Predis
Treatment of problematic waste by Thermal Treatment Technologies
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Jan Deckers
Jurgen Hansen

Contact: jurgen.hansen@belgoprocess.be
Content

- Applicability of thermal treatment technologies
- Problematic waste
- Incineration
- Plasma technology
- Pyrolysis
# Applicability of thermal technologies to common waste types

<table>
<thead>
<tr>
<th>TECHNOLOGY</th>
<th>Organic</th>
<th></th>
<th>Inorganic</th>
<th></th>
<th>Mixed organic-inorganic</th>
<th></th>
<th>Spent resins</th>
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<tbody>
<tr>
<td></td>
<td>Liquids</td>
<td>Solids</td>
<td>Liquids</td>
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<td>Calcination</td>
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<td>High-temperature incineration</td>
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<td>A</td>
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<tr>
<td>Incineration</td>
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<td>NA *</td>
<td>A</td>
<td>A *</td>
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<td>Melting</td>
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<td>Molten salt oxidation</td>
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<td>NA</td>
<td>LA</td>
<td>LA</td>
<td>LA</td>
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<td>Plasma</td>
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<td>A</td>
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<tr>
<td>Pyrolysis</td>
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<td>Synroc</td>
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<td>Thermo-chemical treatment</td>
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<td>NA</td>
<td>A</td>
<td>NA</td>
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<td>Vitrification</td>
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<td>A</td>
<td>A **</td>
<td>NA</td>
<td>A **</td>
<td>A</td>
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<td>Wet combustion</td>
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<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>A ***</td>
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</tbody>
</table>

SOURCE IAEA TECDOC 1527

**Notes:**

- **A:** Technology is applicable to this type of waste
- **NA:** Technology is not applicable to this type of waste
- **LA:** Technology has limited applicability to this type of waste
- ***:** Small pieces of inorganic are acceptable without causing damage or plugging of the system
- ****: Applicable only for the granular or powder form of this waste type
- ****: Applicable only to organic spent resins
Criteria problematic waste

- Mostly mixtures of organic and inorganic waste
- No commonly available treatment methods for obtaining acceptable final products
Examples of problematic waste

- Institutional waste
  - universities, hospitals
- Sludges
  - mixtures organic/inorganic
- Organic liquids
  - mixtures organic/inorganic
- Drumed historical waste
  - insufficient knowledge of content
- Spent resins
- Bitumen waste
Incineration
### Well-known technology

- Well Known technology quite spread over the globe
- With adapting of incinerator or sorting out the waste, one can already treat the problematic waste

<table>
<thead>
<tr>
<th>Country</th>
<th>Facility/ Site</th>
<th>In-Service Date</th>
<th>Capacity</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Austria</td>
<td>Seibersdorf</td>
<td>1983</td>
<td>40 kg/h solid</td>
<td></td>
</tr>
<tr>
<td>Belgium</td>
<td>CILVA, Belgoprocess</td>
<td>1995</td>
<td>80 kg/h solid 50 kg/h liquid</td>
<td>Commerical Treatment: Solids, liquids and ion exchange resins</td>
</tr>
<tr>
<td>Canada</td>
<td>Ontario Power Generation</td>
<td>2002</td>
<td>2 t/d solid 45 l/h liquid (license limit)</td>
<td>Continuous feed, starved air system.</td>
</tr>
<tr>
<td>France</td>
<td>Socodei Centraco</td>
<td>1999</td>
<td>2000 T/yr solid 1100 t/yr liquid</td>
<td>Commercial LLW treatment facility</td>
</tr>
<tr>
<td>Germany</td>
<td>Karlsruhe</td>
<td>Since 1980's</td>
<td>40 kg/h liquids 50 kg/h solids</td>
<td>Solids and liquids</td>
</tr>
<tr>
<td>Japan</td>
<td>PNC, Tokai-Mura</td>
<td>1991</td>
<td>50 kg/h solid</td>
<td></td>
</tr>
<tr>
<td>Russia</td>
<td>TORCH, Sergiev Posad</td>
<td>1982</td>
<td>100 kg/h solid 30 l/h liquid</td>
<td>Solids and liquids</td>
</tr>
<tr>
<td>The Netherlands</td>
<td>COVRA, Vlissingen</td>
<td>1994</td>
<td>60 kg/h solid 40 l/h liquid</td>
<td>Two incinerators, one for liquids, one for animal carcasses &amp; other solids</td>
</tr>
<tr>
<td>Slovakia</td>
<td>Jaslovske Bohunice BSC</td>
<td>2001</td>
<td>50 kg/h solid 10 kg/h liquid</td>
<td>Used in campaigns for LLW</td>
</tr>
<tr>
<td>Spain</td>
<td>ENRESA El Cabril</td>
<td>1992</td>
<td>50 kg/h total solid &amp; liquid</td>
<td>Located at LLW disposal facility</td>
</tr>
<tr>
<td>Sweden</td>
<td>Studsvik</td>
<td>1977</td>
<td>150 kg/h total solid</td>
<td></td>
</tr>
<tr>
<td>Ukraine</td>
<td>Zaporozhye NPP</td>
<td>1993</td>
<td>40 kg/h solid 20 kg/h liquid</td>
<td>New incinerator similar as Belgoprocess</td>
</tr>
<tr>
<td>USA</td>
<td>Energy Solutions, Oak Ridge</td>
<td>1989</td>
<td>2 incinerators, 400 kg/h each</td>
<td>Commercial LLW treatment facility</td>
</tr>
</tbody>
</table>
CILVA incinerator at Belgoprocess site

- **Function of the facility:**
  - Uncompacted and compacted solid waste (PVC quantity 3%, high cal value 25 MJ/kg)
  - Frozen animal carcasses
  - Ion exchange resin
  - Organic liquids: scintillation liquids, organic solvents
  - Aqueous liquid whether or not containing sludges, complexing agents, organics
  - Spent oil (42 MJ/kg)

- **Capacity**
  - 8 ton/week solid waste → 100 h/week
  - 1 - 5 ton/week liquid waste

- **License**
  - 40 GBq/m³ beta-gamma emitters
  - 40 MBq/m³ alpha emitters
  - Max. dose rate each package: 2 mSv/h
Flow diagram

FIG.1: SCHEMATIC FLOW DIAGRAM

BELGOPROCESS
DR34617    REV.: 00
### Chemical emissions

<table>
<thead>
<tr>
<th></th>
<th>mg/Nm³ (1) corrected to 11% O2</th>
<th>EC Directive 2010/75/EC</th>
<th>CILVA</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Daily average values</td>
<td>Incinerator typical measurement campaign</td>
<td></td>
</tr>
<tr>
<td>Total dust</td>
<td>10</td>
<td>&lt;1</td>
<td></td>
</tr>
<tr>
<td>CO</td>
<td>50</td>
<td>16</td>
<td></td>
</tr>
<tr>
<td>TOC</td>
<td>10</td>
<td>&lt;2</td>
<td></td>
</tr>
<tr>
<td>HCl</td>
<td>10</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>HF</td>
<td>1</td>
<td>0,18</td>
<td></td>
</tr>
<tr>
<td>SO₂</td>
<td>50</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>NOX</td>
<td>400</td>
<td>190</td>
<td></td>
</tr>
<tr>
<td>Heavy metals</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \Sigma \text{ Cd, Ti} )</td>
<td>0,05 (2)</td>
<td>&lt;0,037</td>
<td></td>
</tr>
<tr>
<td>( \Sigma \text{ Hg} )</td>
<td>0,05 (2)</td>
<td>&lt;0,01</td>
<td></td>
</tr>
<tr>
<td>( \Sigma \text{ Sb, As, Pb, Cr, Cu, Mn, Ni, V, Sn} )</td>
<td>0,5 (2)</td>
<td>&lt;0,028</td>
<td></td>
</tr>
<tr>
<td>Dioxins and furanen : ng/Nm³</td>
<td>0,1 (3)</td>
<td>0,04</td>
<td></td>
</tr>
</tbody>
</table>

(1) Emissions are standardized at the following conditions: temperature: 273 °K; pressure: 101,3 kPa; 11 % O₂; dry gas
(2) average values over sample period min. 30 min. – max. 8 hours
(3) average values over sample period min. 6 hours – max. 8 hours
Intermediate storage burnable waste
Incinerator and off-gas system
Supercompaction ashes
Embedding supercompacted ashes in concrete
Embedding supercompacted ashes in concrete
Plasma technology
Plasma technology

- Due to the higher temperature of plasma, the range of applicable complex waste types is much more elaborate
  - Organic material is gasified
  - Iron, concrete, glass and other inorganic material is melted to form a slag
- Two industrial facilities in operation
  - Zwilag Zwitserland
  - SERAW Kozloduy NPP Bulgaria
Plasma technology: PMF (Plasma Melting Facility) at Kozloduy NPP

- Joint Venture Iberdrola Ingeniería and Belgoprocess N.V.
- New industrial facility
- EPC turn-key project funded by the EC and the Bulgarian government and ruled by EBRD
- Start up end 2018
Technological benefits

- One single process can treat many RAW streams
  - Applicable to solid organic and inorganic wastes, including asbestos
  - Drummed spent resins and liquid wastes

- Process fulfils ALARA principles
  - Waste packages can be treated “as is” and fed unopened without a need for pre-treatment or sorting out
  - Risks for contamination is eliminated and dose uptake is limited

- A robust waste form is obtained (similar to vitrification)
  - Free from any organic material and liquid/sludge
  - In accordance with the most WAC for long-term storage and disposal
  - Suitable to recondition historical waste which does not meet WAC

- High volume reduction factor
Kozloduy NPP radwaste types to be treated

- **Capacity:** 65kg/h or 250 tons/year
- **Untreated waste:** organic waste in bags
- **Pre-compacted waste:** mixture of organic/inorganic in 200-liter steel drums
- **Supercompacted waste:** organic, wood, concrete, insulation
- **Liquid waste such as oils**
- **Spent resins**
- **Typical activity:** 3.23E+05 Bq/kg
Flow diagram of PMF

- Conveying, shredding and feeding system (A)
- Primary Treatment chamber with Plasma system (B)
- Slag collection and cooling system (D)
- Off-gas cooling and cleaning system (C)
Kozloduy plasma facility

- Primary chamber with plasma torch and secondary chamber

Pictures courtesy of SE-RAW.
Kozloduy plasma facility
Kozloduy plasma facility
Kozloduy plasma facility

- Parts of off-gas and torch cooling unit

Pictures courtesy of SE-RAW.
Kozloduy plasma facility
Taking into nuclear operation of the PMF at KNPP

- May 2018 taking into nuclear operation of the Plasma Melting Facility (120h test). Treated waste:
  - Concrete, building debries in steel drums
  - Mixtures of organic waste and inorganic waste in steel drums
  - Drum with organic waste (wood, plastics, textiles, PVC, etc)

- IN: 57 drums or 6,4 ton
  OUT: 7 molds with slag
- Real $VRF=9,6 \Rightarrow$ required $VRF=5,7$
- Releases (chemical and radiological) in chimney and waste water well within operational limits

- Nov 2018 - Dec 2020: 330 tons radioactive waste treated
  - Outgoing about 65m³ or VRF: 26
Plasma tests problematic waste

- Test facility, Phoenix Solutions, USA
  - With torch up to 1,200 KW
- Full-scope tests with 200 l drums containing conditioned waste:
  - Simulated homogeneous concrete waste containing concentrates or resins
  - Simulated bitumen drums (SBD)
Tests with simulated bitumen drums

- **Goal**
  - Analysis of the obtained slag in relation to final repository: free of organics
  - Demonstration of the plasma process (full scale)
  - Parameterization in relation to process time, VRF

- Drums have to be fragmented. Feeding drums ‘as is’ gives too high energy release and too large instantaneous flue gas volume

- Shredding of the drums with available shredder
Test facility, Phoenix Solutions, USA
Composition simulated bitumen drums

- Gross mass: 250kg per drum
- Each drum contains about 140kg bitumen; saldo are stones, sand, compacted drums with filters, plastic, rags, etc.
Preparation simulated bitumen drums

- 6 SBD drums
- After shredding, the residues are collected in 30- or 55-gallon drums and transported to the plasma furnace
Result simulated bitumen drums

- Slag coming from the 6 SBDs including the steel drums:
  - VRF 8,8
  - Free from organic components
Test with conditioned concrete drums

- **Goal**
  - Analysis of the obtained slag in relation to final repository
  - Demonstration of the plasma process (full scale)
  - Parameterization in relation to process time, VRF, power

- **Simulated waste prepared by the customer (NIRAS/ONDRAF)**
  - 4 drums with homogeneous mixture concrete and concentrates
  - 2 drums with homogeneous mixture concrete and resins

- **Results from tests**
  - Tests where carefully monitored (traceability) and sent back to Belgium for further analysis → first analysis gives positive results (leachability, similar to vitrification)
Typical result concrete with concentrate
Conclusions concrete drums

- Successful tests
  - Melting of simulated drums
  - Pouring of the molten slag and collection of the solidified slag material
  - Transport back to Belgium for further analysis
- Drums can be fed ‘as is’ without additives
- **Volume Reduction Factor** from the simulated concrete drums is:
  - 1.3 for concrete and concentrates
  - 1.5 for concrete with the spent resins
PRIME
Pyrolysis Resins In Mobile Electric Installation
Pyrolysis of medium level waste (MLW) spent resins

- Due to
  - ALARA principles
  - Dose uptake
  - Investment costs
- Spent resins with dose rate >2mSv/h MLW are mostly treated with more conventional methods such as
  - Homogeneous cementation, drying, supercompaction and mixing with polymers
- Worldwide problem to find good acceptable conditioning technique:
  - Volume Reduction Factor (VRF)
  - Acceptance criteria
- Limited experience with thermal treatment technologies for MLW types
PRIME - Goals and Multiple benefits

- **Construction of a pilot plant at Montair in The Netherlands as co-investment Belgoprocess - Montair**
  - End of construction: June 2017
- Inert end product, free of organics
- Easy process & operation: 'as is'
- Safe
- Compact design
- Representative throughput
- All on electrical power
  - Incl. thermal oxidizer
- Easy process & operation: remote controlled
PRIME - Goals and Multiple benefits

- Compact skid mounted design in to cope with dose rates
- Representative throughput
- Low temperature process (max 600°C) to minimise carry over of semi volatile isotopes
- Small footprint
  - Transportable in 20ft containers
- Proven new technology
- Attractive price
Pyrolysis of medium level waste (MLW) spent resins
PRIME installation
PRIME installation
PRIME - Process figures

- Batch process: 100l/batch
  - 2 batched / 24 hours
- Batch input: dry or Soaked wet resins
- Drying and pyrolysis process up to 550°C
  - Within 8h
- Remaining substance after 8h:
  - 13.5kg ashes or MRF = 8
  - 15l ashes or VRF = 7
- Confirmation performance of electrical oxidizer:
  - No CO production (<10mg/Nm³)
- In off-gas a lot of SO₂ (sulphur coming form the cation resins) → due to thermal decomposition of the resins

Soaked /wet resins
Continuing ongoing tests and research (2020-2021)

- Optimilisation of the process
  - NoX reduction in oxidizer

- Pyrolysis of other organic products
  - Charged resins
  - Organic absorbents
  - Sludges or liquids
  - Organics

- Testing with tracers
- Dose calculations
**Conclusions PRIME**

- All results are positive from start
  - Performance of pyrolizer
  - Performance of oxidizer
- Designed capacity of about 200l / 24h is reached
- VRF = 7; MRF = 8
- No swelling of end product
- Complete internal pyrolysis ashes
  - Graphite like product
- Promising new technology
- Nuclearisation Q4 2021
- Patent pending
Conclusions problematic waste

- With sorting out and preparation work, parts of the problematic waste can be treated by **incineration**
- With **plasma technology** practically all problematic waste and even already conditioned waste can be treated ‘as is’
- Compact **pyrolysis** process is practical for medium level waste types such as spent resins
Commercial
At Commercial base

- Treatment of foreign waste in our facility’s
- Decommissioning works
- Waste management services
- Implementing thermal treatment technology’s like;
  - Incineration
  - Plasma technology
  - Pyrolysis
Thanks for your attention