Incineration Technologies (Including Costs)
Incineration for Hazardous Waste Disposal

1. Background of high temperature incineration
2. Types of commercially used high temperature incineration processes
3. Examples of state-of-the-art hazardous waste incinerators
4. Flue gas cleaning techniques for PCDD/PCDF removal
5. Performance of modern high temperature hazardous waste incinerators – actual flue gas emissions
6. Cost of high temperature hazardous waste incineration

Commercially Available Incineration Technologies
Background: Thermal Destruction of Organics in Air

Thermally less stable organic substances

Thermally very stable organic substances

$T_R$ = residence time

Concentration $C/Co$

Temperature $°C$

$T_R$ = 2 s

$T_R$ = 2 s

$T_R$ = 0.5 s

$T_R$ = residence time
Background: Destruction and Reformation of Organics

POPs-waste → rotary kiln / afterburner → quench cooler or heat recovery steam boiler → complete destruction by high temperature combustion → reformation of e.g. PCDD/PCDF from precursors → de-novo-synthesis of e.g. PCDD/PCDF → Residual emissions (e.g. PCDD/PCDF) to APC-train
High Temperature Incineration Technologies for Hazardous Waste Disposal:

1. Rotary Kiln Incineration
   - hazardous waste kiln incineration
   - cement kiln incineration
   - lime kiln incineration

2. Gasification
   - fixed bed gasification
   - BGL gasification
   - entrained flow gasification

3. Liquid Injection
   - injection
   - co-injection

Commercially Used Incineration Technologies
## Incineration Technologies

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<th>Incinerator Types</th>
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<th>Waste Types</th>
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<td>1100 - 1400 °C</td>
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<td>lime kiln*</td>
<td>1600 - 2000 °C</td>
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<td>gasification types</td>
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<td>gasification types</td>
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<td>L: liquids with solids = 5%wt.</td>
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<tr>
<td>S&lt;sub&gt;pu&lt;/sub&gt;: sludge, pumpable at ambient temperature</td>
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<tr>
<td>S&lt;sub&gt;np&lt;/sub&gt;: not pumpable at ambient temperature</td>
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<tr>
<td>S&lt;sub&gt;ut&lt;/sub&gt;: solids, untreated bulk type</td>
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<tr>
<td>S&lt;sub&gt;pt&lt;/sub&gt;: solids, pretreated granular type</td>
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<td>* typically limited in Cl-input</td>
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Emissions and Residues

1. **Bottom Slag:** vitrified glass type material for reuse (road construction, sand blasting etc.) or landfill

1. **Fly Ash:** for internal disposal (e.g. vitrification) or landfill

3. **Neutralized Salts:**
   - From wet flue gas cleaning:
     - HCl \( \rightarrow \) CaCl\(_2\), NaCl or HCl (disposal or recycling)
     - SO\(_2\) \( \rightarrow \) NaSO\(_4\) or CaSO\(_4\) (disposal or recycling)
     - Waste water treatment residue (disposal)
   - From semi dry flue gas cleaning
     - HCl/SO\(_2\)? CaCl\(_2\)/CaSO\(_4\)/CaSO\(_3\) mixture (disposal)

4. **Flue Gas Polishing Residues:**
   - Powdered activated carbon (PAC) / hydrated lime mix
   - Activated coke
     For Internal disposal (e.g. vitrification) or landfill

Background: Incineration Emissions and Residues
Destruction Efficiency for Organics and Performance of Hazardous Waste Incinerators depends on:

Primary combustion temperature = 1000 °C
Secondary combustion temperature = 1200 °C
O₂-content = 6 %vol. (typically ~ 10 %vol.)
Multi-stage flue gas cleaning system including at least one highly effective dedicated organics removal stage
As designed operation and maintenance at all times

Commercially Used Incineration Technologies
Examples: AVG Hamburg – Rotary Kiln Incinerator

- Rotary Kiln Units: 2
- Capacity Per Unit: 6 t/h
- Afterburner Temperature: 1100 – 1200 °C
- Final Product: electricity, steam, HCl, gypsum
- Residue: vitrified slag, WWTS
- Start of Operation: 1993
- Wastes Accepted: all types
- Pretreatment Needs: none
- Input Limitation: non-explosive, non-radioactive
Rotary Kiln Units: 2
Capacity Per Unit: 6 t/h
Afterburner Temperature: 1100 – 1200 °C
Final Product: electricity, steam
Residue: vitrified slag, mixed salts, WWTS
Start of Operation: 1989
Wastes Accepted: all types
Pretreatment Needs: none
Input Limitation: non-explosive, non-radioactive

Examples: HIM Biebesheim – Rotary Kiln Incinerator
Rotary Kiln Units: 2
Capacity Per Unit: 6 t/h
Afterburner Temperature: 1100 – 1200 °C
Final Product: electricity, steam, \( \text{CaCl}_2 \), gypsum
Residue: vitrified slag, WWTS
Start of Operation: 1981
Wastes Accepted: all types
Pretreatment Needs: none
Input Limitation: non-explosive, non-radioactive

Examples: RZR Herten – Rotary Kiln Incinerator
Rotary Kiln Units: 1
Capacity Per Unit: 6 t/h
Afterburner Temperature: 1100 – 1200 °C
Final Product: electricity, steam, HCl, gypsum
Residue: vitrified slag, WWTS
Start of Operation: 1996
Wastes Accepted: all types
Pretreatment Requirements: none
Input Limitation: non-explosive, non-radioactive

Examples: SAVA Brunsbüttel – Rotary Kiln Incinerator
Entrained Flow Gasifiers: 2
Capacity Per Unit: 5 t/h
Gasifier Reactor Pressure: atmospheric
Gasification Reagents: O₂, steam
Reducing Agent: natural gas, light fuel oil
Gasifier Temperature: 1,600 – 1,800 °C
Final Product: methanol (CH₃OH)
Residue: vitrified slag, WW, WWTS
Start of Operation: 1995
Wastes Accepted: liquid & sludge wastes only
Pretreatment Requirements: pumpable
Input Limitation:
- PCB: = 5 %wt. (= 50 g/kg)
- PCDD/PCDF: = 200 µgTEQ/kg
- halogens: = 6 %wt.
- solid content: = 5 %wt.
- non-explosive, non-radioactive

Examples: SVZ Schwarze Pumpe – Entrained Flow Gasifier
Examples: SVZ Schwarze Pumpe – Fixed Bed Gasifier

Fixed Bed Gasification Units: 7

Capacity Per Unit: 15 t/h

Gasifier Reactor Pressure: 25 bar

Gasification Reagents: O₂, steam

Reducing Agent: coal

Gasifier Temperature: 800 – 1,300 °C

Final Product: methanol (CH₃OH)

Residue: slag, WW, WWTS

Start of Operation: 1995

Wastes Accepted: solid wastes only

Pretreatment Requirements: granular < 150 mm

Input Limitation:
- PCB: = 0.5 g/kg
- PCDD/PCDF: none
- Halogens: none
- Non-explosive
- Non-radioactive
SVZ Schwarze Pumpe – Fixed Bed Gasifier

BGL-Gasification Units: 1
Capacity Per Unit: 30 t/h
Gasifier Reactor Pressure: 25 bar
Gasification Reagents: O_2, Steam
Reducing Agent: Coal
Gasifier Temperature: 1400 – 1600 °C
Final Product: methanol (CH_3OH)
Residue: vitrified slag, WW, WWTS
Start of Operation: 2003
Wastes Accepted: solid wastes only
Pretreatment Requirements: granular < 50 mm
Input Limitation:
  - PCB: = 0.5 g/kg
  - PCDD/PCDF: none
  - halogens: none
PCDD/PCDF Adsorption – Powdered Adsorbent Injection

raw gas (e.g. from boiler or spray absorber)

adsorbent (e.g. HOC)

fly ash, reaction products, spent adsorbent

clean gas to stack or additional gas cleaning process
PCDF/PCDD Adsorption – Activated Carbon Reactor (ACR)
PCDD/PCDF Adsorption – Fluidized Bed Adsorber
Performance of Incineration Technologies

Annual Average Emissions

- EU Emission Limit
- RZR Herten IM 1
- RZR Herten IM 2
- SAVA Brunsbüttel
- AVG Hamburg

mg/Nm³

PM | HCl | SO2 | CO | HC

Performance of Incineration Technologies
Performance of Incineration Technologies
Performance of Incineration Technologies

* All PCDD/PCDF emission analyses were performed by accredited laboratories
Cost of High Temperature Incineration for Hazardous Waste Disposal:

1. **Capital Cost:**
   - US$ 35 – 50 million (based on a 6 t/h throughput per unit for a new rotary kiln type facility)

2. **Operating Cost:**
   - highly dependent on heating value, ash, halogen and sulfur content of the waste

3. **Maintenance Cost:**
   - typically 3 – 5% of capital investment cost

Commercially Used Incineration Technologies
Prices for High Temperature Incineration of Hazardous Waste:

1. **High Heating Value Liquids:**
   - US$ 20 – 150 per metric ton

2. **Medium Ash, Medium Heating Value Liquids, Sludges and Solids:**
   - highly dependent on heating value, ash, halogen and sulfur content of the waste
   - typically US$ 250 – 500 per metric ton

3. **High Halogen Solids (e.g. Pesticides):**
   - US$ 1,000 – 1,500 per metric ton

Commercially Used Incineration Technologies