



PlasTEP

Recent developments in environmental applications of electron beam generated plasma

PlasTEP Final Conference

Prof. dr hab. inż. Andrzej Grzegorz Chmielewski

Institute of Nuclear Chemistry and Technology

Berlin, 05 December 2012



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The team

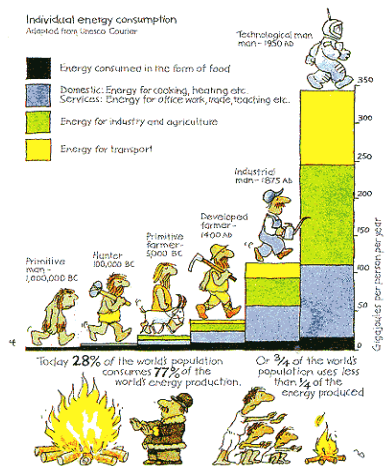
- **Dr. Andrzej Pawelec**
- **Dr. Janusz Licki**
- **Dr. Yongxia Sun**
- **Dr. Zbigniew Zimek**
- **Ms. Sylwia Witman**
- **Mr. Sylwester Bułka**
- **Ms. Dorota Korniszewska**



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What is a problem ?

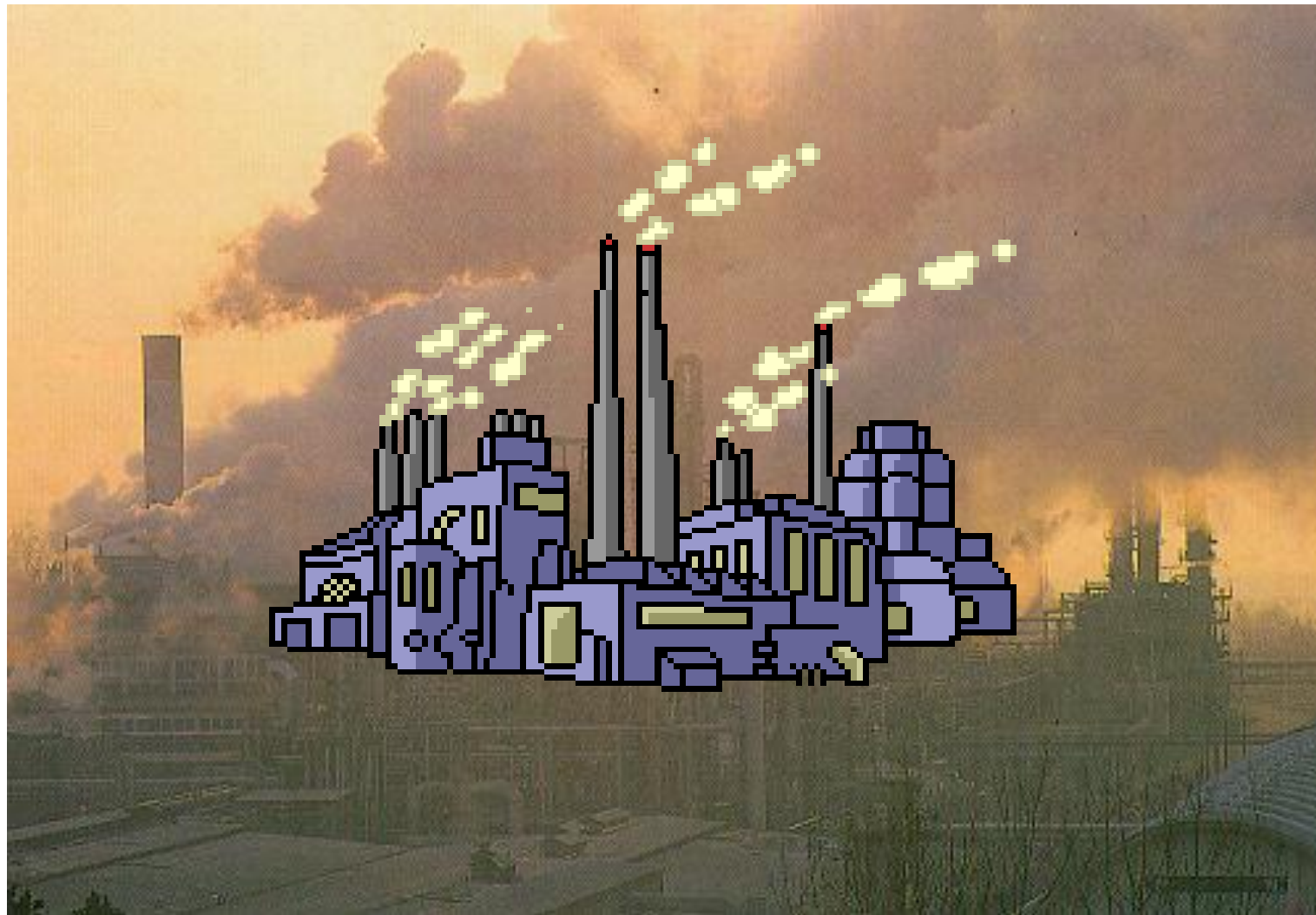


Fossil fuels



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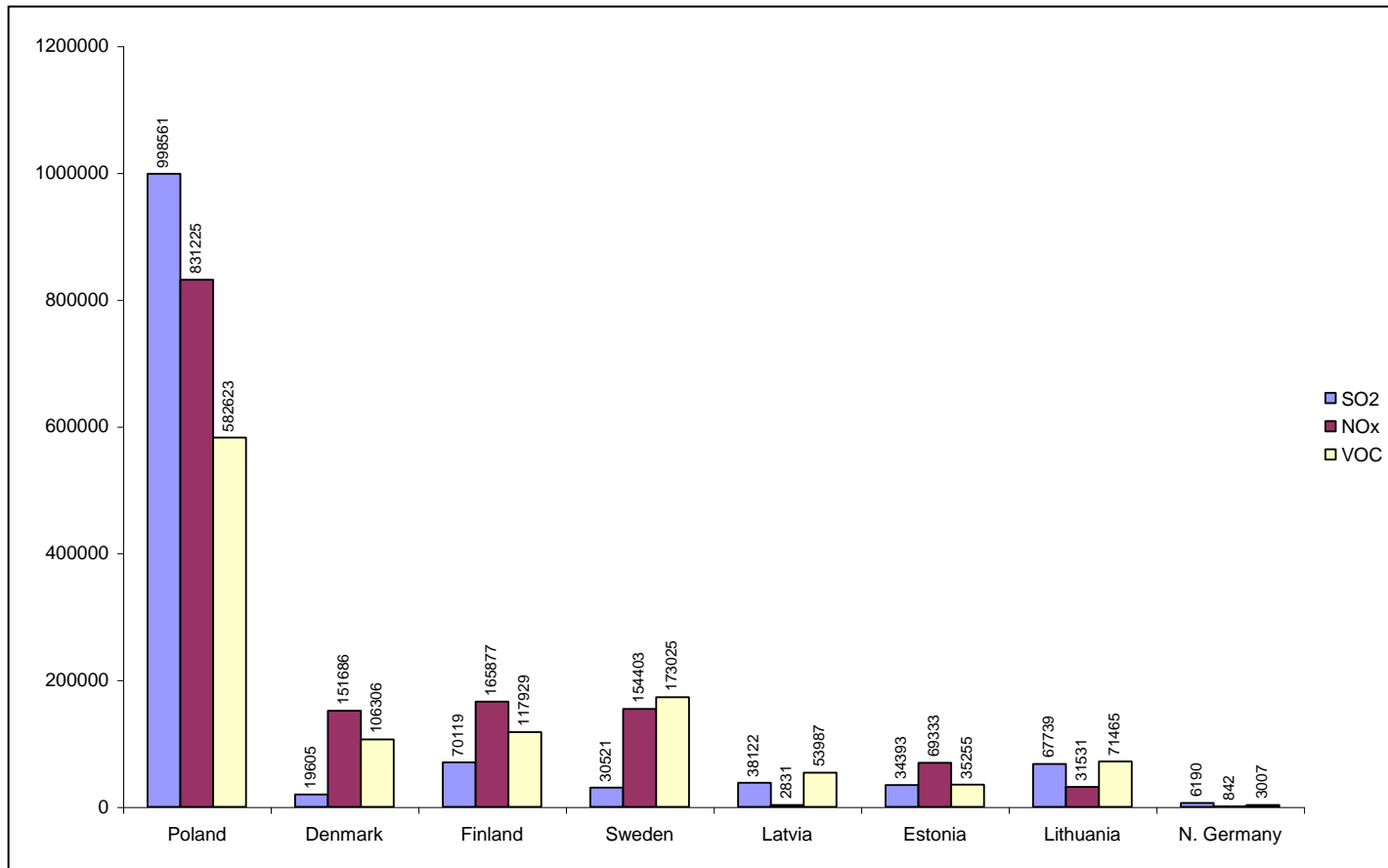


List of the emission processes in the Baltic Sea Region



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Task realized in cooperation with Vilnius Gedyminas
Technical University, Vilnius, Lithuania



Total emission in
BSR countries in
tonnes per year

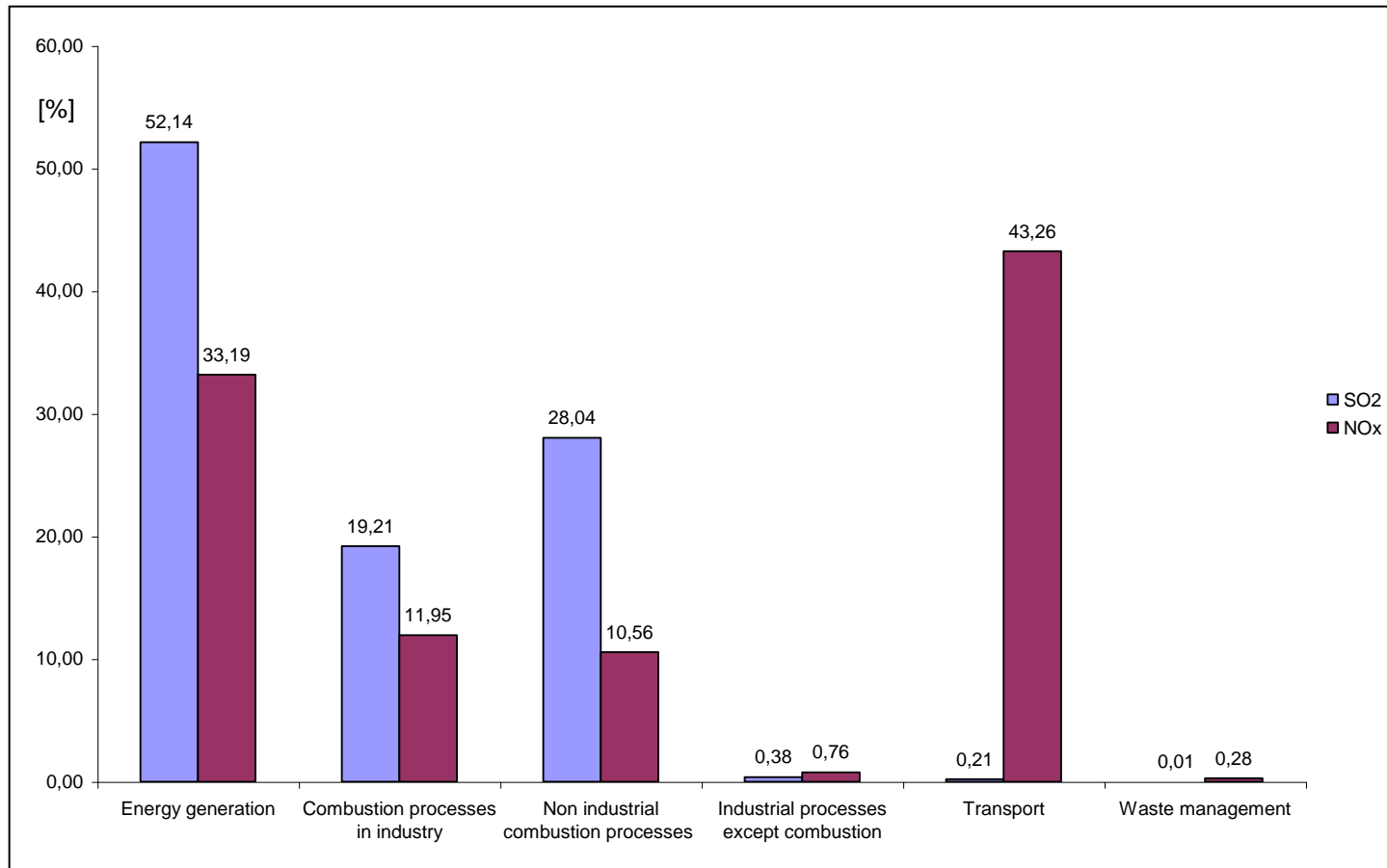
List of the emission processes in the Baltic Sea Region



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Emission structure in Poland in 2009 as typical emission structure in BSR



Part-financed by the
(European Regional Development Fund)



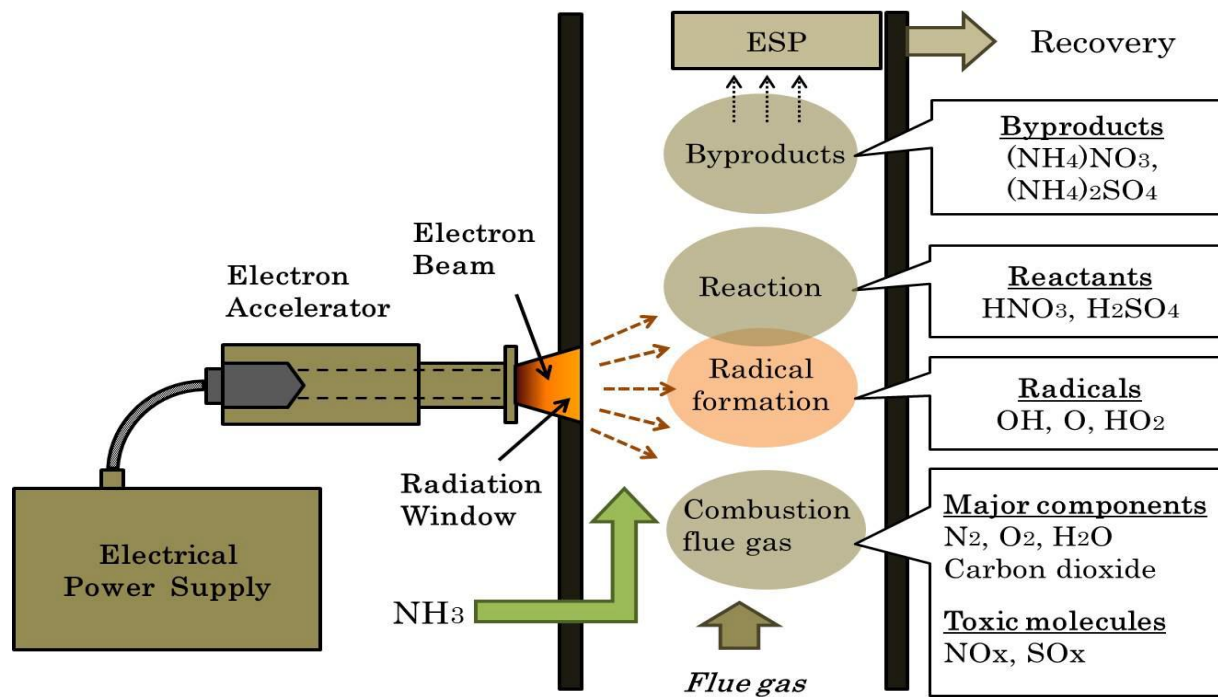
Baltic Sea Region
Programme 2007-2013





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EP Pomorzany



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NPK Fertilizer





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BULGARIA

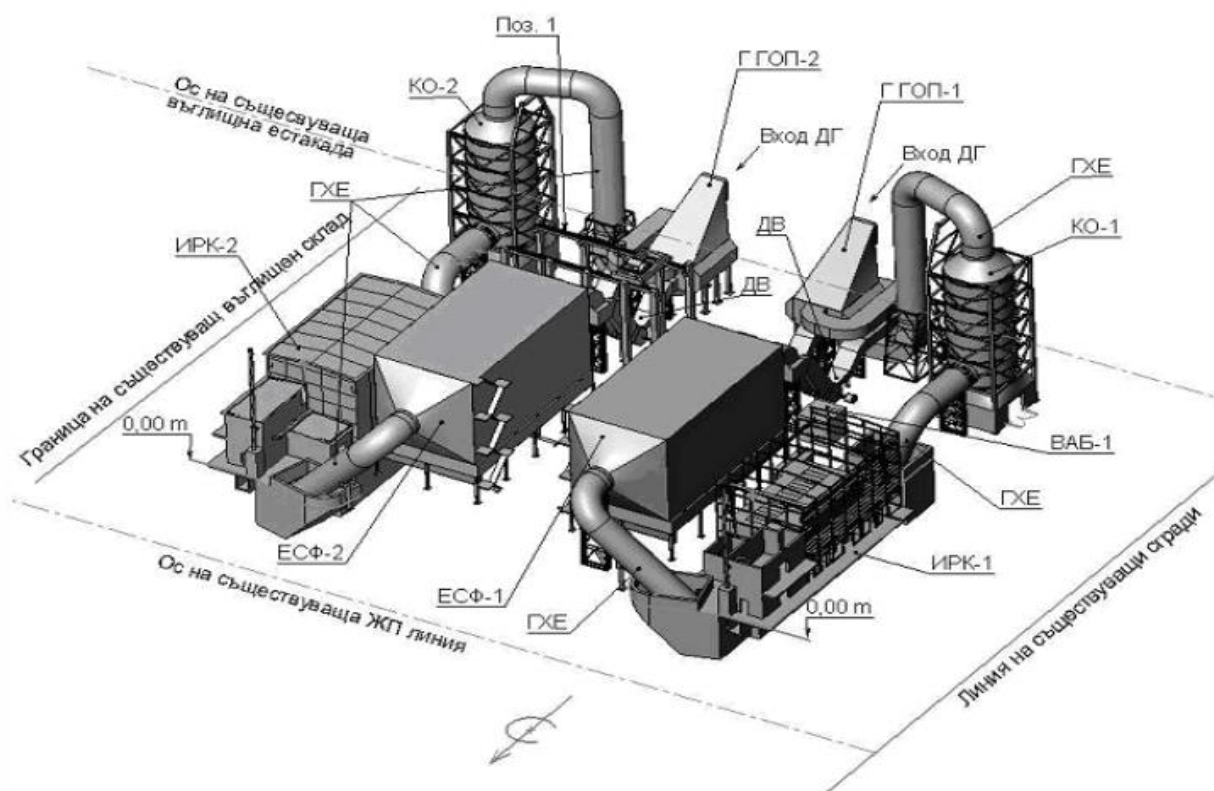


Figure. 2. Basic design of two-stream EBI for flue gas purification



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General view of the pilot plant.



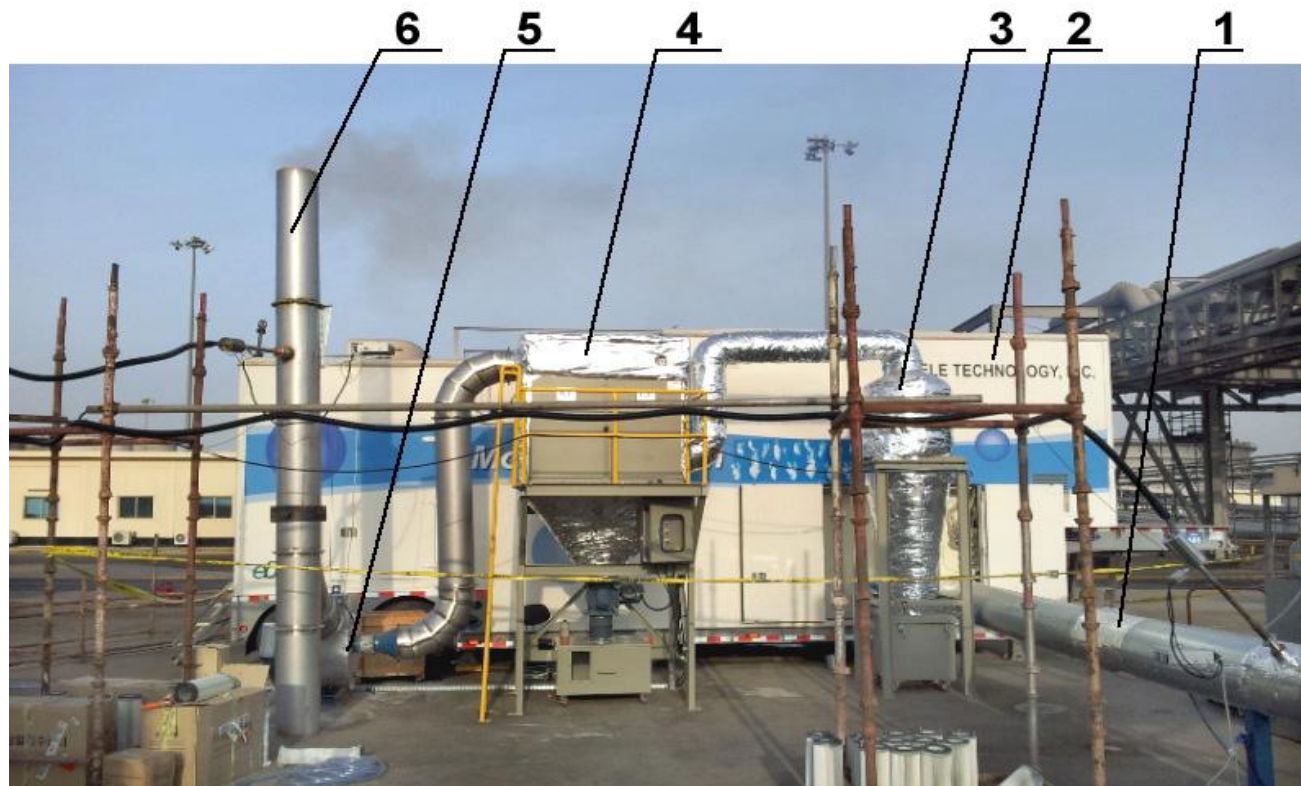
- 1- stack of F 1001 boiler
- 2- boiler F1001
- 3- flue gas duct
- 4- control room
- 5- humidification unit
- 6- pilot plant stack
- 7- bag filter
- 8- insulated duct part
- 9- cyclone
- 10- ammonia storage and injection unit
- 11- EB mobile unit



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Pilot plant process units



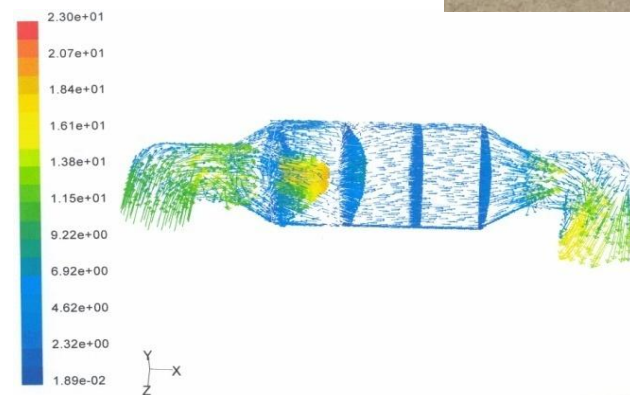
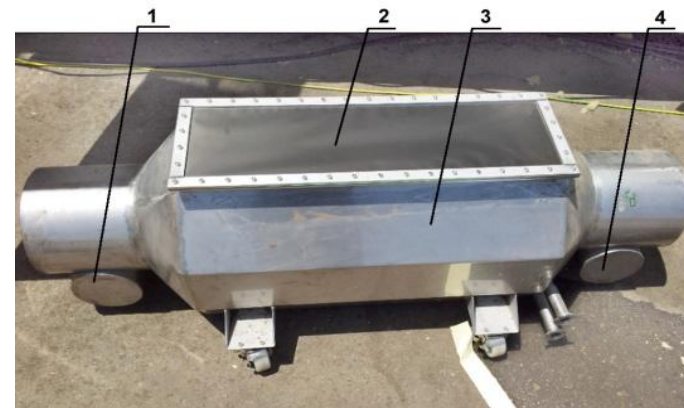
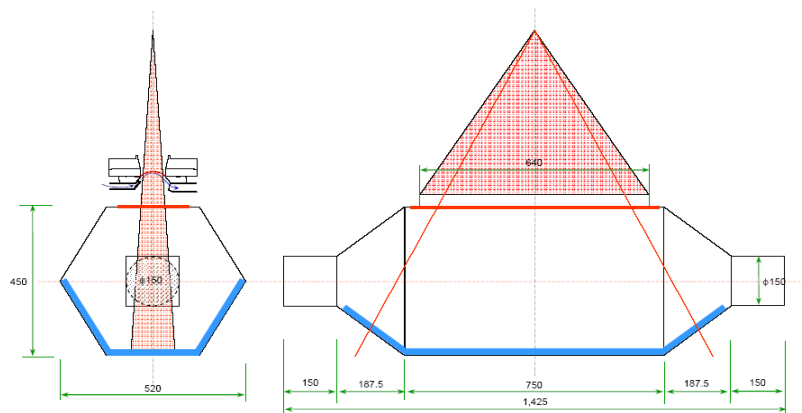
1. inlet to process vessel,
2. EB-TECH mobile unit,
3. cyclone,
4. cartridge filter
5. ID fan
6. stack



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Process vessel



Velocity Vectors Colored By Velocity Magnitude (m/s)

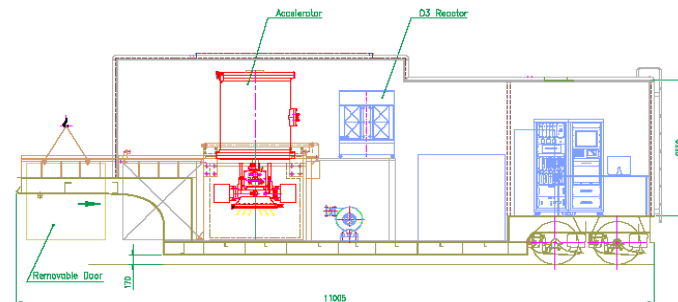
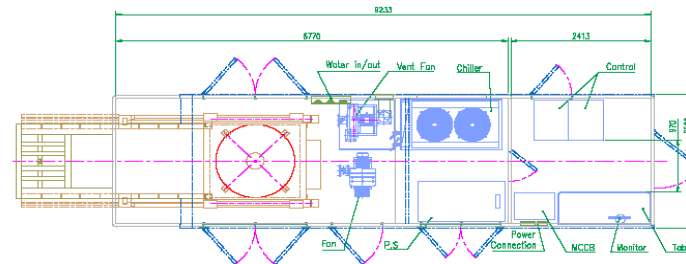
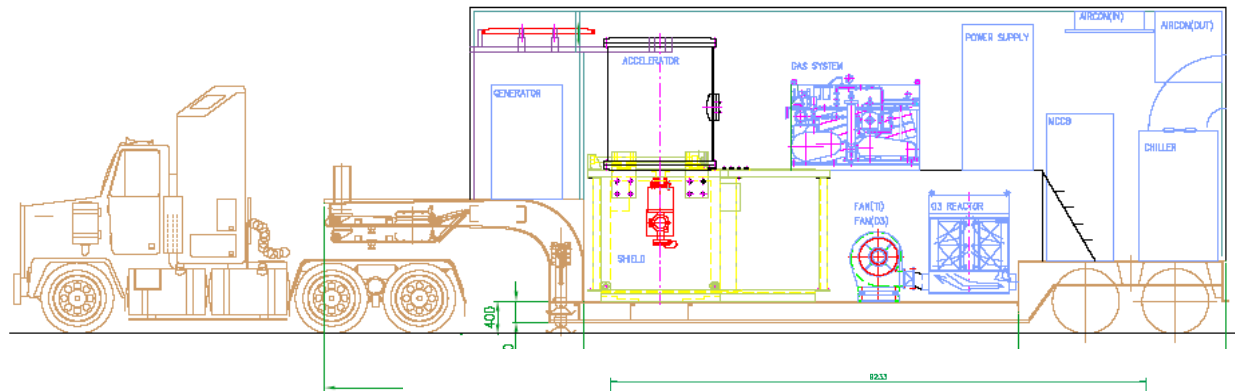
Jun 16, 2011
FLUENT 6.0 (3d, segregated, ske)

EB mobile unit



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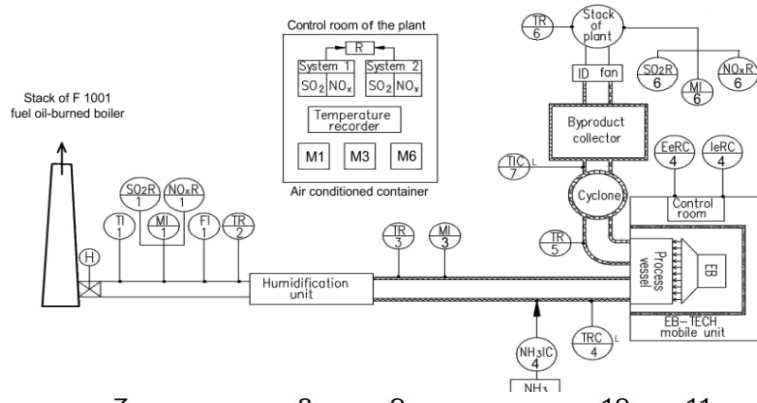


Monitoring system



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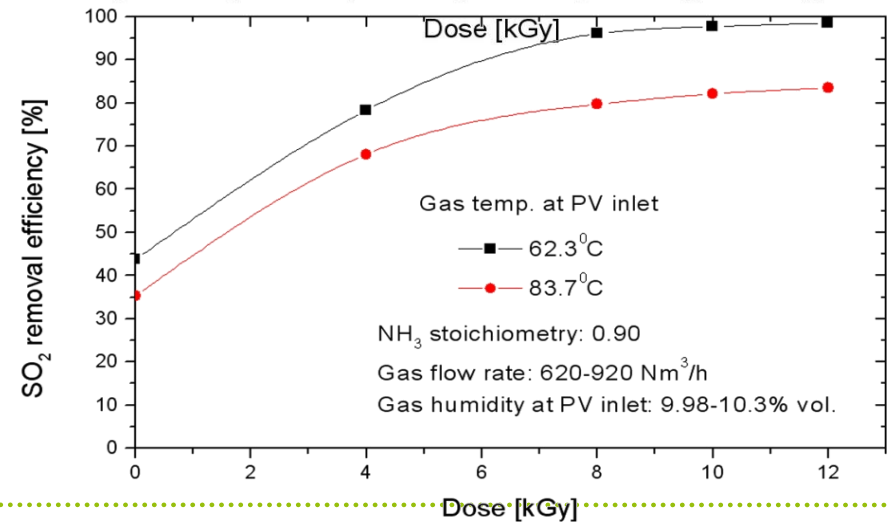
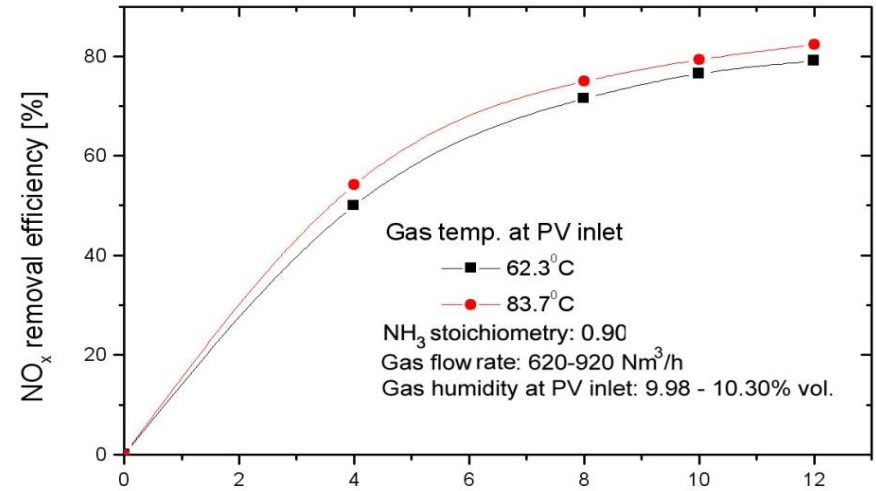
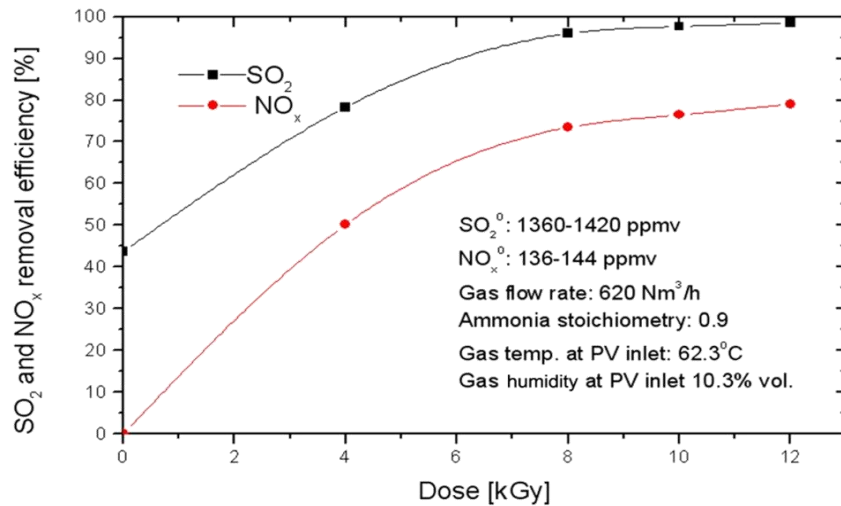


SO₂ and NO_x removal efficiency



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Product

Cl⁻	0.0012	0.0068	0.0032
NO₃⁻	0.35	0.44	0.34
SO₄²⁻	78.19	79.24	79.63
NH₄⁺	21.16	20.28	20.00
Na⁺	0.258	0.025	0.015
Mg²⁺	0.0047	0.0045	0.0012
Ca²⁺	0.027	0.014	0.012

Element	Concentration, mg/kg		
Arsenic	<0.02	<0.02	<0.02
Cadmium	<0.003	<0.003	0.023
Chromium	0.27	0.13	0.90
Cobalt	0.02	0.02	0.04
Lead	1.03	0.45	1.56
Mercury	<0.03	<0.03	<0.03
Nickel	29.8	58.5	102.3
Zinc	12.9	28.4	13.6

Contents of heavy metals (mg/kg) in the byproduct and limits for heavy metals content in the NPK fertilizer established in some countries



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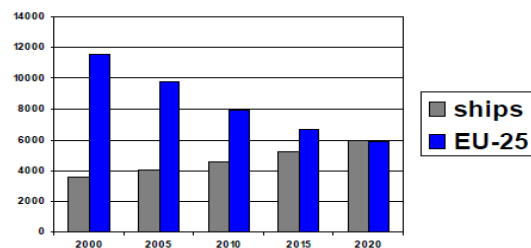
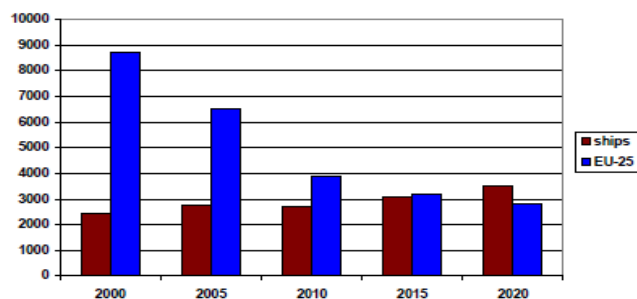
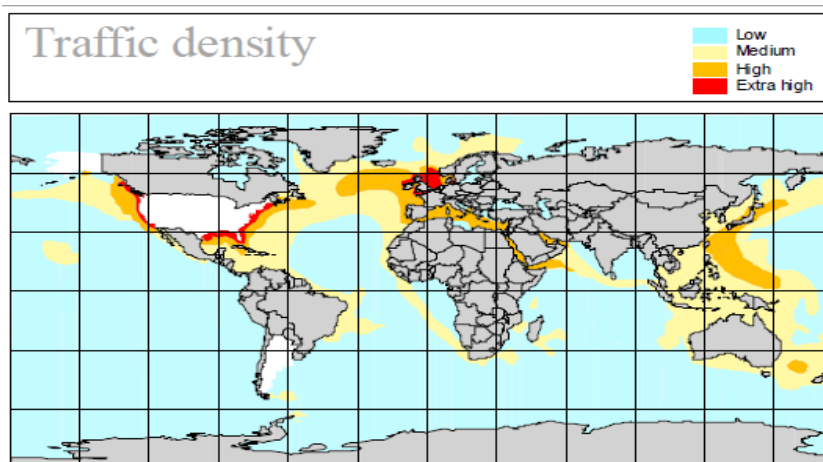
As	Cd	Cr	Co	Pb	Hg	Ni	Zn	Remarks
<0.02	<0.01	0.43	0.03	1.01	<0.03	63.5	18.3	averaged values for byproducts collected by cartridge bag filter
0.24	0.09	1.61	0.03	0.54	1.41	22.80	1476	byproducts collected by ESP
Limits for heavy metals content in NPK fertilizer								
41	39			300	17	420	2800	US EPA CFR40 Part. 503
75	20		150	500	5	180	1350	Canadian Fertilizer Act (1996)
50	50			140	2			Polish standard
	32.2	276.8	12.9	17.8		72.3		mean values of heavy metals concentrations in fertilizers marketed

CARGO SHIPS



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NO_x removal from wet air in the presence of TiO₂ catalyst under electron beam radiation – chemical model description in INCT

Cooperation with dr. H. Nichipor, Belarus based on experimental results obtained in INCT

- $\text{TiO}_2 + \text{electron beam} \rightarrow \text{e}^- + \text{hole}^+$
- $\text{h}^+ + \text{TiO}_2\text{-H}_2\text{O} \rightarrow \text{OH}\bullet + \text{H}^+$
- $\text{e}^- + \text{TiO}_2\text{-O}_2 \rightarrow \text{O}_2^-$
- $\text{TiO}_2 + \text{NO} \rightarrow \text{TiO}_2\text{-NO}$
- $\text{TiO}_2\text{-NO} + \text{OH}\bullet \rightarrow \text{TiO}_2\text{-HNO}_2$
- $\text{TiO}_2\text{-HNO}_2 + \text{OH}\bullet \rightarrow \text{TiO}_2\text{-NO}_2 + \text{H}_2\text{O}$
- $\text{TiO}_2\text{-NO}_2 + \text{OH}\bullet \rightarrow \text{HNO}_3(\text{aq})$

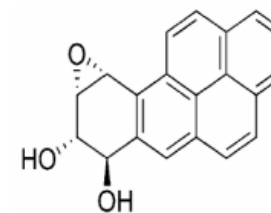
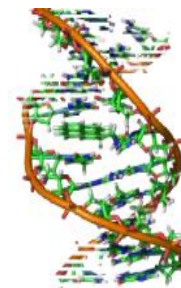
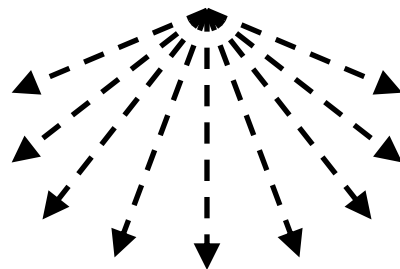
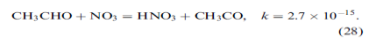
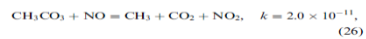
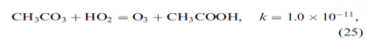
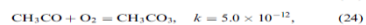
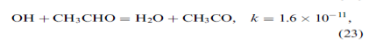
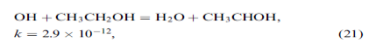
Thus NO is removed from gas phase



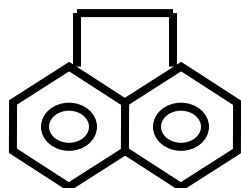
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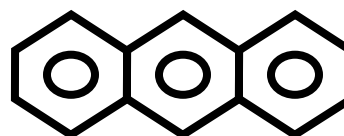
VOC TREATMENT



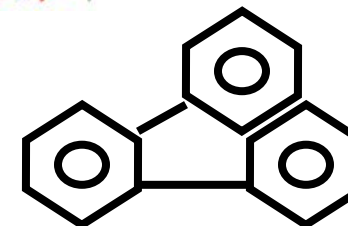
naphthalene



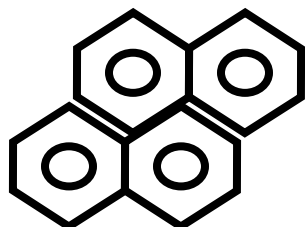
acenaphthene



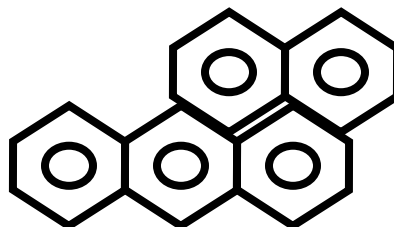
anthracene



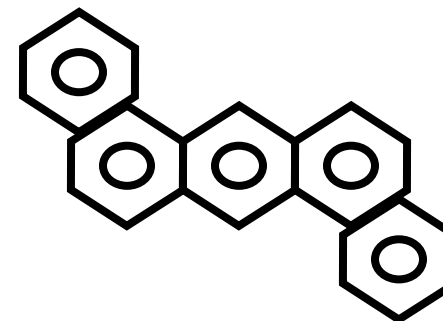
fluoranthene



pyrene



benzo(a)pyrene



dibenzo(a,h)anthracene



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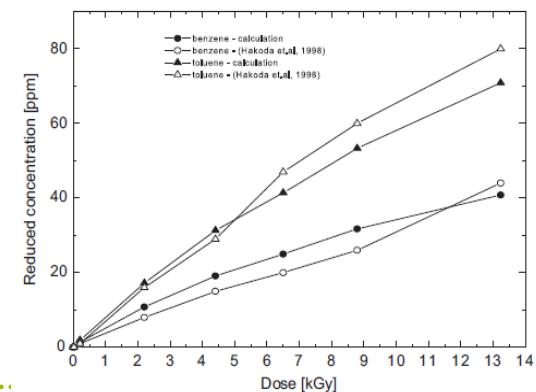
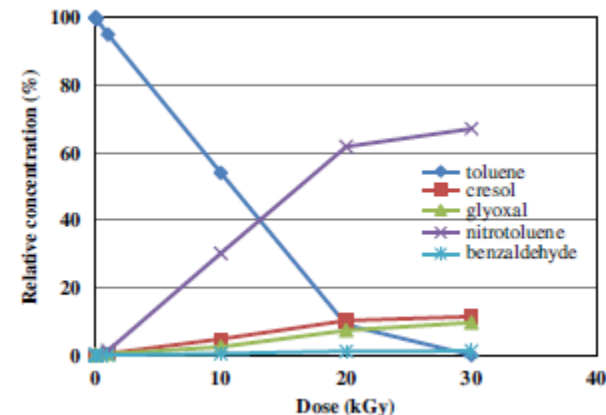
Model VOC eb treatment – experiment vs modelling



For toluene:



Toluene, benzene over 50 kinetic equations in each case; SO_x, NO_x in presence of VOC

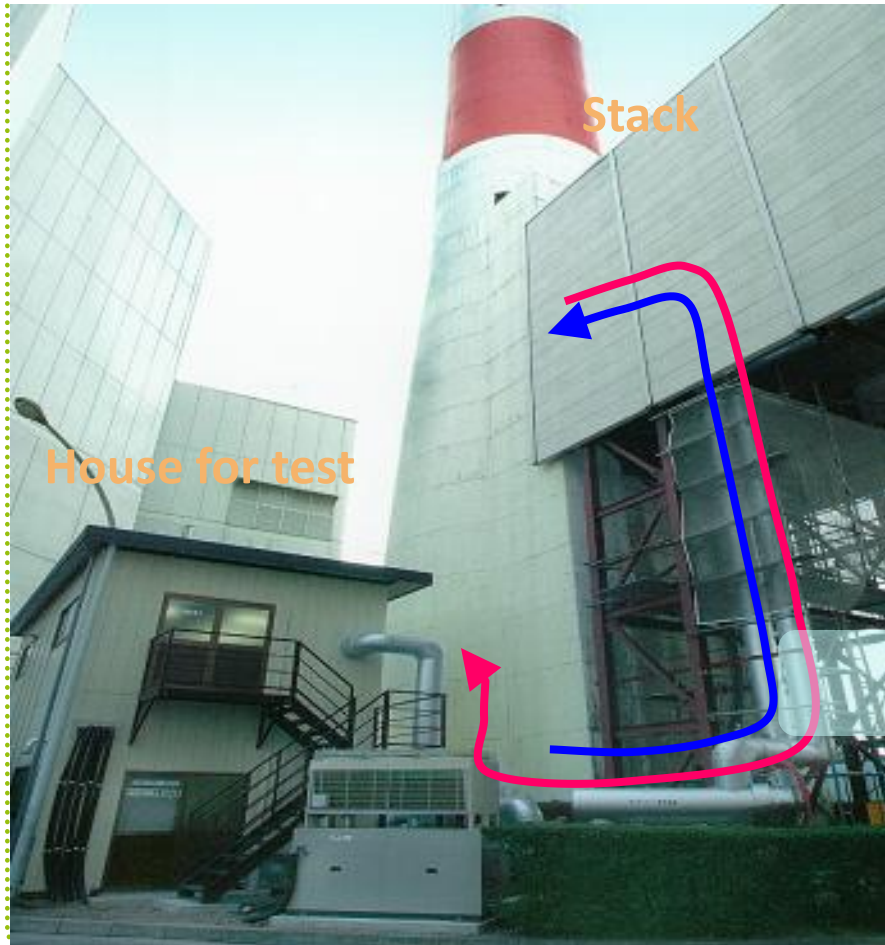


MUNICIPAL WASTE INCINERATION JAERI, Takasaki, Japan



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Electron accelerator & Irradiation vessel

Flue gas out



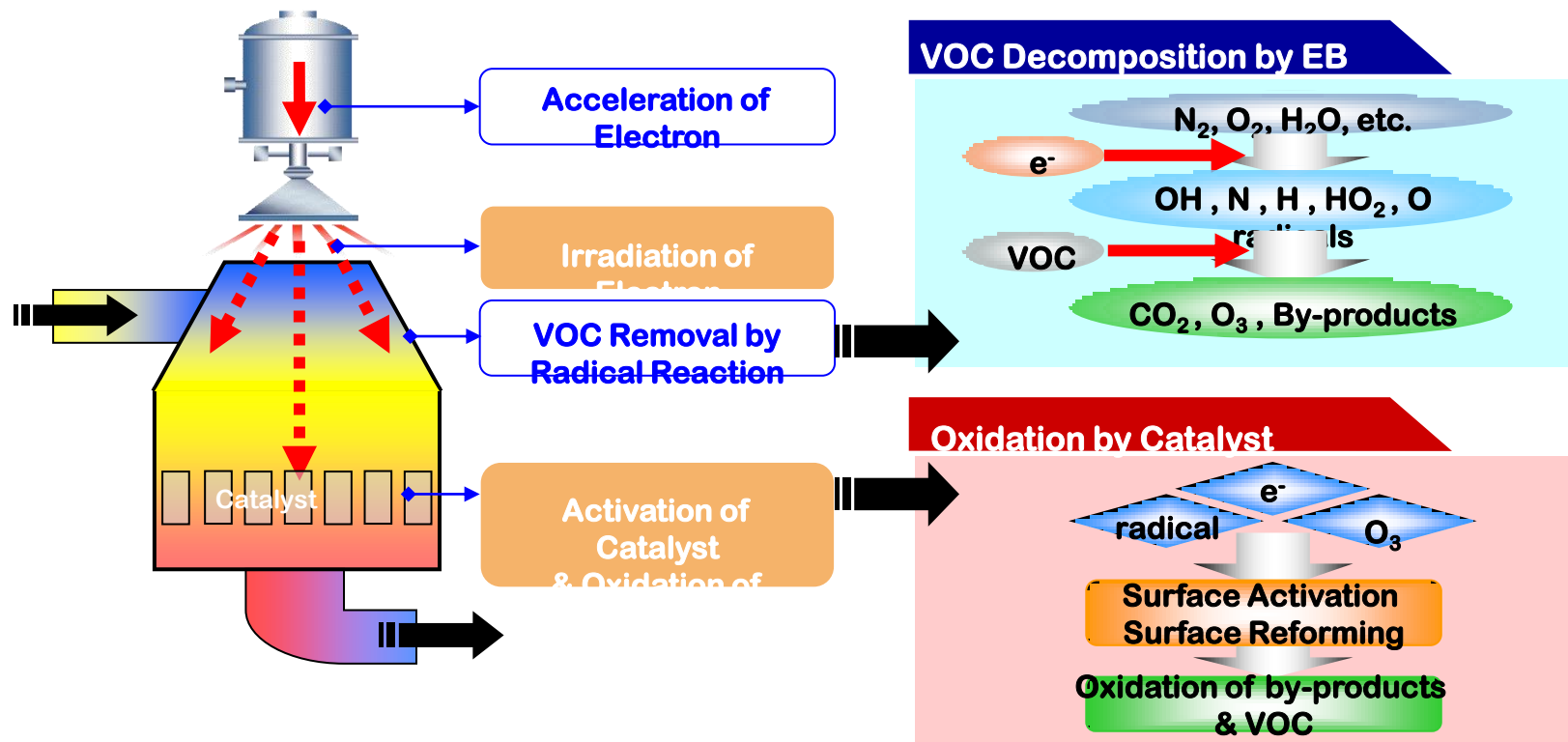
Self-shielded type and Curtain beams
300 keV max. and 40 mA max.

EB/Catalyst Konkuk, ROK



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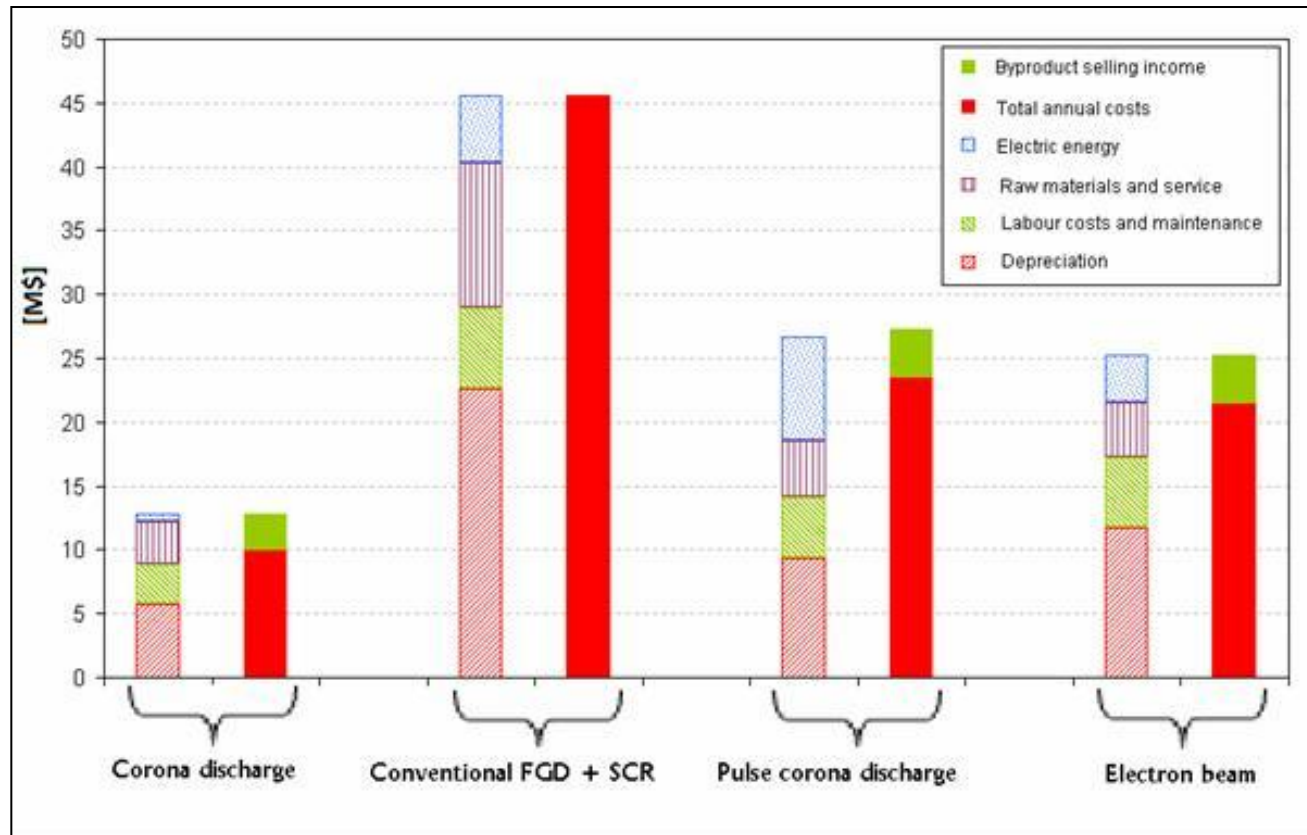


Comparison of selected plasma technologies



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Annual operational costs of selected flue gas treatment technologies



Part-financed by the
(European Regional Development Fund)

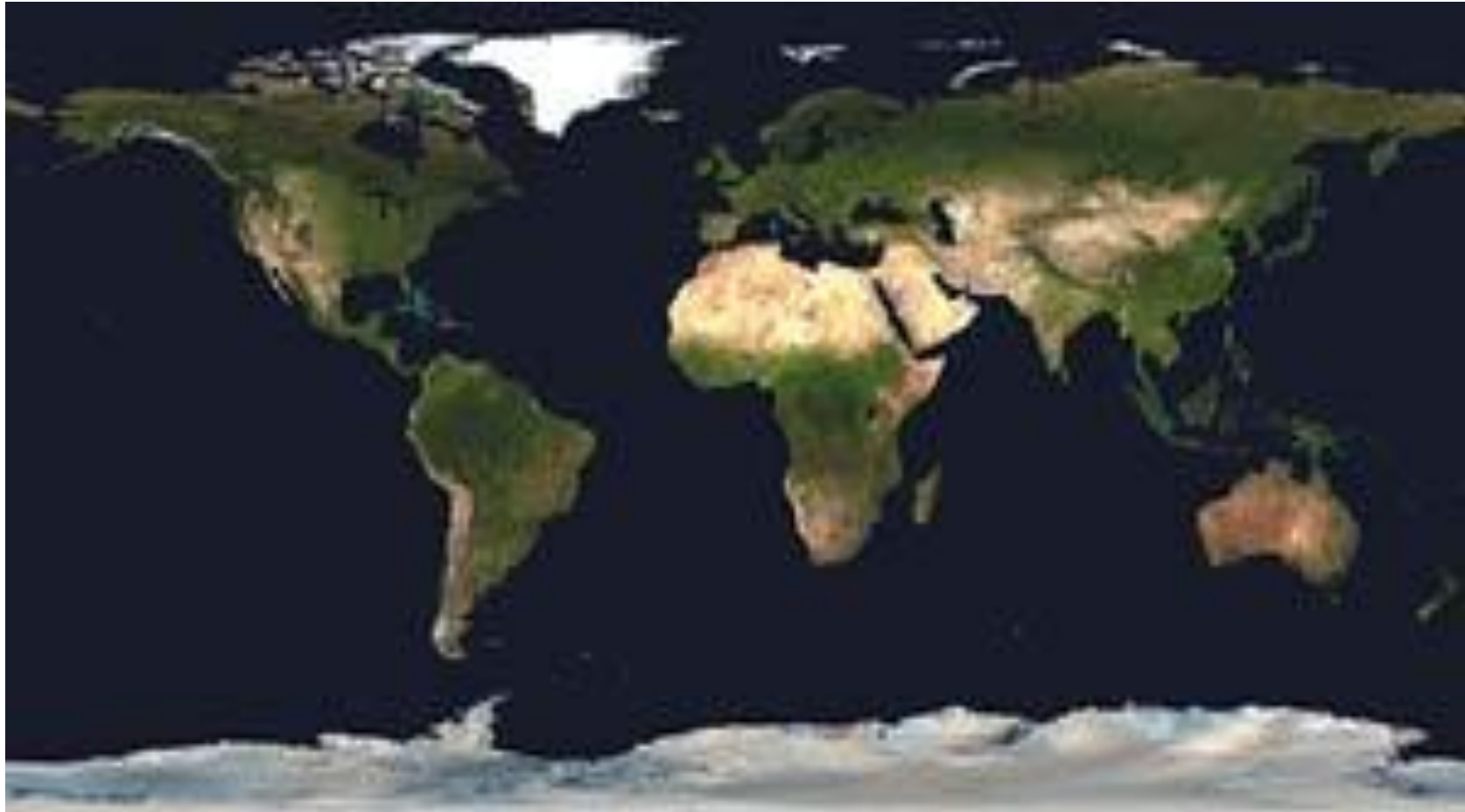


Water



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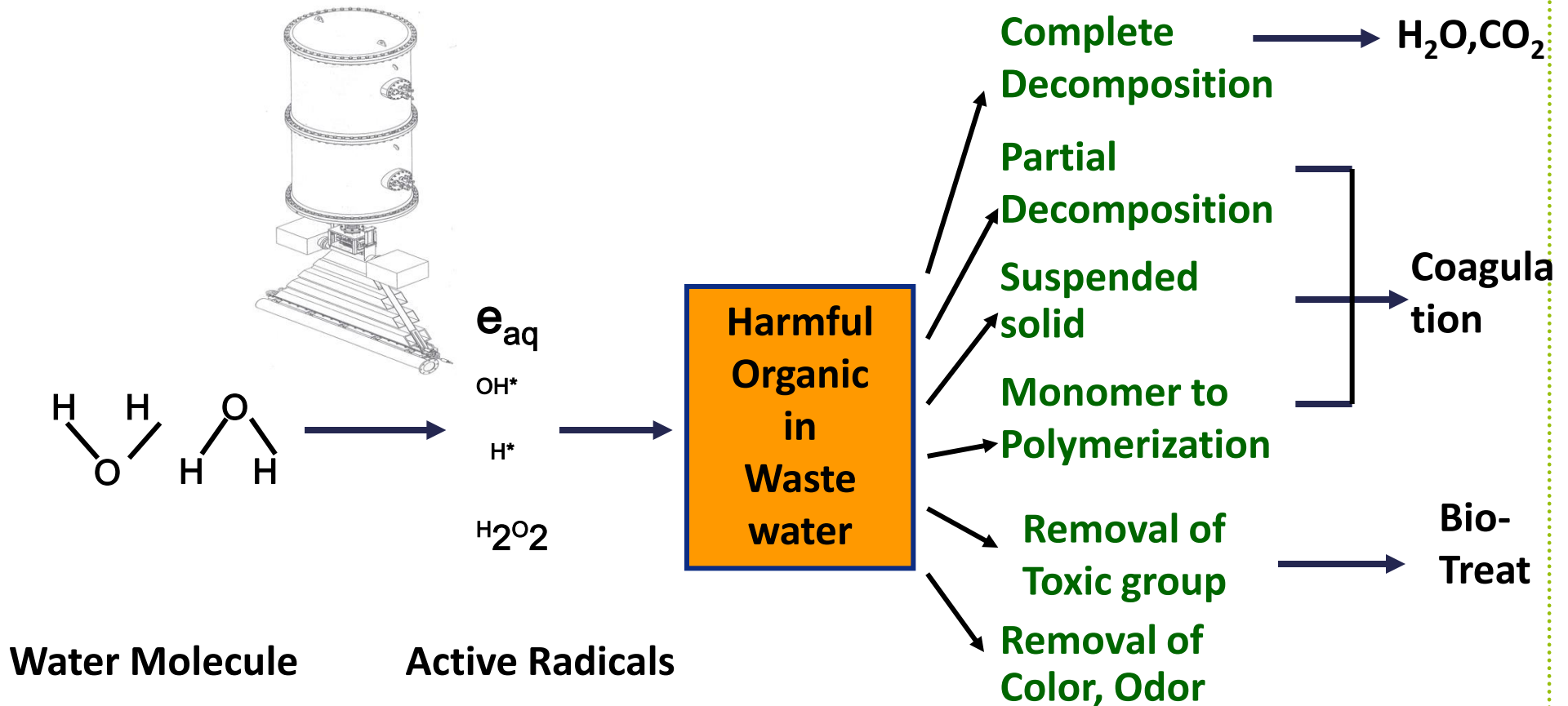


Process principles



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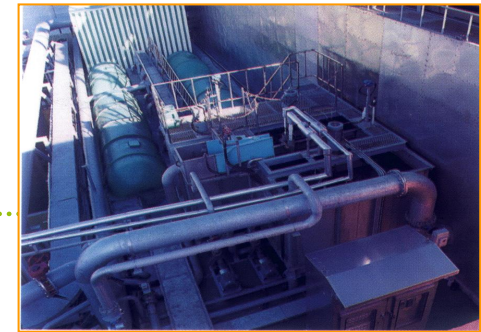
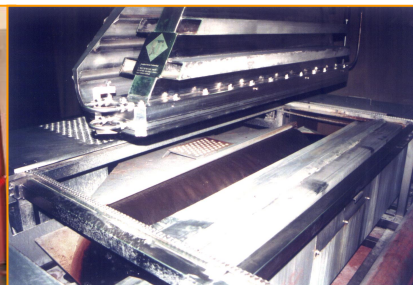
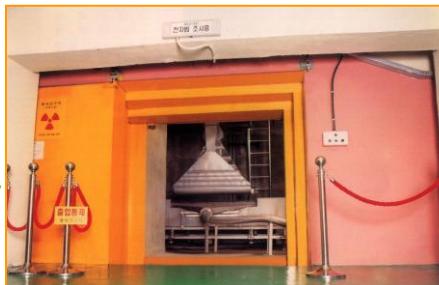
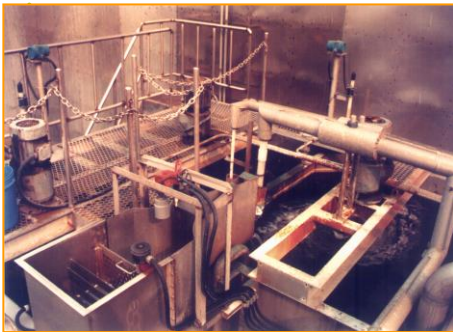
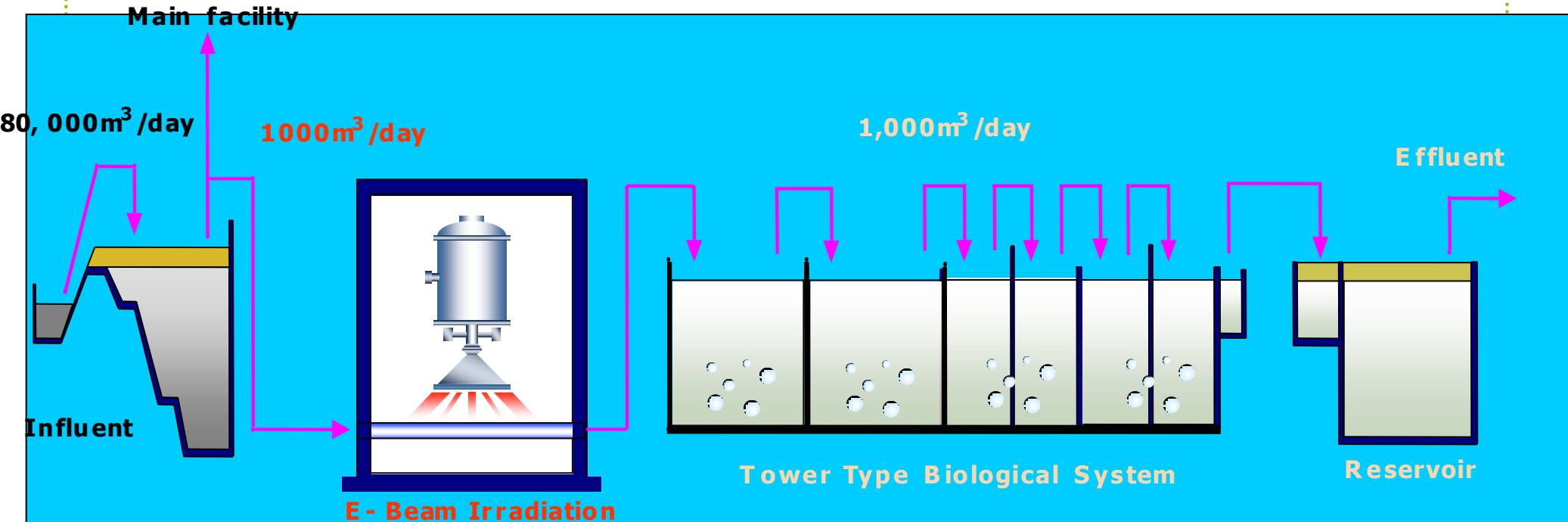
Waste-water treatment

R. of Korea .



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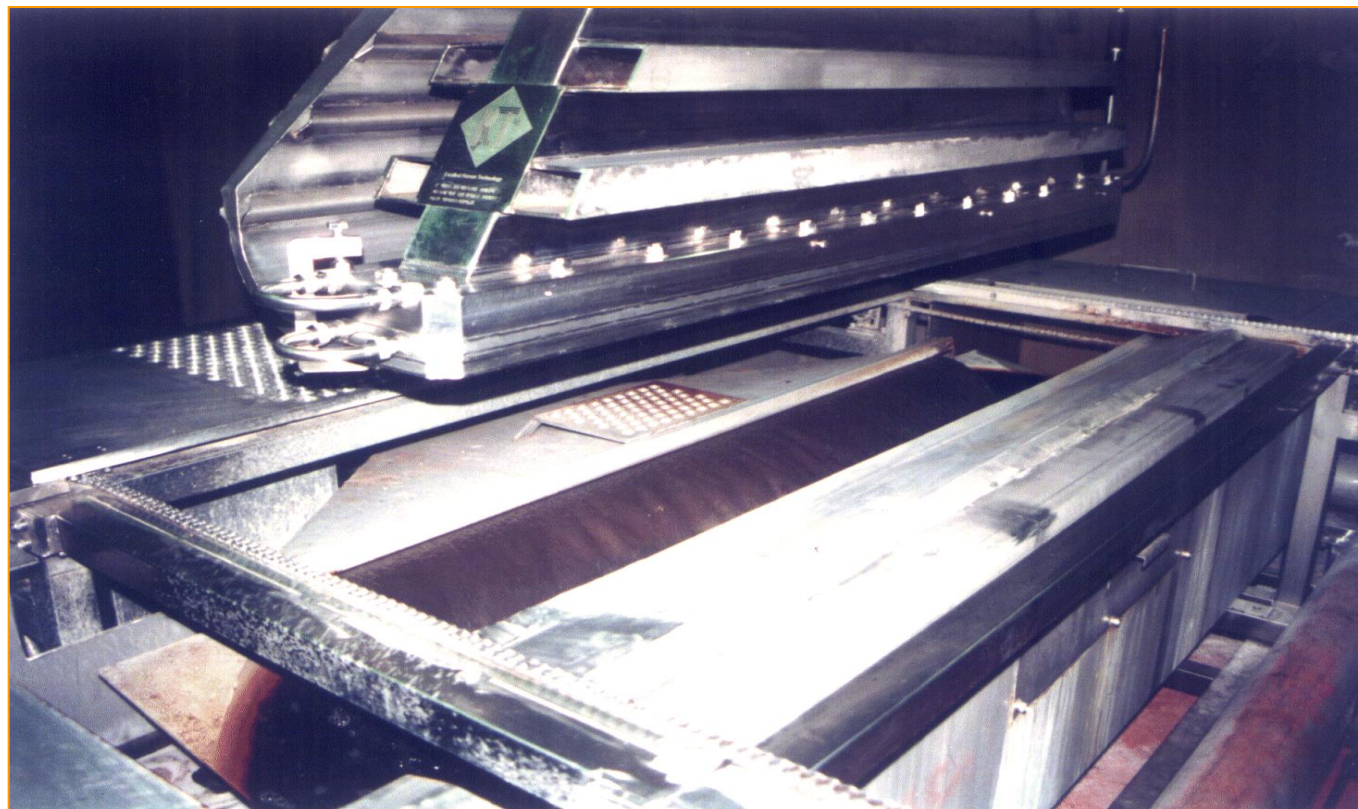




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Process vessel





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More than 30,000 particle accelerators are in operation around the world, serving medicine, industry, energy, the environment, national security, and discovery science. As accelerator science and technology continue to advance, so too will their benefits to society.



Published by the Department of Energy's Office of Science





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PlasTEP as a seed

- (Accelerators for America's Future)
- Sankt Petersburg Workshop -> Accelerators for Future Russia
- Meetings in Vienna -> Accelerators for Europe's Future

List of publications



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- **A. G. Chmielewski, Y. Sun, J. Licki, A. Pawelec, S. Witman, Z. Zimek, 2012. Electron beam treatment of high NO_x concentration off-gases. Radiation Physics and Chemistry, 81(8), 1036-1039.**
- **A. G. Chmielewski, Y. Sun, A. Pawelec, J. Licki, A. Dobrowolski, Z. Zimek, S. Witman, 2012. „Treatment of off-gases containing NO_x by electron beam”. Catalysis today, 191(1), 159-164.**
- **A. G. Chmielewski, A. Pawelec, S. Witman, 2010. Dissemination and fostering of plasma-based technological innovation for environment protection in the Baltic Sea Region PlasTEP. INCT Annual Report**
- **A. G. Chmielewski. „Electron Accelerators for Environmental Protection”. Accelerator Science and Technology, vol.4 (2011) 147-159.**
- **A. G. Chmielewski, A. Pawelec, S. Witman, 2011. Emission processes in the Baltic Sea Region. INCT Annual Report**

List of publications



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- **Yongxia Sun, Andrzej G.Chmielewski. „Mechanism of 4-chlorotoluene decomposition in air mixture in an electron beam generated non-thermal plasma reactor”. in: The 13th International Symposium on High Pressure Low Temperature Plasma Chemistry (Hakone XIII), 9-14.09.2012., Kazimierz Dolny, Poland, p. 258-262.**
- **H.Nichipor, S.Yacko, Y.Sun, A.G.Chmielewski, , Z. Zimek, S. Bułka. “Degradation mechanism of benzene in air under electron beam irradiation” in : 4th Central European Symposium on Plasma Chemistry (CESPC), 21-25.08.2011, Zlatibor, Serbia. P.107-108.**
- **Y.Sun, A.G.Chmielewski, “Overview of multiple pollutants treatment by using electron beam technology” in : 4th Central European Symposium on Plasma Chemistry (CESPC), 21-25.08.2011, Zlatibor, Serbia. P.27-28.**
- **H. Nichipor, E. Dashouk, S. Yacko , Y. Sun, A. G. Chmielewski, Z. Zimek, S. Bułka , 2012. Kinetic modeling of benzene and toluene decomposition in air and in flue gas under electron beam irradiation . Radiation Physics and Chemistry, 81(5), 572-579.**
- **Y.Sun, A.G.Chmielewski, 2012. „Organic pollutants treatment from air using electron beam generated nonthermal plasma – Overview” in book “Organic Pollutants Ten Years After the Stockholm Convention - Environmental and Analytical Update”, ISBN 979-953-307-085-7 , Edited by T. Puzyn & A. Mostrag-Szlichtyng, InTech - open science | open minds. P. 431-454.**

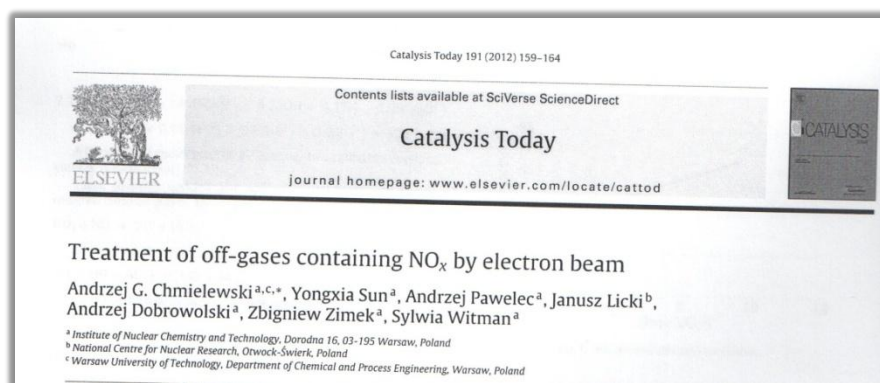
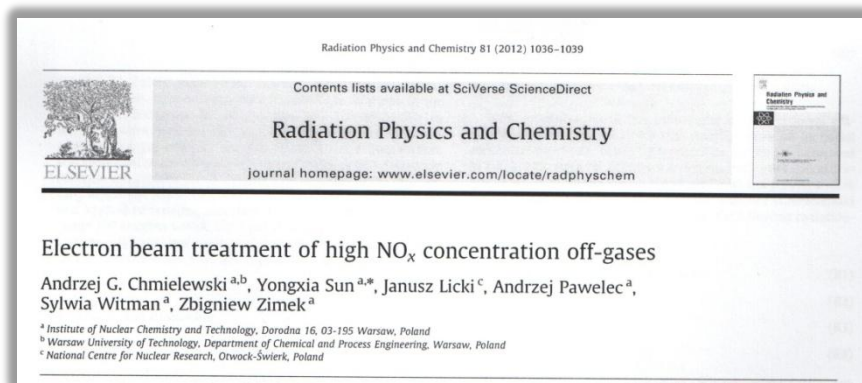


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List of publications

- H. Nichipor, E. Dashouk, S. Yacko, Y. Sun, A. G. Chmielewski, Z. Zimek, S. Bułka, 2012. Kinetic modeling of benzene and toluene decomposition in air and in flue gas under electron beam irradiation. *Radiation Physics and Chemistry*, 81(5), 572-579.
- Y. Sun, A. G. Chmielewski, 2012. „Organic pollutants treatment from air using electron beam generated nonthermal plasma – Overview” in book “Organic Pollutants Ten Years After the Stockholm Convention - Environmental and Analytical Update”, ISBN 979-953-307-085-7, Edited by T. Puzyn & A. Mostrag-Szlichtyng, InTech - open science | open minds. P. 431-454.



List of conference proceedings



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- “VIII Konferencji dla miasta i środowiska .
Problemy unieszkodliwiania odpadów”
Plasma technology for environment protection
A.G. Chmielewski, A.Pawelec, S.Witman
- “ECOpole'10 Conference” *Marzenia czy rzeczywistość-paliwa kopalne, odnawialne źródła energii lub energia atomowa?* Ecological Chemistry and Engineering
A.G. Chmielewski
- “XXXII Międzynarodowa Konferencja ekologiczna. Wytwarzanie Energii Elektrycznej i Ciepła w Aspekcie Pakietu Klimatycznego UE- Stosowane Technologie i Zagrożenia”,
Energetyka i środowisko /Power sector and the environment , A.G. Chmielewski
- XXIV Kongres Techników Polskich”
Technologia jednoczesnego usuwanie wielu zanieczyszczeń z gazów odlotowych przy użyciu wiązki elektronów. A.G. Chmielewski
- VIII Warszawskie Seminarium Doktorantów Chemików ChemSession'11”, *Technologie plazmowe w ochronie środowiska, A.G. Chmielewski, A. Pawelec, S. Witman*

List of conference proceedings



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- “Symposium Spuścizna naukowa Marii Skłodowskiej - Curie”
Ionizing radiation as a tool to protect environment / Promieniowanie jonizujące w ochronie środowiska, A.G. Chmielewski
- “International Symposium on Nitrogen Oxides Emission Abatement NOEA 2011”*Electron Beam Treatment of high NO_x concentration off-gases, A.G. Chmielewski, J. Licki, A. Pawelec, Z. Zimek, Y. Sun, S. Witman*
- “IX Konferencji dla miasta i środowiska .
Problemy unieszkodliwiania odpadów,, *Technologia jednoczesnego usuwania SO₂ i NO_x z gazów odlotowych przy użyciu wiązki elektronów, A.G. Chmielewski, A.Pawelec, S.Witman*
- “The Fourth Central European Symposium on Plasma Chemistry”, *Overview of multiple pollutants treatment by using electron beam technology, Y. Sun, A.G. Chmielewski*
Degradation mechanism of benzene in air under electron beam irradiation, H. Nichipor, S. Yacko, Y. Sun, A.G. Chmielewski, Z. Zimek, S. Bułka



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List of conference proceedings

- “12th Tihany Symposium on Radiation Chemistry”, *Plasma processes including elektron beam for off-gases purification*, A.G. Chmielewski, A. Pawelec, J.Licki, S. Witman, Y. Sun, Z. Zimek
- “IV Ogólnopolska Konferencja Naukowa ,Interdyscyplinarne Zagadnienia w Inżynierii i Ochronie Środowiska, EKO-DOK”, *Technologie plazmowe w ochronie środowiska/ Plasma technology in environmental protection*, A.G. Chmielewski, A. Pawelec, S. Witman
- “IX Warszawskie Seminarium Doktorantów Chemików ChemSession'12”, *Oczyszczanie gazów za pomocą technologii plazmowych w regionie morza bałtyckiego* A.G. Chmielewski, A. Pawelec, S. Witman
- “CYSENI-International Conference of Young Scientists on Energy Issues”, *Radiation induced plasma technology in environment protection* A.G. Chmielewski, A. Pawelec, S. Witman

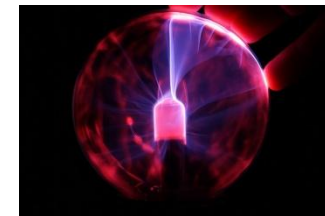
List of conference proceedings



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- “13th International Symposium on High Pressure Low Temperature Plasma Chemistry”, *Mechanism of 4-chlorotoluene decomposition in air mixture in an electron beam generated non-thermal plasma reactor*,
A.G. Chmielewski, Y. Sun
- “III Ogólnopolskie Sympozjum ,Reaktory Wielofazowe i Wielofunkcyjne dla Procesów Chemicznych i Ochrony Środowiska, *Zastosowanie procesów plazmowych w ochronie środowiska.*
A.G. Chmielewski, A. Pawelec, S. Witman-Zajęc, Y.Sun, Z.Zimek, J.Licki
- “III Ogólnopolskie Sympozjum ,Reaktory Wielofazowe i Wielofunkcyjne dla Procesów Chemicznych i Ochrony Środowiska”, *Zastosowanie plazmowego reaktora wielofazowego w ochronie środowiska.*
A.G. Chmielewski, A. Pawelec, S. Witman-Zajęc, A.Dobrowolski



List of articles in the magazines

- "INFRASTRUKTURA" A.G. Chmielewski:

Ochrona środowiska zamiast gwiazdnych wojen

- "PRZEGLĄD PRZEMYSŁU I GOSPODARKI" A.G. Chmielewski, A. Pawelec, S. Witman:

Technologie plazmowe w ochronie środowiska

- "CHEMISTRY AND ENGINEERING" A.G. Chmielewski:

Dreams Or reality – fossil fuels, renewable or nuclear power

- "PROATOM" A.G. Chmielewski:

Extend the field of innovative knowledge

- "CHEMIA W SZKOLE, CZASOPISMO DLA NAUCZYCIELI" A.G. Chmielewski:

Przyszłość energetyczna świata i Polski

- "RADIATION AND INDUSTRIES" A.G. Chmielewski:

*Success of Gas Cleaning by Electron Beam and Other Industrial Applications of Radiation
Processing in Poland,*

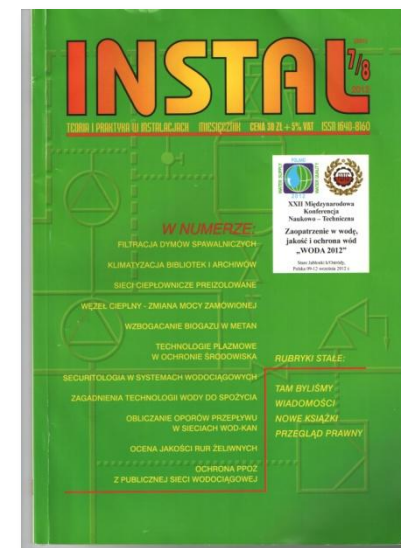
- "INSTAL" A.G. Chmielewski, A. Pawelec, S. Witman:

Technologie plazmowe w ochronie środowiska/ Plasma technology in environmental protection.



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List of lectures

- “ECOpole'10 Conference”, October 13-15, 2010, Poland A.G. Chmielewski:
Marzenia czy rzeczywistość-paliwa kopalne, odnawialne źródła energii lub energia atomowa? Ecological Chemistry and Engineering (vol. 17, no. 3, str. 255-261)
- “Symposium Spuścizna naukowa Marii Skłodowskiej - Curie”, May 19-20, 2011, Poland A.G. Chmielewski:
Promieniowanie jonizujące w ochronie środowiska
- “ International Meeting on Radiation Processing Montreal 2011”, June 13-16, 2011, Montreal A.G. Chmielewski:
Electron Beam Treatment of high NOx concentration off-gases
- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia A.G. Chmielewski, A. Pawelec:
Principles of Basic Engineering study of Electron Beam Flue Gas Treatment Plant
- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia A.G. Chmielewski, S. Witman:
Possibility of EBFGT application for mercury removal
- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia A.G. Chmielewski: *Plasma processes.*

List of lectures



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- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia
A.G. Chmielewski: *PM 2,5.*
- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia A.G. Chmielewski, S. Witman: *Mercury emissions.*
- “PlasTEP Summer School and Training Course”, August 2, 2011, Warsaw/Szczecin, Poland A.G. Chmielewski, A. Pawelec:
Experiences from exploitation of industrial EBFGT plant and perspectives of future development.
- “PlasTEP Summer School and Training Course”, July 20, 2012, Vilnius/Kaunas, Lithuania, Pawelec: *Electron beam as a special application for NOx/SOx reduction – basics and example*
- “National seminar on applications of electron accelerators in science, education, health care, environment and industry with international participation”, June 21, 2012, A.G. Chmielewski: *Industrial application of electron accelerators*
- In “Workshop PlasTEP – Plasma Technologies for environment protection”, September 28, 2012, Tallinn, Estonia A. Pawelec: *Electron beam as a special application for SOx/NOx reduction*
- In “SME Workshop PlasTEP – Plasma Technologies for environment protection”, October 23, 2012, Roskilde, Denmark ,A. Pawelec: *NOx/SOx Reduction by Electron Beam Technology*

List of co-organized events



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- **VIII Conference of the City and the Environment, Problems of Waste Disposal 29.11.2010 Warsaw, Poland**
- **III Targi Czystej Energii CENERG, Agencja SOMA, 23-25.03.2011, Warsaw, Poland**
- **PlasTEP Summer School and Training Course, 25. 07-05.08. 2011, Warsaw/Szczecin, Poland**
- **Coordination Meeting on Radiation Engineering Nanostructures, 16-18.11.2011, Warsaw, Poland**
- **IX Conference of the City and the Environment, Problems of Waste Disposal 28.11.2011, Warsaw, Poland**
- **Workshop “PlasTEP – Plasma Technologies for environment protection”, 14.05.2012, Warsaw, Poland**
- **Semi-Annual Meeting PlasTEP– Plasma Technologies for environment protection 15.05.2012, Warsaw, Poland**
- **X Conference of the City and the Environment, Problems of Waste Disposal 26.11.2012 Warsaw, Poland**
- **IRAP 2012 10th meeting of the Ionizing Radiation and Polymers Symposium 14-19.10.2012, Kraków, Poland**

III Clean Energy Fair CENERG, 23-25.03.2011, Warsaw, Poland

The Trade Show's sectors cover such subject as renewable energy sources, RES production and equipment. The subject is close connected to environmental protection technologies. Therefore INCT has organized PlasTEP stand and presented the project to visitors. There were noticed huge interest in plasma technologies between visitors.



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PlasTEP Summer School and Training Course Warsaw/ Szczecin in 2011



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In 2011 for the first time the international PlasTEP summer school – “Plasma technology For Environment Protection” has been combined with Training for entrepreneurs and their employees.

The Institute of Nuclear Chemistry and Technology in Warsaw, Warsaw University of Technology and West Pomeranian University of Technology in Szczecin were organizers of the second edition of the summer school.



From 25th July to 5th August 2011 about 30 participants from industry and academic institutions met in Poland in order to explore knowledge about innovative technologies that use low-temperature plasma.

PlasTEP Summer School and Training Course Warsaw/ Szczecin in 2011 c.d.



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The summer school lasted twelve days and included lectures and discussions of international experts in the field of plasma technology and environment protection.

In particular, development of techniques for purification of gases from harmful impurities and remove petroleum contamination from seawater were discussing.

The lectures were supplemented with practical, group work concerning essential issues in the field of plasma technology.

The participants had the opportunity to assess potential and notice possibilities of applications of plasma technology for environment protection.

One of the points of the summer school program was the visit of industrial installation of simultaneous removal of SO₂ and NO_x from flue gases with use of electron beam in “Pomorzany” Power Plant.

The summer school included also visit to the Institute of Plasma Technology in Greifswald (Germany).



Master Thesis

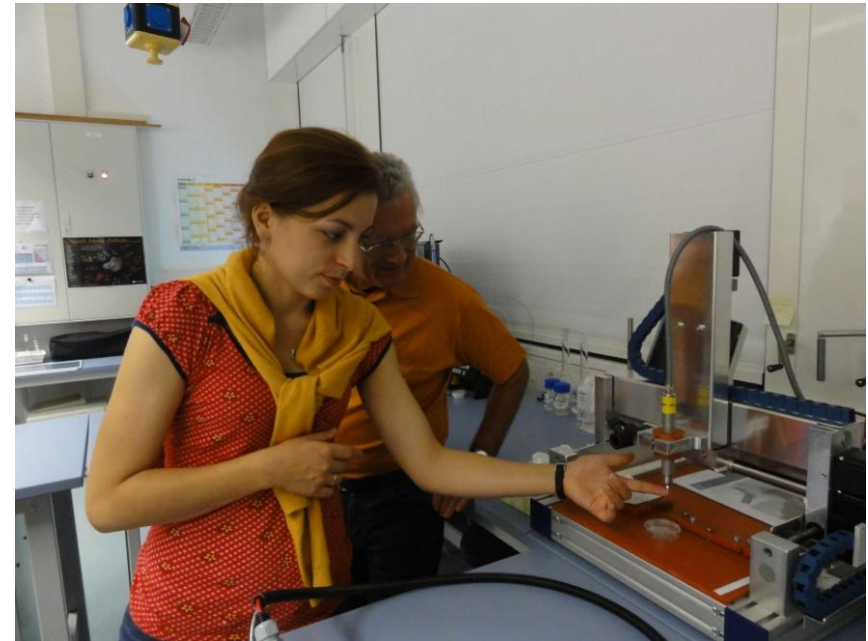


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"Methods of plasma gas treatment – a comparison of technical and economic parameters" – Agnieszka Molenda, Supervision: Professor A. G. Chmielewski

At the end of the PlasTEP Summer School and Training Course Warsaw/ Szczecin participants received certificates .

A student from Poland – Agnieszka Molenda (student of Professor Andrzej Grzegorz Chmielewski, Warsaw University of Technology) took a second place among students, in the test entitled to receive a certificate.



Conference “For City and Environment”



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The conference

"For City and Environment –
problems of wastes processing"

is traditional one-day event devoted
to the matters of wastes processing
and environment protection.

INCT was co-organizer of
the conference. During the event,
PlasTEP project was presented.



PlasTEP Summer School and Training Course participation

The lectures were given during following events:

- First edition of the summer school was held in July 11, 2010, Riga, Latvia .
- The next edition of the summer school was held in Vilnius and Kaunas in 2012.



Companies cooperating with INCT

1. **EnerGoVision** Sanok, Poland, Mr. Antoni Dziuban
2. **Thermal Power Plant Sviloza** Svishtov/ Bulgaria
3. **KC COTTRELL** , 160-1, Donggyo-dong, Mapo-gu, Seoul, 121-817 Korea, Mr. Park Kisuh
4. **NIPAG RAFFLENBEUL ANLAGENBAU GMBH**, Voltastrasse 5 D-63225 Langen, Mr. Bernd Hansel
5. **Research Institute of Science& Technology**, Hyoja-Dong, Nam-Gu, Pohang City, 790-330 Gyeongbuk, Korea, Mr. Dong Jun Koh
6. **Jeju National University**, 66 Jejudaehakno, Jeju, Korea 690-756, Mr. Young Sun Mok



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Companies cooperating with INCT



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7. **A.P.MOLLER-MAERSK A/S** (M&M),
Copenhagen, Denmark
8. **EB Tech Co.**, 550 Yongsan-dong, Yuseong-gu Daejeon, 305-500 Korea, Mr. Kim Sung- Myun
9. **Korea Atomic Energy Research Institute**,
1266 Sinjeong-dong, Jeongeup-si,
Jeollabuk-do 580-185 Korea,
Mr. Jung In-Ha
10. **NEDERMAN Manufacturing Poland**,
Okólna 45 Marki 05-270 Poland
11. **ChemTech** ul. Kolejowa 53, 05-092
Łomianki, Poland, Mr. Krzysztof
Januszkiewicz
12. **Dalkia Polska**, ul. Ostrobramska 75 c, 04 -
175 Warszawa Poland, Mr. Piotr Legat



Scientific visits



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23.09.2012 – 06.10.2012 **dr Henrietta Nichipor**

- **Research of VOC removal. Modeling based on experimental research performed within the framework of PlasTEP project.**

26.11.2012 – 27.11.2012 **Mr. Bernd Hansel**

visit in the laboratory in Institute of Nuclear Chemistry and Technology

The titles of presentations:

- **Selective Removal of Hydrogen Sulfide and Odor Removal for the Use of Biogas or Landfill Gases in Combustion Engines for Power Generation”**
- **Molecular Sieves and Non Thermal Plasma Processes for Minimizing Waste Air Abatement Costs**



SEMINARIUM INSTYTUTU CHEMII I TECHNIKI JĄDROWEJ

ul. Dorodna 16, 03-195 Warszawa

W dniu 27.11.2012 r. o godz. 10:30

w sali seminaryjnej IChTJ

Bernd Hansel

Rafflenbeul Anlagenbau GmbH, Niemcy

wygotosi wykład

**MOLECULAR SIEVENS AND NON THERMAL PLASMA
PROCESSES FOR MINIMIZING WASTE AIR ABATEMENT COSTS**





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Thank you for your attention.

