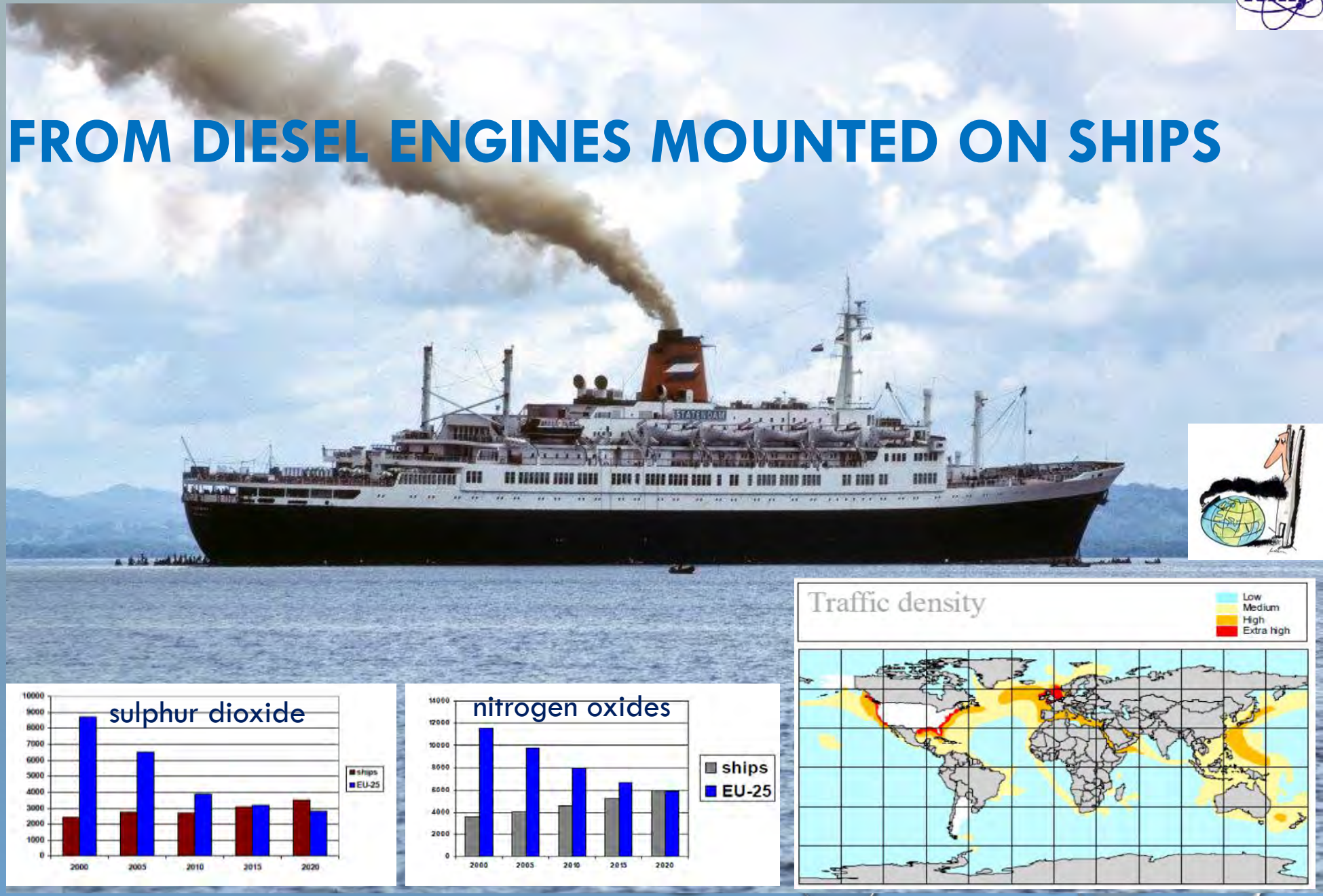
- Two stroke Diesel up to 81 MW
- 6 to 14 pistons (each 1820 dm^3)
- Heavy oil
- Consumption 250 ton fuel/day
- Typical off-gases –

13 % O_2, 5.2% CO_2, 5.35% H_2O,

1500 ppmv NOx,

600 ppmv SOx,

60 ppmv CO,



HYBRID SOLUTION FOR NO REMOVAL IS BASED ON THE PROCESS CHEMISTRY

Back reactions !

$$NO + O = NO_2, \quad k = 3.0 \times 10^{-11},$$

$$NO_2 + O = NO_3, \quad k = 2.2 \times 10^{-11},$$

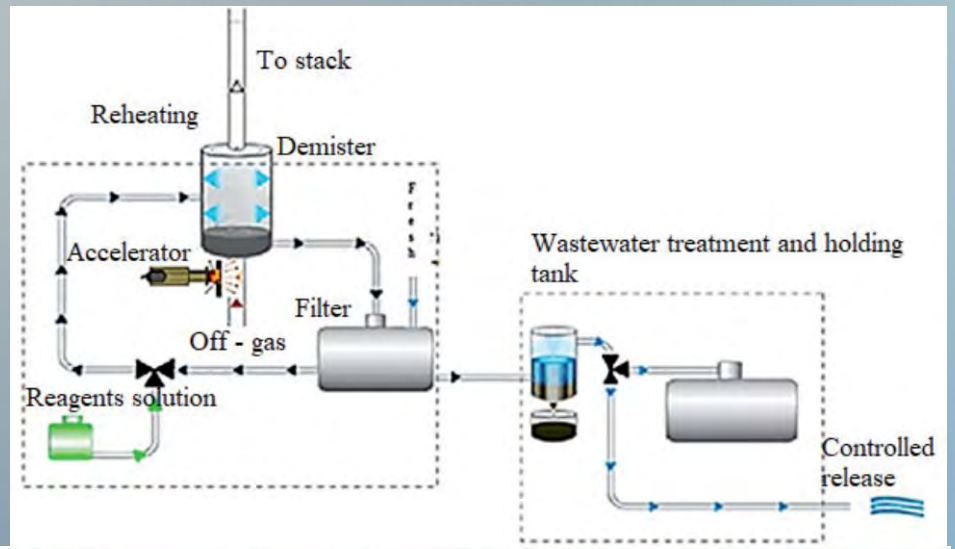
$$O + NO_2 = O_2 + NO, \quad k = 9.7 \times 10^{-12},$$

$$O + NO_3 = O_2 + NO_2, \quad k = 1.7 \times 10^{-11}.$$

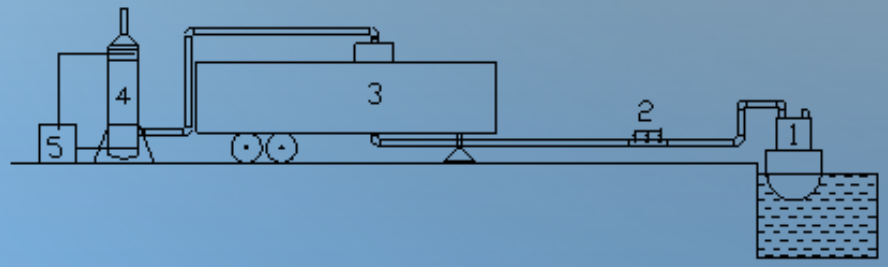
Critical reactions !

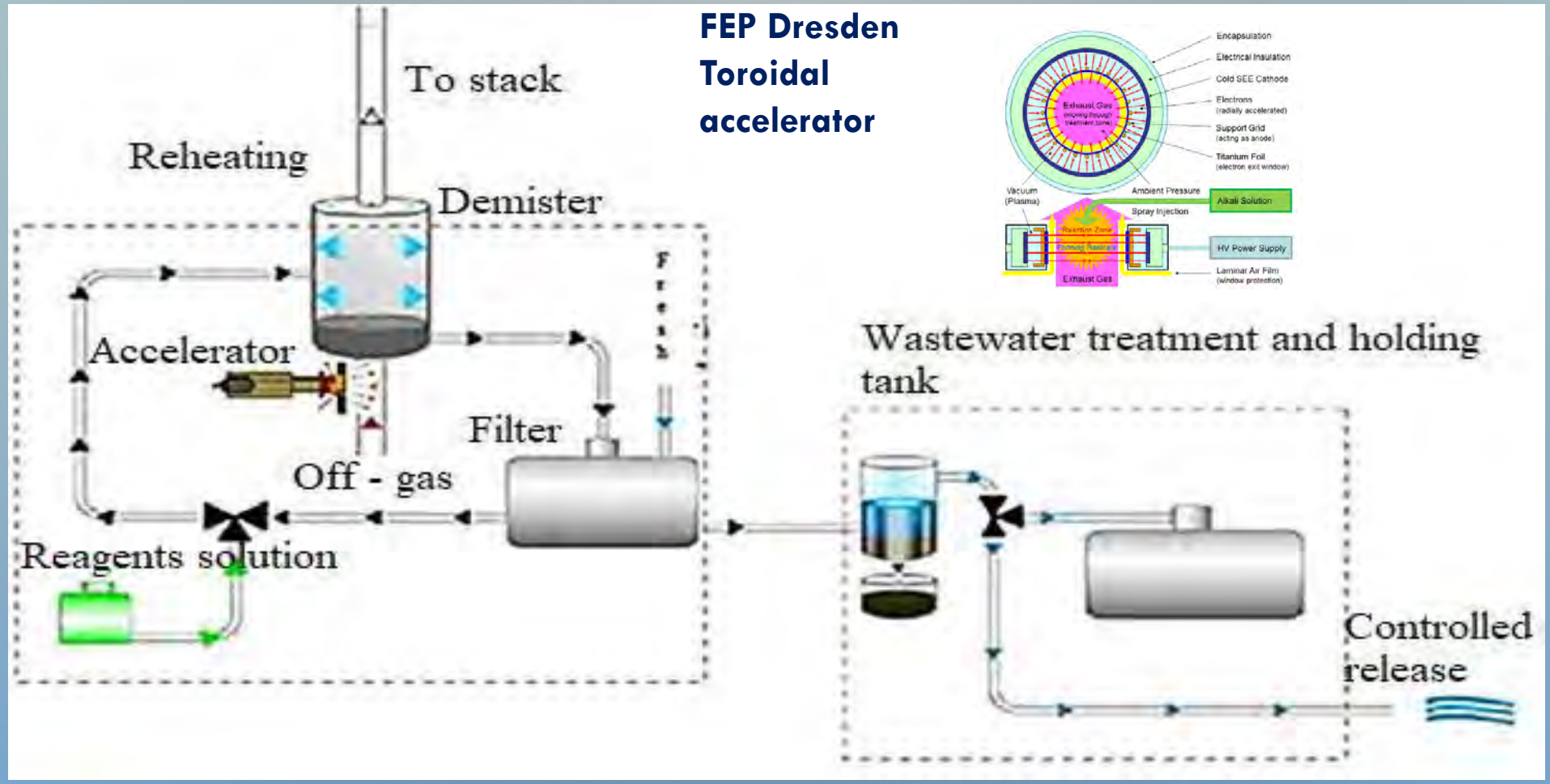
$$OH + NO = HNO_2, \quad k = 3.2 \times 10^{-11},$$

$$OH + NO_2 = HNO_3, \quad k = 6.0 \times 10^{-11},$$



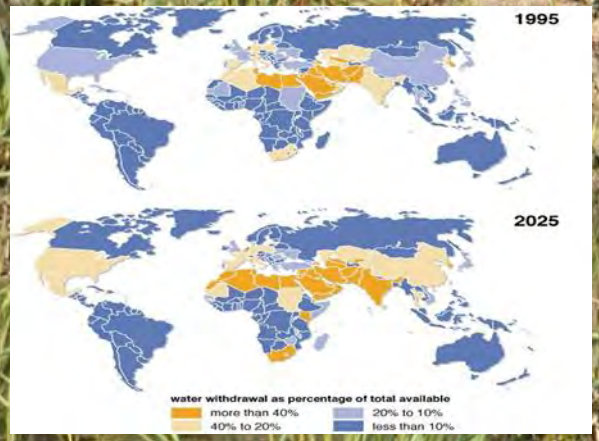
FIELD TEST SHIPYARD RIGA, LATVIA



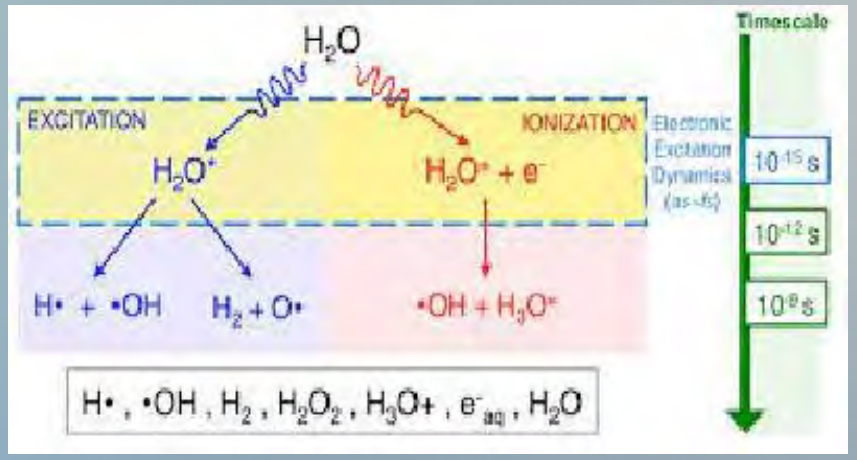


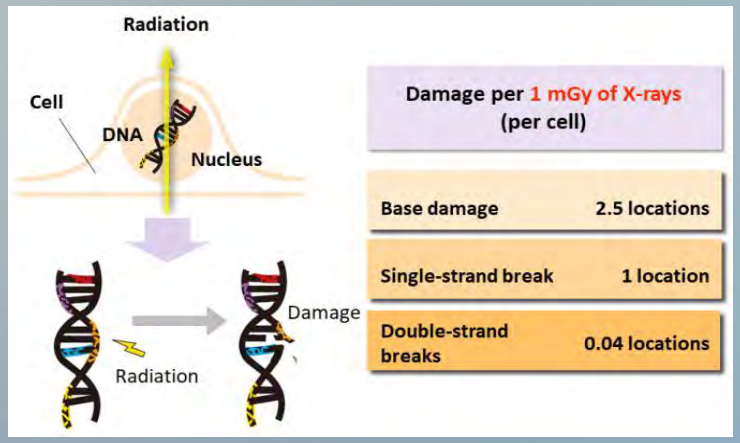
CONCEPTUAL SCHEME OF THE INSTALLATION USING EB TECHNOLOGY FOR SO_x AND NO_x REMOVAL AS APPLIED ON BOARD

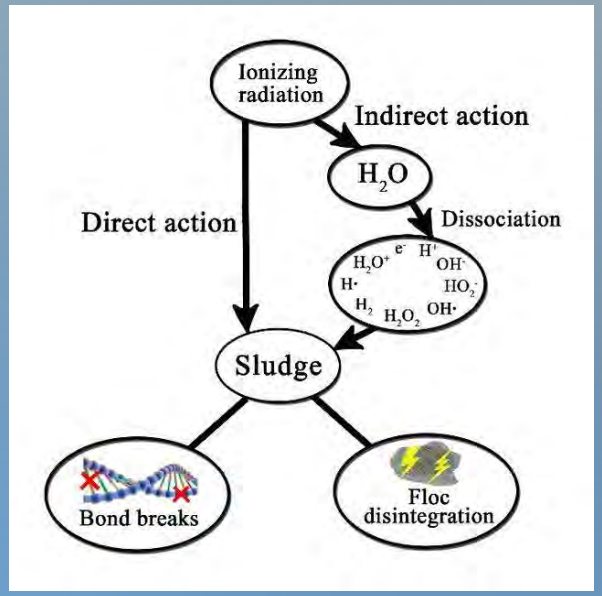
WATER & SOIL

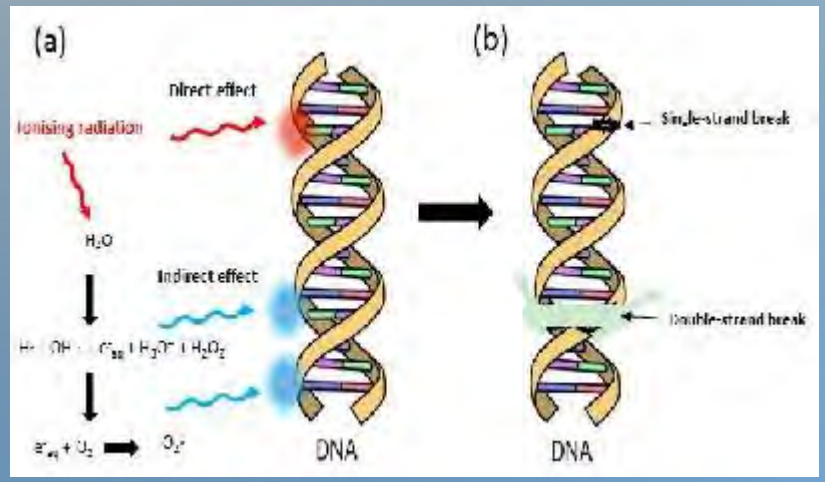

1995
2025
water withdrawal as percentage of total available
more than 40%
40% to 20%
20% to 10%
less than 10%

PROCESS CHEMISTRY AND BIOCHEMISTRY









SHIPYARD REMONTOWA SA

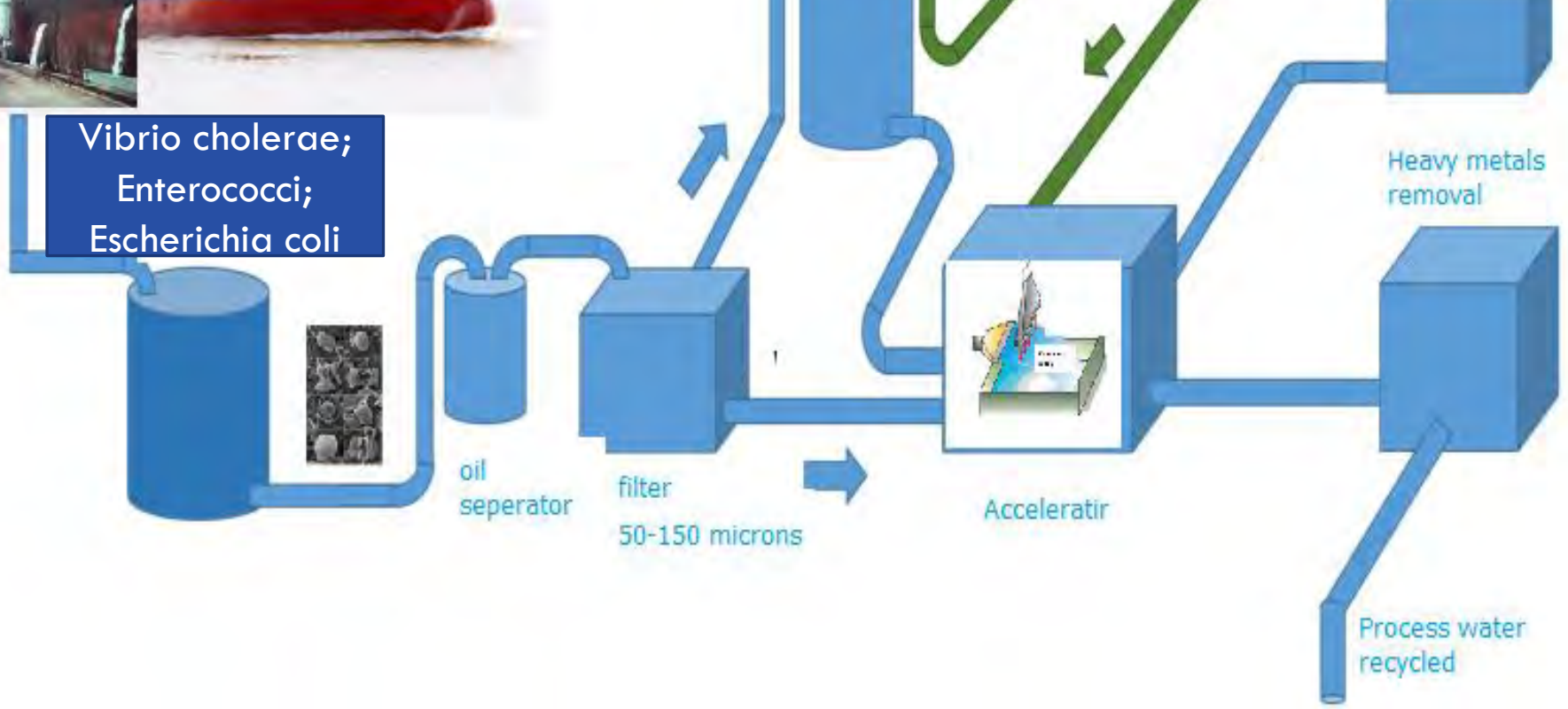
BALAST WATER DISCHARGE

- BALLAST WATER DISCHARGE TYPICALLY CONTAINS A VARIETY OF BIOLOGICAL MATERIALS, INCLUDING PLANTS, ANIMALS, VIRUSES, AND BACTERIA. THESE MATERIALS OFTEN INCLUDE NON-NATIVE, NUISANCE, EXOTIC SPECIES THAT CAN CAUSE EXTENSIVE ECOLOGICAL AND ECONOMIC DAMAGE TO AQUATIC ECOSYSTEMS, ALONG WITH SERIOUS HUMAN HEALTH ISSUES INCLUDING DEATH.

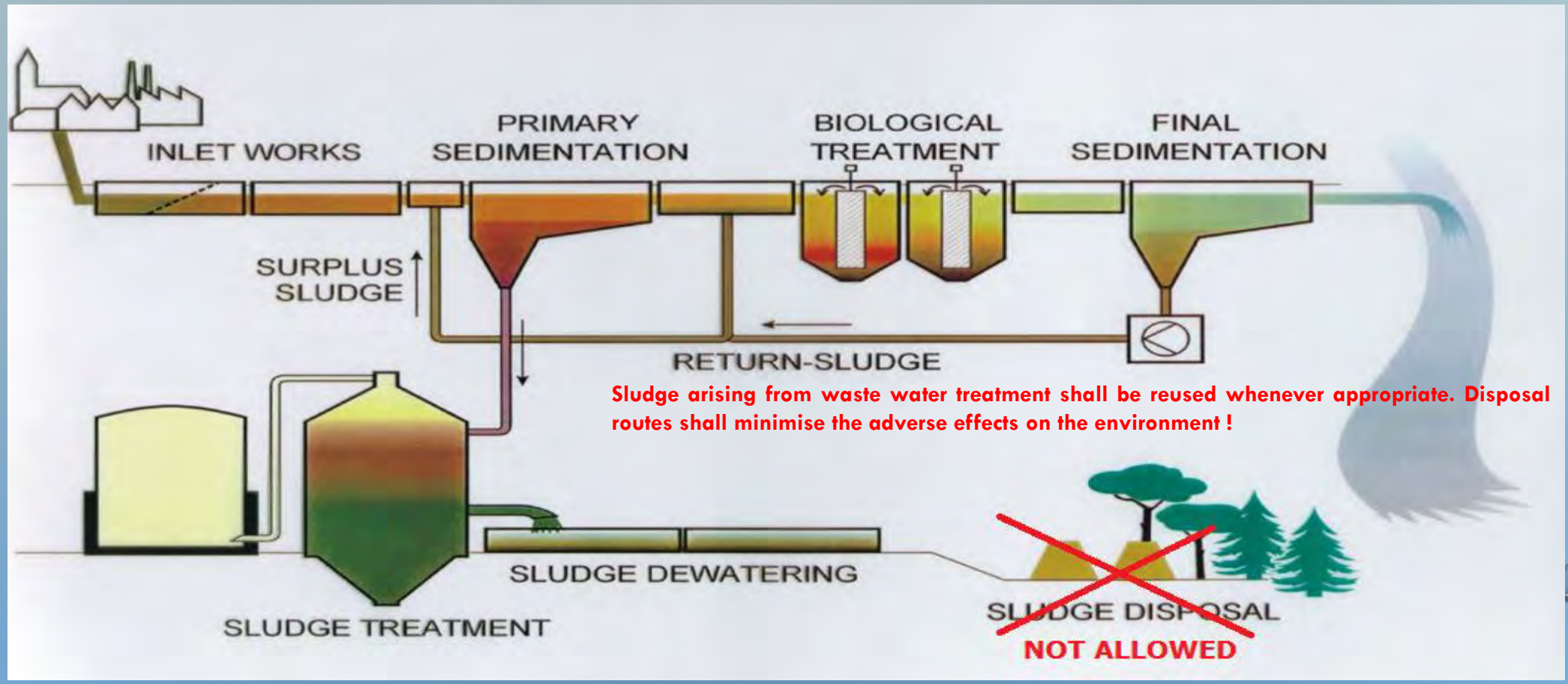
- A) ***VIBRIO CHOLERAE*** (O1 I O139) LESS THAN 1 CFU (COLONY FORMING UNIT - CFU) PER 100 ML OR LESS THAN 1 CFU PER 1 GRAM (WET MASS) ZOOPLANKTON SAMPLE;
- B) ***ESCHERICHIA COLI*** LESS THAN 250 CFU IN 100 ML;
- C) ***ENTEROCOCCI*** LESS THAN 100 CFU IN 100 ML.

„GREEN" DOCK

Vibrio cholerae;
Enterococci;
Escherichia coli



SCHEME OF A MUNICIPAL WATER TREATMENT PLANT



PATOGENS TO BE REMOVED

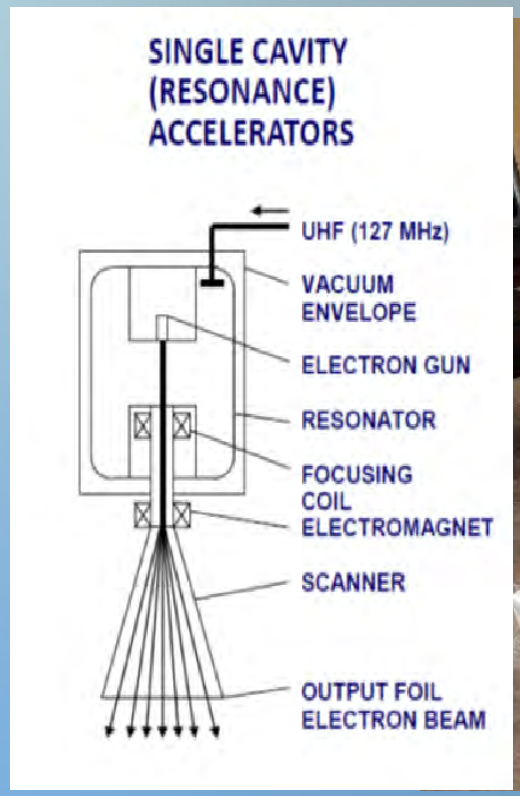
PATHOGENIC BACTERIA ACCEPTABLE CONTENT

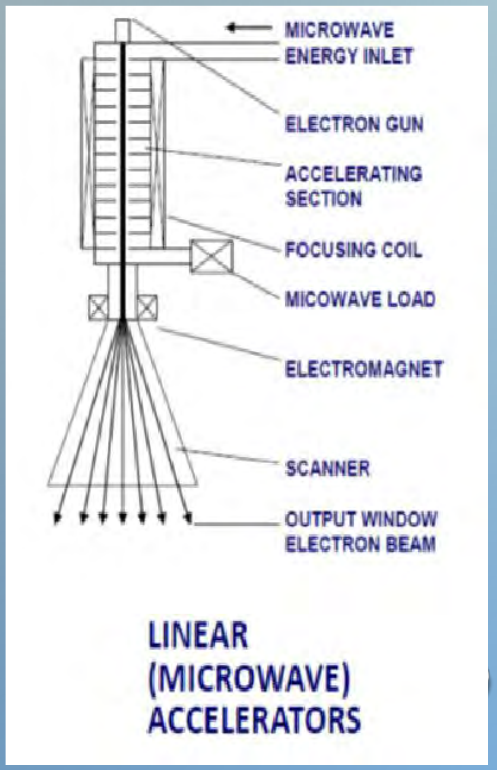
- IN POLAND ONE PATHOGENIC BACTERIA SPECIES IS CONSIDERED: *SALMONELLA*
- NONE LIVING CELLS OF *SALMONELLA* CAN BE DETECTED IN 100G SAMPLE OF MUNICIPAL SLUDGE

SPECIES OF PARASITES WHICH HAVE TO BE DETECTED:

- *ASCARIS SP.* – HUMAN PARASITIC ROUNDWORM
- *TRICHURIS SP.* – HUMAN WHIPWORM
- *TOXOCARA SP.* – ANIMAL (MOSTLY CATS AND DOGS) PARASITIC WORMS
- PARASITES AND EGGS ACCEPTABLE CONTENT = 0

FIS INSTALLATION USED FOR THE FLOW IRRADIATION OF SEWAGE SLUDGE CONNECTED TO AN ILU-6 ELECTRON ACCELERATOR.
SAMPLE OF SEWAGE SLUDGE SEALED IN A POLYETHYLENE BAG IRRADIATED BY AN ELEKTRONIKA 10/10 ELECTRON ACCELERATOR.





BACTERIA & LIVING EGGS OF HELMINTHS

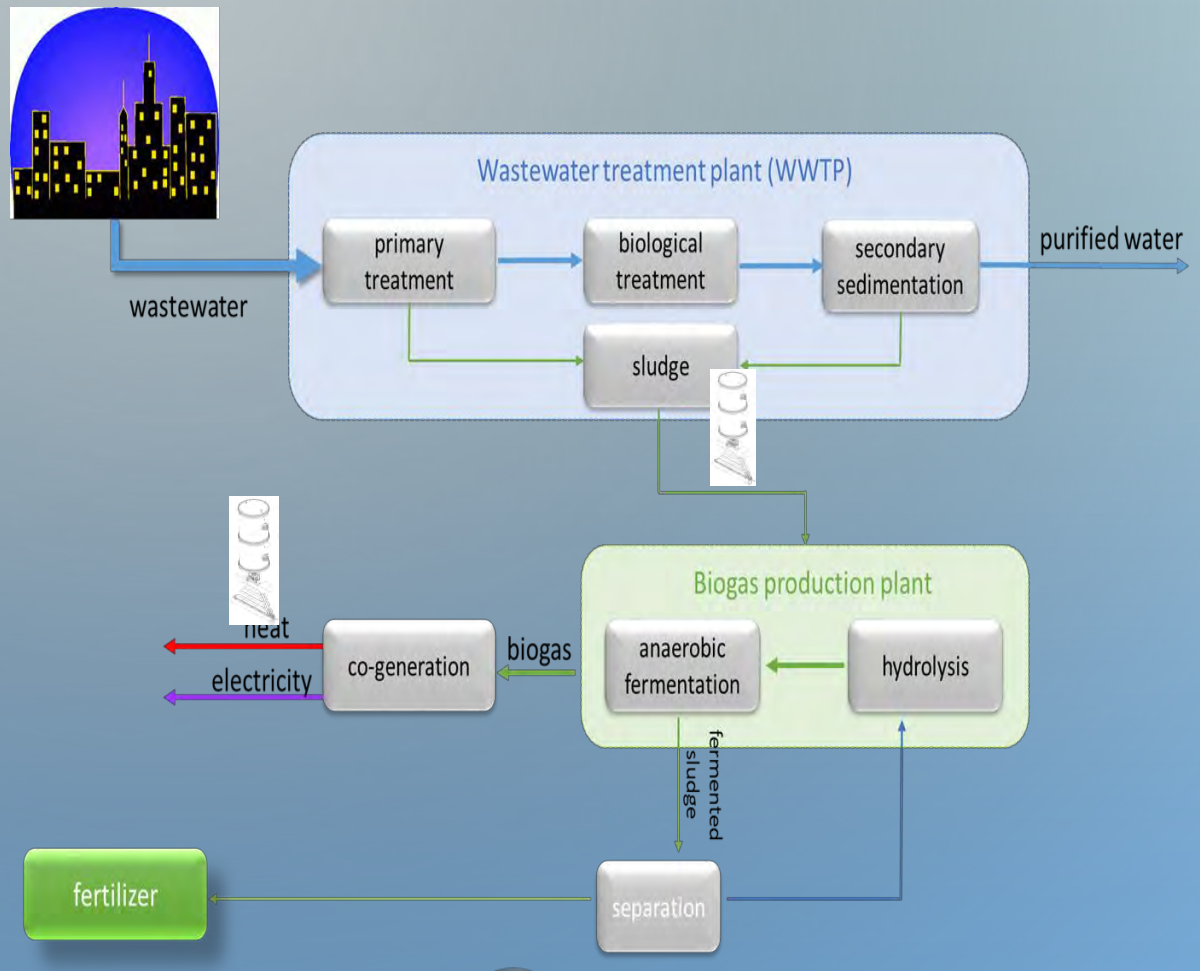
Dose (kGy)	Detected Species	Result (CFU)
0	*Escherichia coli*,	6.2×10^4
	Salmonella spp.	9.2×10^2
	Clostridium perfringens	1.1×10^2
2	*Escherichia coli*,	9.8×10^3
	Salmonella spp.	1.3×10^2
	Clostridium perfringens	0.9×10^2
3	*Escherichia coli*,	1.4×10^2
	Salmonella spp.	0.4×10^2
	Clostridium perfringens	ca.0.2×10^2
4	*Escherichia coli*,	none detected
	Salmonella spp.	none detected
	Clostridium perfringens	none detected
5	*Escherichia coli*,	none detected
	Salmonella spp.	none detected
	Clostridium perfringens	none detected

Dose (kGy)	Detected Species	Result (Number of Living Eggs)
0	*Ascaris* spp.	21
	Trichuris spp.	9
	Toxocara spp.	3
2	*Ascaris* spp.	16
	Trichuris spp.	4
	Toxocara spp.	1
3	*Ascaris* spp.	4
	Trichuris spp.	none detected
	Toxocara spp.	none detected
4	*Ascaris* spp.	none detected
	Trichuris spp.	none detected
	Toxocara spp.	none detected
5	*Ascaris* spp.	none detected
	Trichuris spp.	none detected
	Toxocara spp.	none detected

HYBRYD BIOGAS – EB SYSTEM

Advantage of proposed solution:

- **Environmental friendly technology**
- Biogas production is **disposal of problematic wastes**
- Production of **renewable power through combined heat and power cogeneration**
- Production of microbiologically safe organic fertilizer **due to electron beam hygenization**
- Technology can be applied in any place with sufficient biomass resources while there is **no need for external electric energy supply**



A MESSAGE TO THE DISTINGUISHED CONFERENCE PARTICIPANTS AND ACCELERATOR MANUFACTURERS

ELECTRON ACCELERATORS ARE WIDELY USED FOR RADIATION PROCESSING, HOWEVER, FURTHER BEYOND HORIZON NEEDS BREAKTHROUGH IN MACHINE ENGINEERING, REGARDING NEW MATERIALS FOR WINDOWS, CATHODES AND OTHER ELEMENT FABRICATION, HIGHER ELECTRICAL CONVERSION EFFICIENCY, THEIR RELIABILITY AND LONG LASTING WORK IN HARSH INDUSTRIAL CONDITIONS. FURTHERMORE, THE COST FACTOR IS VERY IMPORTANT IN ORDER TO COMPETE WITH CONVENTIONAL TECHNOLOGIES. WE HOPE THAT SUCH NOVELTIES MAY DIFFUSE TO INDUSTRY THROUGH INTERNATIONAL PROJECTS LIKE CERN COORDINATED I.FAST "INNOVATION FOSTERING IN ACCELERATOR SCIENCE AND TECHNOLOGY, "

Funding projects

- I.FAST - Innovation Fostering in Accelerator Science and Technology, Grant Agreement No 101004730. & Ministry of Education and Science co-financing grant
- Tango 2 (TANGO2/341079/NCBR/2017) entitled “Plasma technology to remove NOx fromoff-gases” NCBiR/NCN
- INNOship „Eko dok” POIR.01.02.00-00-0007/18 "Design and verification on a pilot scale, environmentally friendly, integrated with the floating dock, the system of collection and treatment of ballast water and sludge from the ship and technological waters from the ship hull cleaning process, using ionizing radiation for the utilization of pollutants”NCBiR


THANK YOU FOR YOUR
ATTENTION !