New trends and developments in VOC removal with use of electron beam

Yongxia Sun
Contents

- VOCs introduction

- General mechanism for VOCs removal by electron beam (EB)

- VOCs Removal using Electron Beam
  - Aliphatic VOCs (mainly chlorinated compounds)
  - Aromatic VOCs (BTX, chlorinated benzene and toluene)

- New trend for VOCs Removal – (EB – Catalyst Hybrid System)
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**VOCs (Volatile organic compounds) introduction**

- Hazardous compounds
- They can cause
  - Ozone depletion in stratosphere and ozone formation in troposphere
  - Global warming chemicals
- Emitted from various industrial processes
Table 1. Main sources of VOC emission in the BSR countries in 2009 (Prof. Dors. M.)

<table>
<thead>
<tr>
<th>Sector</th>
<th>Country</th>
<th>Emission-2009</th>
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<td>3 A 2 Industrial coating application</td>
<td>Germany</td>
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<td>3 D 3 Other product use</td>
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<td>3 D 1 Printing</td>
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<td>3 D 3 Other product use</td>
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<td>59.49</td>
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<td>3 C Chemical products</td>
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<td>1 A 3 b i Road transport: Passenger cars</td>
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<td>3 D 2 Domestic solvent use including fungicides</td>
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(http://www.plastep.eu/fileadmin/dateien/Outputs/Emission_sources.pdf)
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General mechanism for VOCs removal by electron beam (EB)

Electron Beam (EB)

Base gas (e.g., air, H2O etc.)

Pollutants → e, ions, radicals

Residual pollutants, CO₂, other by-products
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VOCs Removal using Electron Beam

- Studied in lab scale since 1980’
- in batch and flow systems
- Aliphatic VOCs (mainly chlorinated compounds)
- Aromatic VOCs (BTX, chlorinated benzene, toluene and naphthalene)
VOCs Removal using Electron Beam (cont.)

- Aliphatic VOCs (mainly chlorinated compounds)
  - Chlorinated methane, chloroethylenes, 1,1,1-trichloroethane etc.
Investigated Cl-HC

1,1-dichloroethylene)  trans-dichloroethylene)  (cis-dichloroethylene

A. Aliphatic (and Isomers)

(1,4-dichlorobenzene)  (1-chloronaphthalene)

B. Aromatic
VOCs Removal using Electron Beam (cont.)

1,1-DCE, cis-DCE, trans-DCE decomposition vs. dose under EB-irradiation ($C_0$: 900~1000ppm)
Degradation-products formation expressed in terms of relative carbon concn. vs. dose in EB-irradiation for 903.8 ppm 1,1-DCE
Degradation products expressed as relative carbon concn. vs. dose in EB-irradiation for 957.0 ppm trans-DCE
Degradation products expressed as relative carbon concn vs. dose in EB-irradiation for 661.4 ppm cis-DCE
1,4-DCB decomposition in different gas mixtures
(initial concn of 1,4-DCB is about 50ppm)
1-Chloronaphthalene decomposition in air mixture under EB-irradiation
1-Chloronaphthalene decomposition in N\textsubscript{2} under EB-irradiation
VOCs Removal using Electron Beam (cont.)

Dependence of the removal efficiency of toluene and 4-chlorotoluene on the dose under EB radiation (initial concentrations of toluene and 4-chlorotoluene were 63.4 ppm and 51.9 ppm, respectively)
VOCs Removal using Electron Beam (cont.)

Dependence of the removal efficiency of toluene and 4-chlorotoluene on the initial concentrations of toluene and 4-chlorotoluene under EB radiation
By-products of 4-CT under EB irradiation

Gas phase

Solid phase
By-products of toluene decomposition under EB radiation
Removal efficiency of organic compounds from the simulated waste off-gas vs. dose under EB radiation
GC-MS spectrums of identified VOCs from the simulated waste off-gas before and after 3.5 kGy irradiation

- (0 kGy)
- (3.5 kGy)
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- New trend for VOCs Removal – (EB–Catalyst Hybrid System)
New trend for VOCs Removal – (EB–Catalyst Hybrid System)

• Increase removal efficiency of VOCs
• Diminish undesired organic by-products
• Active laboratories in this field (Japan, Korean)
New trend for VOCs Removal – (EB–Catalyst Hybrid System)

Factors influence on removal efficiency of VOCs, toluene as an example

• Hybrid reactor type
• Various catalysts and catalytic weight
• Support material
• Water vapor

Hybrid reactor type

Various catalysts and catalytic weight

The removal efficiency of toluene using the EB–catalyst coupling system with various catalysts.

Various catalysts and catalytic weight

The removal efficiency of toluene using the EB–catalyst coupling system with various catalysts.

Toluene removal efficiencies by support materials in a combined system: (a) Platinum (b) Palladium.

Water vapor

Relative humidity ranges from 40%-100%, no significant water effect on EB-catalyst hybrid system
VOC treatment by using electron beam with catalyst in INCT

• studied in batch system

• TiO$_2$/ γAl$_2$O$_3$ catalyst was used

• ILU-6 pulse accelerator (2 Mev, 60mA) was used for irradiation
Different concentration of toluene removal at 14.48 kGy absorbed dose
Pulse mode influence on toluene removal at the 43.45 kGy absorbed dose
Conclusions

• **VOCs can be decomposed under EB radiation.** Decomposition efficiency: heavy chlorinated > less-chlorinated, toluene > 4-chlorotoluene

• **Lower dose rate led to higher removal efficiency.**

• **EB-catalyst hybrid system is a new tread for VOCs treatment.**
  - Removal efficiency of toluene was increased by 30% using EB-catalyst hybrid system (at 1500ppmC Toluene, 8.7kGy).
  - Decrease of undesirable by-products as well as increase of CO$_2$ formation

• **Optimal parameters for EB-catalyst hybrid system**
  - The catalyst (Pt and Pd),
  - The economical weight (0.1 wt%)  
  - The support material (Zeolite)
Thank you for your attention 😊