Towards a holistic approach for risk assessment when reusing slag with enhanced NORM content in building materials

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NuTeC

Nuclear Technological Center (NuTeC, www.nutec.be)
Center of Environmental Studies (CMK, www.uhasselt.be/cmk)

Industrial Sciences: “Nuclear and environmental Engineering”
- Environmental Technology-Radiochemistry
- Medical Nuclear Technology

Application and development of nuclear measurement methods

Environmental and energy related research (pyrolysis)

EMR dosimetry
1. Taking into account NORM in the risk assessment?

2. Scientific approach NORM4Building network

3. Collaboration opportunities
NORM

Ore: ‘Naturally Occurring Radioactive Materials’

Processing

Residues with enhanced concentrations of NORM

Cassiterite (contains SnO₂)

Rutile sand (contains TiO₂)

Zirconium sand

Fly ash

Red mud

deposition in pipeline

Oil & gas industry
Metal processing: how radionuclides (U-238 decay chain) can behave during smelting?

(similar for decay chain of Th-232)
extraction of rare earths from monazite;
production of thorium compounds and manufacture of thorium-containing products;
processing of niobium/tantalum ore;
oil and gas production;
geothermal energy production;
$\text{TiO}_2$ pigment production;
thermal phosphorus production;
zircon and zirconium industry;
production of phosphate fertilisers;
cement production, maintenance of clinker ovens;
coal-fired power plants, maintenance of boilers;
phosphoric acid production;
primary iron production;
tin/lead/copper smelting;
ground water filtration facilities;
mining of ores other than uranium ore.

Including relevant secondary processes
Member States can add other relevant activities
## Reuse in building materials

<table>
<thead>
<tr>
<th>Residues from NORM processing industry (with interesting properties for reuse in building materials)</th>
<th>Codification EU-Waste Catalogue?</th>
<th>Estimated production (Milion Tons/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>coal fly-ash</td>
<td>001 02 or 10 01 16</td>
<td>44 (2003, EU 15)</td>
</tr>
<tr>
<td>slag and bottom ash from a coal-fired power plant</td>
<td>10 01 01 or 10 01 14</td>
<td>8 (2003, EU 15)</td>
</tr>
<tr>
<td>phosphorous slag from thermal phosphorus production</td>
<td>06 09 02</td>
<td>-</td>
</tr>
<tr>
<td>phosphogypsum from phosphoric acid production,</td>
<td>-</td>
<td>180 (2003, World)</td>
</tr>
<tr>
<td>red-mud, (bauxite residue), from alumina production</td>
<td>01 03 07</td>
<td>120 (2003, World)</td>
</tr>
<tr>
<td>unprocessed slag from primary iron production</td>
<td>10 02 02</td>
<td>260-310 (2011, World)</td>
</tr>
<tr>
<td>steel or stainless steel, lead slags</td>
<td>10 04 01</td>
<td>130-210 (2011, World)</td>
</tr>
<tr>
<td>copper slags, from primary and secondary production</td>
<td>10 06 01</td>
<td>24,6 (2009, World)</td>
</tr>
<tr>
<td>tin slags from primary and secondary production</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>specific residues originating from pyro- and hydro-metallurgies producing platinum group metals or rare earth elements</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

[1] Ecoba - SPECIAL PRINT CPI 04/06  
New Euratom-BSS in addition to CPR

Residues of NORM processing industry to be recycled in building materials?

**BSS Art. 75.2 + Indicative list in Annex XI + CPR**

![ACI formula]

\[ ACI = \frac{C_{Ra226}}{300} \frac{Bq}{kg} + \frac{C_{Th232}}{200} \frac{Bq}{kg} + \frac{C_{K40}}{3000} \frac{Bq}{kg} \]

**Index \( \leq 1 \)?**

Results may be requested by the regulatory authority

**TS 351014 + CPR art. 18 + BSS Annex VII & VIII**

![ACI values]

Based on a presentation by Stéphane Calpéna (EC-DG-ENER-D4), EU-NORM 2, Prague (2014)
• Materials including by-products or residues from NORM industries such as
  – fly ash,
  – phosphogypsum,
  – phosphorous slag
  – tin slag
  – copper slag
  – red mud (residue from aluminium production)
  – residues from steel production
Using NORM for building materials?

- Suitable chemical and physical properties?
  - (Pre)treatment of residues?
- Gamma exposure towards occupants?
- Indoor air quality?
  - Radiological and chemical noxes?
- End-of-life considerations?
  - Leachability?

A need to check under what conditions materials can be used and where!

Focus on reuse of residues in:
- Ceramic
- Cement
- Geopolymers
- Concrete
1. Taking into account NORM in the risk assessment?

2. Scientific approach NORM4Building network

3. Collaboration opportunities
Main objective ‘NORM4BUILDING’

- Exchange of multidisciplinary knowledge and experiences (radiological, technical, economical, legislative, ecological, ...)

Stimulate the reuse of NORM residues in new tailor-made sustainable building materials while considering exposure to external gamma radiation and the resulting indoor air quality.
COST - network
(Research and Technological development Framework Program)

• ORGANIZATION OF MEETINGS:
  – 12-13/02/2014  Israel, Dead Sea Hotel
    • Linked to INS conference
  – 16-17/06/2014  Czech Republic, Prague
    • Linked to EU-NORM 2 symposium
  – 17-18/09/2014  UK, Sheffield
    • Linked to 34th Annual Cement and Concrete Science Conference (CCS2014)
  – 11-12/06/2015  Austria, Vienna (upcoming)
    • Linked to the ICRM symposium
  – 8-9/10/2015     Belgium Leuven (upcoming)

• SHORT-TERM SCIENTIFIC MISSIONS
• TRAINING SCHOOLS
• PUBLICATIONS and DISSEMINATION

www.norm4building.org
Scientific focus working groups

Working Group 1
1. Studying **state of the art** in the reuse of NORM residues in building materials
2. Development of a **data base with good practices**

Working Group 2
1. Develop **new options** for tailor-made building materials to incorporate NORM residues.

Working Group 3
1. Improve **measurement capacity** for NORM containing building materials
2. **Standardization** of measurement protocols and development of (pre-)standards.

Working Group 4
1. Improving **dosimetric models** for a number of building scenarios.
2. Investigating the influence of different **legislative radioprotection scenarios**.
Norm4Building Database

Evaluation of practices

- Criteria for evaluation of practices were set.
- Gathering information on NORMs currently used for building materials
- Including representative national surveys

Information per entry

General information:
- By-product name; Industrial sector
- Country
- Total amount of by-product [Mt], Number of surveyed samples
- References

Chemical features

Radiological features
- Activity concentration (terrestrial isotopes: Ra-226; Th-232, K-40)
- Activity concentration index

Impact:
- NORM aspects are taken into account for reuse
- ’Good practices database’ as guideline for reuse for industry
Working Group 2
‘Options for new tailor-made building materials’

Industry → (Product) Residue → (Virgin raw materials) Residue → Building Material

Working Group 1
Study new develop options

- Analytical model with relation between % of virgin raw materials substituted and radiological content
- Recommendations on use secondary raw materials in geopolymers considering the radiological content.

Working Group 2
Radiological content linked to...

- Pretreatment of the raw materials
- Development and application of the building material
- Effect of inherent and engineered properties
Validated *(in-situ)* measurement protocols for:

a) Activity Concentration Index  
b) Radon (possibly thoron) emanation and exhalation rate

**Intercomparisons** using several measurements protocols and instruments

**Towards standardisation**

a) Proposal for a **calibration procedure**  
b) Steps in the development of **standard materials**

**Towards certification**

a) Factsheet for **unified certification procedure of construction materials**.

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**MetroNORM**  
Metrology for processing materials with high natural radioactivity
Improved (more realistic) dosimetrical models

For use of NORMs in
a) Cement
b) Concrete
c) Ceramics

Specific focus on use of NORMs in geopolymers.

Evaluation of implementation on market.

a) Round table discussions with all stakeholders
b) End-of-Life?
   • Leachability

Evaluation of legislation

a) Impact EU-BSS
b) Comparison of alternative national legislative scenarios
Towards a more realistic assessment of the radiological impact when using NORM in building materials?

- Experimental building material related parameters 
  ➔ modeling of impact NORM in building materials 
  1. Gamma dose estimation 
  2. Radon dose estimation 
  3. Leachability/breakdown modelling of radiological and chemical impact
1. Gamma dose estimation:

✓ Input parameters:
   1. Ra-226, Th-232 and K-40 activity concentration (measured)
   2. Density, thickness, information on structure of dwellings

✓ Steps in the modeling approach:
   3. Elaborated an index (ACI) accounting for density and thickness (done)
   4. Further development of indexes in order to consider the actual structure of dwellings (all concrete but 1 wall in bricks, etc...) (future)

→ Towards a more realistic screening, gamma dose modeling
2. Radon dose estimate

✓ Input parameters:
   1. Ra-226 activity concentration (input from database)
   2. Rn exhalation (new ISO standard)

✓ Steps in the modeling approach:
   3. Rn exhalation modeling
      ✓ Model of Rn exhalation for real life circumstances and important properties of building materials (decomposition, crack generation, porosity...)
   4. Rn activity concentration by modeling to account for ventilation, dwelling size, convection, ....
   5. Dose estimate
3. Leachability/breakdown modelling of radiological and chemical impact

✓ Input parameters:

<table>
<thead>
<tr>
<th>Leaching methods</th>
<th>Test</th>
<th>Standards</th>
<th>To investigate:</th>
</tr>
</thead>
<tbody>
<tr>
<td>➢ Method 1313 - Liquid-Solid Partitioning as a Function of Eluate pH using a Parallel Batch Procedure</td>
<td>pH dependence test</td>
<td>Construction products (CEN/TS14429)</td>
<td>In addition to other metals also: U, Ra, Pb and Po (Council Directives 1998/83/EC and 2013/51/EURATOM)</td>
</tr>
</tbody>
</table>

✓ Steps in the modeling approach:

- Modeling scenarios for important properties of building materials (mixtures, materials with different layers, carbonation, oxidation,...)
Leaching behavior rather similar between different materials in spite of their difference in composition.

Hans van der Sloot and David S. Kosson, Presentation at WG 4 sub group COST meeting, Hasselt 31/10/2014
Leaching studies

• Studies are available on heavy metals leaching from construction materials relative to the European drinking water Directive 98/83/EC
  – Example for paving concretes made with CEM III/A type cements (36–65% of slag) leaching tests (NEN 7345) show:
    • heavy metals leaching $<\text{parametric values (European Directive 98/83/EC)}$
    • The partial replacement of clinker with blast-furnace slag, within the limits defined in NBN EN 197-1 has little effect on the leaching behaviour of the concrete

• For the Leaching behaviour of natural occurring radionuclides relative to the COUNCIL DIRECTIVE 2013/51/EURATOM more study is required.


*COUNCIL DIRECTIVE 2013/51/EURATOM, 'laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption'
Towards a more realistic assessment of the radiological impact when using NORM in building materials?

- Experimental building material related parameters ➔ modeling of impact NORM in building materials
  1. Gamma dose estimation
  2. Radon dose estimation
  3. Leachability/breakdown modelling of radiological and chemical impact

Input for (expanded) life cycle assessment (LCA)
  - Taking into account NORM aspect in LCA
Reusing slag with enhanced NORM content in building materials

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Organization – collaboration

Management Committee

Advisory board:
- NORM processing and construction industries
- Regulators

Working Group 1
Working Group 2
Core Group
Working Group 3
Working Group 4

MetroNORM

European Alara Networks (EAN-NORM,...)
EU-NORM, European Commission working groups
(National) policy makers

Other COST actions
Inter-COST workshops?

• Eureka!
  5415 Newcomat
• FP7 Suscon,
  Leema and ASEE

Core Group

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MetroNORM

European Alara Networks (EAN-NORM,...)
EU-NORM, European Commission working groups
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Other COST actions
Inter-COST workshops?
Collaboration with industry

- Development of research and innovation projects to valorize NORM residues of industrial partners
- Workshops and round tables specifically for training of participants from industry
- Industrial partners get access to database of good practices
Collaboration in the Cost network

- 25 European countries + European Commission
- A strong variety of (so far) about 96 experts
Current status of the COST Network

Interested?
www.norm4building.org

Contact:
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