End-of-Waste criteria for NORM residues in Belgium: examples and challenges
NORM regulations in Belgium

Belgian NORM regulations => Royal Decree of July, 20 2001

Art.4 : list “work activities involving natural radiation sources”
  > initially based on restricted list of activities
  > since 2020, = any work activity dealing with material with AC > Exemption levels

Art.9 : industries are submitted to declaration

Objective of declaration: dose-impact assessment (workers and population)

⇒if possibility to exceed 1 mSv/a, corrective measures or licensing
NORM regulations in Belgium

⇒ Use of clearance/exemption levels of EC document “Radiation Protection 122 II”

Derived from a dose criterion of **0.3 mSv/a**

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Clearance/exemption levels (Bq/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>U-238sec (incl. U-235sec)</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.1 (mono-landfill)</td>
</tr>
<tr>
<td>U nat</td>
<td>5</td>
</tr>
<tr>
<td>Th-230</td>
<td>10</td>
</tr>
<tr>
<td>Ra-226+</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.1 (mono-landfill)</td>
</tr>
<tr>
<td>Pb-210+</td>
<td>5</td>
</tr>
<tr>
<td>Po-210</td>
<td>5</td>
</tr>
<tr>
<td>Th-232sec</td>
<td>0.5</td>
</tr>
<tr>
<td></td>
<td>0.1 (mono-landfill)</td>
</tr>
<tr>
<td>Th-232</td>
<td>5</td>
</tr>
<tr>
<td>Ra-228+</td>
<td>1</td>
</tr>
<tr>
<td>Th-228+</td>
<td>0.5</td>
</tr>
<tr>
<td>K-40</td>
<td>5</td>
</tr>
</tbody>
</table>

If AC < clearance: no additional constraints for residue management (**exception**: mono-landfill)
⇒ clearance from further surveillance

If AC > clearance: follow-up necessary
⇒ NORM residues treatment facilities must notify FANC
(NB: also applies to reuse/recycling activity)

⇒ **Acceptance criteria** in function of type of treatment
## Reference values for acceptance criteria

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Activity concentration</th>
<th>Input (single batch of residues)</th>
<th>Output (after residue processing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Co-)incineration</td>
<td></td>
<td>( C_{\text{exemption}} )</td>
<td>RP 122 II</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( C_{\text{max}} )</td>
<td>10 Bq/g</td>
</tr>
<tr>
<td>Building materials</td>
<td></td>
<td>( C_{\text{exemption}} )</td>
<td>RP 122 II</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( C_{\text{max}} )</td>
<td>10 Bq/g</td>
</tr>
<tr>
<td>Other uses</td>
<td></td>
<td>Case by case (dose assessment &lt; 0.3 mSv/y)</td>
<td></td>
</tr>
</tbody>
</table>

- Activity index (building)
- RP 122 II (road construction)

⇒ **2022**: 11 sites authorized for **disposal** of NORM residues

But only few notifications regarding recycling / reuse
Interface with other regulations

Waste regulations
(Waste framework directive 2008/98/EC)

Radiation Protection
(BSS directive 2013/59/euration)

Construction Products
(Construction Products Regulations EU 305/2011)

NORM residues

REACH
Waste Framework Directive


Art. 4 => waste hierarchy (ladder of Lansink)

```
A  Prevent
B  Reuse
C  Recycle
D  Energy
E  Incinerate
F  Land fill
```

“Member States shall take measures to encourage the options that deliver the best overall environmental outcome”

⇒ Specific waste streams may depart from the waste hierarchy
Waste Framework Directive: end-of-waste criteria

Art. 6: “End-of-waste” criteria => specify when a waste become a secondary raw materials

⇒ “The criteria shall include limit values for pollutants where necessary and shall take into account any possible adverse environmental effects of the substance or object”

⇒ Methodology to derive end-of-waste criteria developed by Joint Research Centre (JRC) [http://ec.europa.eu/environment/waste/framework/end_of_waste.htm]

- For some specific waste streams (metal scrap, glass)
  ⇒ end-of-waste criteria fixed at European level

- Other streams
  ⇒ «end-of-waste» certificate delivered by national/regional waste authority upon application by waste producer
End-of-waste application

Radioactivity not integrated in end-of-waste criteria → 2 parallel regulations

Waste authority
Assessment of end-of-waste application

Waste producer
Application for end-of-waste status
Delivery end-of-waste certificate

Radiation Protection authority
Assessment of dose-impact

consultation
notification
Authorization

Reuse / recycle
Transboundary aspects

Calcium silicate slag from thermal phosphorous production
⇒ Used in the Netherlands e.g. as road bed or dykes construction material
(see e.g. IAEA SRS 78 “Radiation Protection and management of NORM residues in the phosphate industry)
⇒ But “end-of-waste” certificate delivered at national level
⇒ “end-of-waste” has to be demanded in each country of use
⇒ Dutch producer of calcium silicate slag asked for “end-of-waste” certificate to Belgian (Flemish) waste authority
⇒ Waste authority asked advice FANC on radiation protection aspects
⇒ Favourable advice FANC
⇒ Delivery of end-of-waste certificate for reuse of calcium silicate slag in Belgium
Example of reuse/recycling in Belgium: phosphogypsum

**Active phosphate factory (sulfuric acid process)**

⇒ More than 80% of PG is reused: most of it as **building material** (plaster) + additive for **cement-industry** and **soil amendment**

⇒ excess of PG disposed onto stack

⇒ Reporting radioactivity level to FANC

⇒ Use essentially magmatic phosphate

⇒ Low-content of radioactivity (I < 1)

Application for end-of-waste status to the local waste authority

⇒ **Positive advice FANC**
Reuse of filter-cakes from TiO$_2$ production

**HCl process:** two successive filtration / neutralization steps

⇒ **Two filter cakes** (AC: 100 – 700 Bq/kg U-238, Ra-226)

**First filter cake:**
- Used as additive in production of bricks
- ACI filter-cake > 1 but less than 5% in bricks
  (⇒ no issue for RP)

**Second filter-cake:**
- Used in layer of capping of nearby phosphogypsum stack and other landfill
- Reuse of **60 000 tons** of filter-cake each year
Recycling of NORM in non-ferrous metal production

Non-ferrous metal production in Belgium: Sn, Pb, Cu, Zn + Cr, Sb, Mo, Bi, Co, Ge, noble metals,…

Examples of secondary raw materials with significant NOR content:

<table>
<thead>
<tr>
<th>Raw material</th>
<th>Main nuclide of concern</th>
<th>Range of activity concentration (kBq/kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sn/Pb ingot from primary tin extraction</td>
<td>Pb-210, Po-210</td>
<td>Up to 600</td>
</tr>
<tr>
<td>Co concentrate</td>
<td>U-238 (without progenies)</td>
<td>0.1 up to 10</td>
</tr>
<tr>
<td>Copper / cobalt cement (from Zn or Co production)</td>
<td>U-238 (without progenies)</td>
<td>1 up to 50</td>
</tr>
<tr>
<td>Flue dust from primary Zn production</td>
<td>(Pb-210)</td>
<td>Up to 0.6</td>
</tr>
<tr>
<td>Leaching residues of flue dust from waste incineration</td>
<td>Pb-210</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Po-210</td>
<td>80</td>
</tr>
</tbody>
</table>
Recycling of NORM in non-ferrous metal production

No secular equilibrium in most of secondary raw materials

- Po-210 up to ~10 X Pb-210 (flue dust)
- uranium present without any progenies (copper cement)

Residues of one process are raw materials for another:
  e.g. copper cement = residue from Zn or Co production
  ⇒ used as raw material for Cu production

Also *non-NORM issues* (orphan sources or its consequences)
  ⇒ Several cases reported of Cs-137 contamination in some secondary raw material (e.g. flue dust)
Recycling / reuse of scrap metals

NORM contaminated scrap metals

- Significant quantities of scrap decontaminated in the context of major decommissioning projects
- High-pressure water-jetting and acid-bath technique

Decontamination and further recycling of small quantities (scrap yard) remains challenging

- Not cost-efficient
- Smelting of trivial quantities of contaminated scrap not accepted by operator from perception point of view
Conclusions

➢ Regulatory process for reuse/recycling of NORM is the same as for use of NORM as raw material (e.g. zirconia in tiles)
➢ Reuse / recycling involves parallel regulatory processes
➢ Delivery of « end-of-waste » certificate
➢ Several successful examples (phosphogypsum, TiO2 filter-cakes, secondary raw material metal industry)
➢ Reuse/recycling = balance between many factors
  ▪ technical feasibility;
  ▪ specifications by end-user;
  ▪ cost efficiency;
  ▪ acceptability by companies and public opinion;
  ▪ regulations & administrative burden.