Recycling of Metallic Residues with NORM Contamination by Melting

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Siempelkamp Nukleartechnik GmbH, Krefeld, Germany
Agenda

- Siempelkamp Group
- Recycling Business
- GERTA Plant
- Waste Management
- Lessons Learned
- Radiation Protection
- Summary
Siempelkamp Group

Siempelkamp Group
Figures 2011 (Mio. €)
Order intake: 327.4
Turnover: 705.7
Employees: 3,305

Nuclear Technology
Figures 2011 (Mio. €)
Order intake: 121.6
Turnover: 107.0
Employees: 600

Machinery

Foundry

Nuclear

Recycling
Siempelkamp Recycling Business

CARLA
Centrale Anlage zum Recycling Leichtaktiver Abfälle

- start of operation in 1989
- melting plant approved according to § 7 of the German Radiation Protection Ordinance for the treatment of radioactive materials
- annual capacity: 4,000 Mg
- artificial radioactive material

GERTA
Grosstechnische Einrichtung zum Recycling Toxischer Abfälle

- start of operation in 1998
- melting plant licensed according to BImSchG (German federal immission control act)
- annual capacity: 2,000 Mg
- NORM, Hg, Asbestos, PCB, PCDD/F

Purpose
Recycling, decontamination, secure inclusion of remaining activity
• designed for melting steel scrap of all qualities
• accredited waste management company
• capacity 2,000 Mg/year
Clients

- **Petrochemical**
  Exploration and production of oil and gas

- **Chlorine**
  Chlorine gas production using the mercury process

- **Tungsten**
  Manufacture of welding electrodes and filaments

- **Fertilizer**
  Production of phosphorous fertilizer

- **Pigment / Paper**
  Production of aggregates for building materials and colors
Acceptance Criteria

- Metal > 95 weight %
- NORM individual check (1 mSv/y)
- Mercury < 1 weight %
- Organics < 5 weight %
- Asbestos < 0.1 weight %
- PCB < 50 mg/kg Σ
- PCDD/F < 10,000 ng/kg

<table>
<thead>
<tr>
<th>Waste Code Number</th>
<th>Kind of Waste: Designation according to AVV (* hazardous wastes)</th>
<th>Restrictions</th>
<th>Activity according to EfbV</th>
</tr>
</thead>
<tbody>
<tr>
<td>05 07 01*</td>
<td>mercury containing sludges, here only mercury containing tubes and components The acceptance of sludges is specifically prohibited.</td>
<td>Limitation: Hg-share &lt; 1 %</td>
<td>Storage, treatment and recycling</td>
</tr>
<tr>
<td>06 04 04</td>
<td>mercury containing wastes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>06 04 99</td>
<td>wastes a. n. g.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>06 07 01*</td>
<td>asbestos containing wastes from electrolysis</td>
<td>asbestos share &lt; 0.1 %</td>
<td></td>
</tr>
<tr>
<td>06 13 04*</td>
<td>wastes from asbestos processing</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 01 04</td>
<td>packagings of metal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15 01 10*</td>
<td>packagings containing residues of hazardous materials or being polluted by hazardous materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 02 09*</td>
<td>transformers and condensors, containing PCB</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16 02 12*</td>
<td>used equipment containing free asbestos</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 04 05</td>
<td>iron and steel</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 04 07</td>
<td>mixed metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>17 04 09*</td>
<td>metal wastes, being polluted by hazardous materials</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 12 02</td>
<td>iron metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>19 12 03</td>
<td>non-iron metals</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Technical Data

Storage Capacity

500 Mg outside on sealed areas
200 Mg inside in 3 bunkers
contamination specific

Dismantling

thermal: 75 KW
up to 100 mm
separately exhausted

mechanical: 650 Mg
800 mm width
Technical Data

**Furnace**
- 8 Mg capacity
- induction furnace
- 1,350°C - 1,550°C
- charging device
- exhaust system

**Off-Gas Processing**
- cyclone
- air cooler
- fabric filter
- fixed bed absorber
- 28,500 m³/h in two systems
### Material / Nuclide Distribution

#### Concentration of radionuclides in the waste streams

**Delivery** 100 %

**Melting** 100 %

- **Metal** 95 %
- **Slag** 3 %
- **Dust** 2 %

<table>
<thead>
<tr>
<th>Nuclides</th>
<th>Melt</th>
<th>Slag</th>
<th>Dust</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-238, U-235</td>
<td>1 %</td>
<td>98 %</td>
<td>1 %</td>
</tr>
<tr>
<td>Th-232, Th-234</td>
<td>&lt; 1 %</td>
<td>&gt; 98 %</td>
<td>1 %</td>
</tr>
<tr>
<td>Ra-226, Ra-228</td>
<td>-</td>
<td>98 %</td>
<td>2 %</td>
</tr>
<tr>
<td>Pb-210</td>
<td>-</td>
<td>7 %</td>
<td>93 %</td>
</tr>
<tr>
<td>Po-210</td>
<td>-</td>
<td>2 %</td>
<td>98 %</td>
</tr>
</tbody>
</table>
Metal Reuse

- metal ingots of one ton each
- free of contamination
- for reuse in steel works
Slag Disposal

Radiological expert opinion in 2002 (Thierfeld, S., Wörlen, S.)

Input:

- **Scrap input (1000 Mg/y total):**
  - 775 Mg/y from oil and gas industry
  - 75 Mg/y from fertilizer industry
  - 75 Mg/y from paper industry
  - 75 Mg/y tungsten material

- **Slags from melting NORM**
  - maximum 100 Mg/y

- **Slag Disposal**
  - continuous discharge for recycling
  - maximum 8 Mg per batch
  - mixing ratio at least 1 : 4

- **Recycling Method**
  - recycling to road construction material on landfill sites

Output:

<table>
<thead>
<tr>
<th>Nuclide</th>
<th>Specific activity [Bq/g]</th>
<th>Annual activity $[10^9$ Bq]</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-238sec</td>
<td>21</td>
<td>8.4</td>
</tr>
<tr>
<td>Th-232sec</td>
<td>15</td>
<td>6</td>
</tr>
<tr>
<td>Ra-226+</td>
<td>25</td>
<td>10</td>
</tr>
<tr>
<td>Pb-210++</td>
<td>40</td>
<td>16</td>
</tr>
</tbody>
</table>

In compliance with the above stated values, the 1 mSv/y criterion is given for slag recycling.
Radiological expert opinion in 2000 (Urban, M.)

**Input:**

- **Filter Dust to be disposed off**
- **Underground Depository**
  - **Mine Air**
  - **Exhaust Air of pit**
  - **Direct Radiation**
  - **Inhalation**
  - **Inhalation**
  - **Depository staff**
  - **Population**

**Output:**

- Maximum 100 Mg per year
- Max. 70 Bq/g in total (relating to U-238sec, Th-232sec, Ra-226+ and Pb-210++)
- Exposure to staff << 10 µSv/y due to direct radiation and inhalation
- Unintended exposure to staff due to damaged drum < 10 µSv by ingestion
- Geological Radon concentration inside the cavern: 70 – 150 Bq/m³,
- Increase of Radon concentration inside the cavern due to disposal of 25 Mg/y only 1 Bq/m³ (within natural deviation)

- Dumping of 2 x 160 pcs. 200 l drums per year
- Containing mercury and NORM
Experiences (quantitative)

- Recycling of 20,000 Mg in 14 years
- 6,200 Mg of NORM
- 18,500 Mg clean steel returned
- 1,000 Mg of slag successfully recycled
- 600 Mg of filter dust disposed
### Experiences (radiological)

<table>
<thead>
<tr>
<th></th>
<th>Oil / Gas</th>
<th>Tungsten/Thorium</th>
<th>Phosphate</th>
<th>Paper</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amount</td>
<td>~ 4,800 Mg</td>
<td>~ 800 Mg</td>
<td>~ 400 Mg</td>
<td>~ 200 Mg</td>
</tr>
<tr>
<td>Contamination</td>
<td>NORM</td>
<td>NORM</td>
<td>NORM</td>
<td>NORM</td>
</tr>
<tr>
<td>Mercury</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>NORM decay chain</td>
<td>Ra-226++</td>
<td>Th-232sec</td>
<td>U-238sec</td>
<td>Ra-226++</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>U-235+</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Th-232sec</td>
<td></td>
</tr>
<tr>
<td>Specific activity of adherences</td>
<td>Up to 250 Bq/g, Ø 10 Bq/g</td>
<td>Up to 65 Bq/g, Ø 12 Bq/g</td>
<td>Up to 130 Bq/g, Ø 60 Bq/g</td>
<td>Up to 250 Bq/g, Ø 3,5 Bq/g</td>
</tr>
</tbody>
</table>

- no remaining activity in the metals
- complex geometries easily decontaminated
- safe inclusion of activity in an eluate permanent matrix
- reliable and tolerant of variable NORM characteristics
- high recycling quota, up to 95 %
Investigation of the SNT GERTA process due to the requirements of § 97 of the German Radiation Protection Directive

- How much is the dose for the workers in GERTA while processing NORM contaminated metal scrap?

- Is the dose probably more than 1 mSv per year?

- To ascertain, if this limit is exceeded, a lot of various dose measurements were necessary.

- Data were recorded during three measurement campaigns involving dismantling and melting of NORM material from oil- and gas production industry and tungsten industry.
Dose Measurements

Estimation of personal dose while processing NORM contaminated metal scrap

Rainer Kreh, Siempelkamp Nukleartechnik GmbH, Krefeld
Shaheen Dewji, University of British Columbia, Vancouver, Canada

5th International Symposium on Naturally Occurring Radioactive Material
March 19th-22nd, 2007, Seville, Spain
Time Statistics

Part of the daily worktime
In the melting area

- Melting hall 3,43 hrs
- Furnace control 1,72 hrs
- Pouring and slag removal 1,11 hrs
- Exhausting system 0,46 hrs
- Internal transports 0,23 hrs
- Outdoor 0,71 hrs
- Sundries 0,47 hrs

41%
21%
9%
6%
3%
14%
6%

Part of the daily worktime
In the dismantling area

- Dismantling hall, shear 3,48 hrs
- Thermal cutting room 2,26 hrs
- Internal transports 0,68 hrs
- Outdoor 0,96 hrs
- Sundries 0,61 hrs

44%
28%
12%
8%
8%
### Calculated annual dose rates for the main working areas

(related to a ratio of NORM and non-NORM contaminated material of 1:1)

<table>
<thead>
<tr>
<th>Method</th>
<th>Cutting [mSv/y]</th>
<th>Melting [mSv/y]</th>
<th>calculated annual Dose [mSv/y]</th>
</tr>
</thead>
<tbody>
<tr>
<td>personal EPD</td>
<td>0.04</td>
<td>0.10</td>
<td>0.14</td>
</tr>
<tr>
<td>workplace EPD</td>
<td>0.03</td>
<td>0.26</td>
<td>0.29</td>
</tr>
<tr>
<td>TLD</td>
<td>0.07</td>
<td>0.21</td>
<td>0.28</td>
</tr>
</tbody>
</table>

- PPE not considered
- Incorporation dose not relevant
- Excretion analytics showed values below detection limits
- Currently stationary thermo luminescence dosimeter at work place, monthly evaluation.
No Harm to Workers, Public and Environment

- more than 20,000 Mg of contaminated material recycled
- more than 6,200 Mg of NORM Scrap
- safe inclusion of activity in an eluate permanent matrix
- process reliable and tolerant of variable NORM characteristics
- process completely compliant to the 1 mSv/y criterion
- intensive working place studies and monitoring
- limited acceptance amounts
- limited disposal amounts
- fixed activity budget
- reviewed waste management for secondary wastes
Thank you for your Attention!

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