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
The team

- Dr. Andrzej Pawelec
- Dr. Janusz Licki
- Dr. Yongxia Sun
- Dr. Zbigniew Zimek
- Ms. Sylwia Witman
- Mr. Sylwester Bułka
- Ms. Dorota Korniszewska
What is a problem?
Environmental impact
List of the emission processes in the Baltic Sea Region

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

<table>
<thead>
<tr>
<th>Country</th>
<th>SO2</th>
<th>NOx</th>
<th>VOC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Poland</td>
<td>998561</td>
<td>831225</td>
<td>30521</td>
</tr>
<tr>
<td>Denmark</td>
<td>19605</td>
<td>166877</td>
<td>38122</td>
</tr>
<tr>
<td>Finland</td>
<td>70119</td>
<td>170929</td>
<td>34393</td>
</tr>
<tr>
<td>Sweden</td>
<td>30521</td>
<td>173025</td>
<td>67739</td>
</tr>
<tr>
<td>Latvia</td>
<td>38122</td>
<td>34393</td>
<td>6190</td>
</tr>
<tr>
<td>Estonia</td>
<td>38122</td>
<td>34393</td>
<td>6190</td>
</tr>
<tr>
<td>Lithuania</td>
<td>151686</td>
<td>154403</td>
<td>831225</td>
</tr>
<tr>
<td>N. Germany</td>
<td>165877</td>
<td>200000</td>
<td>106306</td>
</tr>
</tbody>
</table>

Total emission in BSR countries in tonnes per year
List of the emission processes in the Baltic Sea Region

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

<table>
<thead>
<tr>
<th>Process</th>
<th>SO2 (%)</th>
<th>NOx (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy generation</td>
<td>33.19</td>
<td>0.21</td>
</tr>
<tr>
<td>Combustion processes in industry</td>
<td>11.95</td>
<td>0.38</td>
</tr>
<tr>
<td>Non industrial combustion processes</td>
<td>10.56</td>
<td>0.76</td>
</tr>
<tr>
<td>Industrial processes except combustion</td>
<td>0.38</td>
<td>0.21</td>
</tr>
<tr>
<td>Transport</td>
<td>43.26</td>
<td>0.01</td>
</tr>
<tr>
<td>Waste management</td>
<td>0.28</td>
<td>0.00</td>
</tr>
</tbody>
</table>
EP Pomorzany
NPK Fertilizer
BULGARIA

Figure. 2. Basic design of two-stream EBI for flue gas purification
General view of the pilot plant.

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

1. inlet to process vessel,  
2. EB-TECH mobile unit,  
3. cyclone,  
4. cartridge filter,  
5. ID fan  
6. stack
Process vessel
EB mobile unit
Monitoring system
SO₂ and NOₓ removal efficiency

SO₂ and NOₓ removal efficiency [%]

SO₂: 1360-1420 ppmv
NOₓ: 136-144 ppmv
Gas flow rate: 620 Nm³/h
Ammonia stoichiometry: 0.9
Gas temp. at PV inlet: 62.3°C
Gas humidity at PV inlet: 10.3% vol.

Gas temp. at PV inlet
- 62.3°C
- 83.7°C
NH₃ stoichiometry: 0.90
Gas flow rate: 820-920 Nm³/h
Gas humidity at PV inlet: 9.98 - 10.30% vol.

Dose [kGy]

SO₂ removal efficiency [%]
## Product

<table>
<thead>
<tr>
<th>Element</th>
<th>Concentration, mg/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cl⁻</td>
<td>0.0012</td>
</tr>
<tr>
<td></td>
<td>0.0068</td>
</tr>
<tr>
<td></td>
<td>0.0032</td>
</tr>
<tr>
<td>NO₃⁻</td>
<td>0.35</td>
</tr>
<tr>
<td></td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>0.34</td>
</tr>
<tr>
<td>SO₄²⁻</td>
<td>78.19</td>
</tr>
<tr>
<td></td>
<td>79.24</td>
</tr>
<tr>
<td></td>
<td>79.63</td>
</tr>
<tr>
<td>NH₄⁺</td>
<td>21.16</td>
</tr>
<tr>
<td></td>
<td>20.28</td>
</tr>
<tr>
<td></td>
<td>20.00</td>
</tr>
<tr>
<td>Na⁺</td>
<td>0.258</td>
</tr>
<tr>
<td></td>
<td>0.025</td>
</tr>
<tr>
<td></td>
<td>0.015</td>
</tr>
<tr>
<td>Mg²⁺</td>
<td>0.0047</td>
</tr>
<tr>
<td></td>
<td>0.0045</td>
</tr>
<tr>
<td></td>
<td>0.0012</td>
</tr>
<tr>
<td>Ca²⁺</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>0.014</td>
</tr>
<tr>
<td></td>
<td>0.012</td>
</tr>
<tr>
<td>Arsenic</td>
<td>&lt;0.02</td>
</tr>
<tr>
<td></td>
<td>&lt;0.02</td>
</tr>
<tr>
<td></td>
<td>&lt;0.02</td>
</tr>
<tr>
<td>Cadmium</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>0.023</td>
</tr>
<tr>
<td>Chromium</td>
<td>0.27</td>
</tr>
<tr>
<td></td>
<td>0.13</td>
</tr>
<tr>
<td></td>
<td>0.90</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>0.02</td>
</tr>
<tr>
<td></td>
<td>0.04</td>
</tr>
<tr>
<td>Lead</td>
<td>1.03</td>
</tr>
<tr>
<td></td>
<td>0.45</td>
</tr>
<tr>
<td></td>
<td>1.56</td>
</tr>
<tr>
<td>Mercury</td>
<td>&lt;0.03</td>
</tr>
<tr>
<td></td>
<td>&lt;0.03</td>
</tr>
<tr>
<td></td>
<td>&lt;0.03</td>
</tr>
<tr>
<td>Nickel</td>
<td>29.8</td>
</tr>
<tr>
<td></td>
<td>58.5</td>
</tr>
<tr>
<td></td>
<td>102.3</td>
</tr>
<tr>
<td>Zinc</td>
<td>12.9</td>
</tr>
<tr>
<td></td>
<td>28.4</td>
</tr>
<tr>
<td></td>
<td>13.6</td>
</tr>
</tbody>
</table>
## Contents of heavy metals (mg/kg) in the byproduct and limits for heavy metals content in the NPK fertilizer established in some countries

<table>
<thead>
<tr>
<th>As</th>
<th>Cd</th>
<th>Cr</th>
<th>Co</th>
<th>Pb</th>
<th>Hg</th>
<th>Ni</th>
<th>Zn</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;0.02</td>
<td>&lt;0.01</td>
<td>0.43</td>
<td>0.03</td>
<td>1.01</td>
<td>&lt;0.03</td>
<td>63.5</td>
<td>18.3</td>
<td>averaged values for byproducts collected by cartridge bag filter</td>
</tr>
<tr>
<td>0.24</td>
<td>0.09</td>
<td>1.61</td>
<td>0.03</td>
<td>0.54</td>
<td>1.41</td>
<td>22.80</td>
<td>1476</td>
<td>byproducts collected by ESP</td>
</tr>
</tbody>
</table>

### Limits for heavy metals content in NPK fertilizer

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>41</td>
<td>75</td>
<td>50</td>
</tr>
<tr>
<td>39</td>
<td>20</td>
<td>50</td>
</tr>
<tr>
<td>300</td>
<td>150</td>
<td>140</td>
</tr>
<tr>
<td>17</td>
<td>500</td>
<td>140</td>
</tr>
<tr>
<td>420</td>
<td>500</td>
<td>17</td>
</tr>
<tr>
<td>2800</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>1350</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean values of heavy metals concentrations in fertilizers marketed
CARGO SHIPS

Traffic density

Graph showing the number of ships from 2000 to 2020.

Graph showing traffic density around the world.
NOx 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

• TiO₂ + electron beam → e⁻ + hole⁺
• h⁺ + TiO₂⁻ H₂O → OH⁻ + H⁺
• e⁻ + TiO₂-O₂ → O₂⁻
• TiO₂ + NO → TiO₂-NO
• TiO₂-NO + OH⁻ → TiO₂⁻ HNO₂
• TiO₂⁻ HNO₂ + OH⁻ → TiO₂-NO₂ + H₂O
• TiO₂⁻ NO₂ + OH⁻ → HNO₃(aq)

Thus NO is removed from gas phase
VOC TREATMENT

\[
\begin{align*}
\text{OH} + \text{CH}_3\text{CHOH} &= \text{H}_2\text{O} + \text{CH}_3\text{CHO}, \\
&\quad k = 2.9 \times 10^{-12}, \\
\text{CH}_3\text{CHO} + \text{O}_3 &= \text{CH}_3\text{CHO} + \text{HO}, \\
&\quad k = 1.9 \times 10^{-14}, \\
\text{OH} + \text{CH}_3\text{CHO} &= \text{H}_2\text{O} + \text{CH}_3\text{CO}, \\
&\quad k = 1.6 \times 10^{-14}, \\
\text{CH}_3\text{CO} + \text{O}_3 &= \text{CH}_3\text{CO}_2, \\
&\quad k = 5.0 \times 10^{-12}, \\
\text{CH}_3\text{CO}_2 + \text{HO} &= \text{CH}_3\text{COOH}, \\
&\quad k = 1.0 \times 10^{-13}, \\
\text{CH}_3\text{CO}_2 + \text{NO} &= \text{CH}_3\text{CO} + \text{NO}_2, \\
&\quad k = 2.0 \times 10^{-14}, \\
\text{CH}_3\text{CO}_2 + \text{NO}_2 &= \text{CH}_3\text{CO}_2\text{NO}, \\
&\quad k = 1.2 \times 10^{-11}, \\
\text{CH}_3\text{CHO} + \text{NO}_3 &= \text{CH}_3\text{CO} + \text{NO}_2, \\
&\quad k = 2.7 \times 10^{-13}. \\
\end{align*}
\]

naphtalene  acenaphtene  anthracene  fluoranthene  pyrene  benzo(a)pyrene  dibenzo(a,h) anthracene
Model VOC eb treatment – experiment vs modelling

\[
\begin{align*}
\text{VAC-} & \text{OH-}O_2-O' \rightarrow \text{HC(O)CHOH} + \text{HC(O)CH}=\text{CHCHO} \\
\text{VAC-} & \text{OH-O}_2-O'' \rightarrow \text{HCOCHO} + \text{HC(O)CH}=\text{CH-COOH} \\
\text{HC(O)CHO} & + O_2 \rightarrow \text{HCOCHO} + \text{HO}_2 \\
\text{HC(O)CH} = \text{CHCHO} + O_2 & \rightarrow \text{HC(O)CH} = \text{CHCHO} + \text{HO}_2
\end{align*}
\]

For toluene:
\[
\begin{align*}
\text{VAC-} & \text{OH-O}_2-O' \rightarrow \text{HC(O)CHOH} + \text{CH}_3\text{C(O)CH}=\text{CHCHO} \\
\text{HC(O)CHO} & + O_2 \rightarrow \text{HCOCHO} + \text{HO}_2
\end{align*}
\]

Toluene, benzene over 50 kinetic equations in each case; SOx, NOx in presence of VOC
MUNICIPAL WASTE INCINERATION
JAERI, Takasaki, Japan

Electron accelerator & Irradiation vessel

Stack

House for test

Flue gas out

Self-shielded type and Curtain beams 300 keV max. and 40 mA max.
**EB/Catalyst Konkuk, ROK**

**VOC Decomposition by EB**
- **N₂, O₂, H₂O, etc.**
- **OH, N, H, HO₂, O**
- **CO₂, O₃, By-products**

**Oxidation by Catalyst**
- **Surface Activation**
- **Surface Reforming**
- **Oxidation of by-products & VOC**
Comparison of selected plasma technologies

Annual operational costs of selected flue gas treatment technologies
Water
**Process principles**

Water Molecule → Active Radicals

- Harmful Organic in Waste water
- Complete Decomposition → H₂O, CO₂
- Partial Decomposition
- Suspended solid
- Monomer to Polymerization
- Removal of Toxic group
- Removal of Color, Odor
- Coagulation
- Bio-Treat
Waste-water treatment

R. of Korea

In 1980, 80,000 m³/day of influent is treated using E-Beam Irradiation followed by a Tower Type Biological System. The effluent is then stored in a reservoir.
Process vessel
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
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


List of publications


List of publications


List of conference proceedings

- “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

- “Sympozjum Spuścizna naukowa Marii Skłodowskiej - Curie”
  Ionizing radiation as a tool to protect environment / Promieniowanie jonizujące w ochronie środowiska, A.G. Chmielewski


- “IX Konferencji dla miasta i środowiska”
  Problemy unieszkodliwiania odpadów, Technologia jednoczesnego usuwania SO₂ i NOx 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
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


List of conference proceedings

- “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-Zając, 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*.
List of articles in the magazines

- "INFRASTRUKTURA"  A.G. Chmielewski:
  Ochrona środowiska zamiast gwiezdnich 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.
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)

- “Sympozjum Spuścizna naukowa Marii Skłodowskiej - Curie”, May 19-20, 2011, Poland A.G. Chmielewski:
  Promieniowanie jonizujące w ochronie środowiska

  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

List of lectures

- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia
  A.G. Chmielewski: *PM 2.5.*

- “PlasTEP Summer School”, July 11, 2010, Riga, Latvia

- “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*

  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

- 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.
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.
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 NOx 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).
"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”

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 Kaunus in 2012.
Companies cooperating with INCT

1. **EnerGoVision** Sanok, Poland, Mr. Antoni Dziuban

2. **Thermal Power Plant Svioza 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 Uniwersity**, 66 Jejudaehakno, Jeju, Korea 690-756, Mr. Young Sun Mok
Companies cooperating with INCT

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

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
Thank you for your attention.