COMPARISON OF EXCESS RADIOLOGICAL RISK OF BUILDING MATERIALS AND INDUSTRIAL BY-PRODUCTS

According to I-index (EU-BSS) and revised room model (IAEA SSG-32)
INTRODUCTION OF REUSE OF BY-PRODUCTS IN BM PRODUCTION

The depletion of raw materials and development of low CO₂ emitting energy and material resources requires innovative solutions to develop new eco-innovative BMs.

The revised EU’s Waste Framework Directive with its objective to reach 70% of preparation for reuse, recycling and other forms for material recovery → main EU policy driver.

Although, the reuse of BPs could be beneficial in economical point of view the new types of synthetic materials are raising concerns among authorities, public and scientists.

To get an insight view into the radiological features of potentially reusable BPs a review of the reported scientific data and a proper dose assessment method are necessary.
INTRODUCTION OF BY-BM PROJECT

Gamma-dose
Th-232, K-40, Ra-226
and their progenies
External exposure

Rn/Tn exhalation
Rn-222 & Rn-220 Progenies
Internal exposure

Internal structure

Leaching
Toxic & radioactive compounds
Internal exposure
Geopolymer team in SPACE
• Experience geopolymer preparation & characterization
• Excellent university and infrastructure

Q
Queen's University
Belfast

By-BM GEOPOLYMERS
By-products and samples
CKD; PFA; GGBS
Full material character.
Mechanical and internal structure
Radiological character.
Gamma spect.; l-index; Rn-222 em/ex

NuTec in UHasselt
• Great experience in NORMs
• Excellent infrastructure for radiological characterization
• Leader of COST TU1301 NORM4Building Action

Dissemination
Public
Industry
Academic
Re-use of industrial by-products

The depletion of raw materials requires innovative solutions to develop new eco-innovative building materials from industrial by-products.

In some cases, components of building materials may affect human health and cause environmental risks. In addition to the potentially toxic compounds, the risk from the elevated level of natural radioactive isotopes cannot be ignored. These components can be found also in industrial by-products.

Although, the re-use of industrial by-products could be beneficial in an economical point of view the new types of synthetic materials are raising concerns among authorities, public and scientists.

As result of elevated indoor time, the isotopes found in dust can significantly contribute to radiation exposure in two ways:

- **External exposure**: The gamma radiation (extremely high frequency electromagnetic and ionizing radiation, and are thus biologically hazardous)
- **Internal exposure**: The inhaled radon (radioactive noble gas) and its progenies significantly augment the risk of the evolution of lung cancer 2nd risk after smoking. It can exhaled and accumulate in badly aerated spaces e.g. in buildings.

Geopolymers (synthesised inorganic material) can be alternative low-carbon binders produced with the re-use of industrial wastes.

The geopolymers are very promising for replacing traditional building materials.

Despite the fears from artificial radioactivity, the radiation exposure received by population originated mainly from natural sources which is several magnitudes higher than from nuclear industry.
Data was looking for with following conditions:

- **Individually reported sample information** about the Ra-226, Th-232 and K-40 were obtained by **gamma spectrometry**
- **Average results** were used only if the investigated material **originated from same site**, e.g. quarries, mines, brand, type of BM
- In several cases the U-238 activity concentration values were published
  - To avoid the disequilibrium in the decay chain the **data was imported** into the database only if the results were obtained from the Rn-222 progenies (Bi-214, Pb-214)
EU-BSS
COUNCIL DIRECTIVE 2013/59/EURATOM

- In the EU to control the gamma-exposure originated from BMs, the I-index is recommended for the member states to screen them
- **Identified types of BM, the activity concentrations** of primordial radionuclides Ra-226, Th-232 (or its decay product Ra-228) and K-40 shall be determined
- The I-index value of 1.0 can be used as a conservative screening tool for identifying materials that during their use would cause doses exceeding the reference level (1 mSv/y excess in addition to outdoor exposure) in the case of bulk amount inbuilt

\[
I = \frac{C_{Ra-226}}{300Bq/\text{kg}} + \frac{C_{Th-232}}{200Bq/\text{kg}} + \frac{C_{K-40}}{3000Bq/\text{kg}}
\]

- For application of the index to such constituents, in particular residues from industries processing NORM recycled into BMs, an appropriate partitioning factor needs to be applied
- The calculation of **dose needs to take into account** other factors such as density, thickness of the material and type of BMs (bulk or superficial)
I-INDEX VS. IAEA SSG32

The I-index (RP112)

- Fixed parameters of concrete building
  - Density and thickness of the walls are 2350 kg/m³, 20 cm, respectively
  - Room dimension: 4 m x 5 m x 2.8 m
  - Dose conversion factors: 0.7 Sv/Gy
  - Background dose rate 50 nGy/h
  - Annual exposure time: 7000 hours
  - Makes possible the screening

IAEA SSG32

- Dose assessments without computer calculations for the most typical construction arrangements
- The thickness of the wall and the density of applied BMs are also taken into consideration
- Summing the separately calculated dose rates due to walls, floor, and ceiling
- Background dose rate 60 nGy/h
- Dose conversion factors: 0.7 Sv/Gy
- Different occupancy factors (0.8 was used)
- Makes possible a dose rate calculation

IAEA SSG32 DOSE ASSESSMENT METHOD

- **Risica et al.** have carried out a sensitivity analysis concerning the effects of changes in the parameters for the room on the dose in the room and found the following results:

  - The absorbed dose rate in air was calculated as a function of room dimensions for a fixed height of 2.8 m and various widths and lengths of the room ranging from 2 m to 10 m were used, in both rectangular and square shapes.

  - The variation in the dose rate in air in relation to the position in the room was found to be limited to approximately 10% at a distance of up to 1 m from the walls.

  - The maximum variation in the dose rate obtained was 6% from the calculation for a room with a volume of 60 m³.
IAEA SSG32 DOSE ASSESSMENT METHOD

• The gamma dose rate is calculated in the middle of the standard sized room shown in Figure

• The effects of doors and windows will lower the dose rate by only a minor amount and so for simplicity doors and windows are not considered in the calculation

• In many cases, BMs themselves provide significant shielding against gamma radiation from the soil in the terrestrial background

• In the case of massive concrete structures, the shielding is almost complete

The absorbed dose rate in air in the room was calculated as a function of the wall, floor and ceiling thickness
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RESULTS
### Material name | # | Density kg/m³ | Material name | # | Density kg/m³
--- | --- | --- | --- | --- | ---
Aggregate | 9 | 1900 | Sandstone | 14 | 2323
Basalt | 3 | 3000 | Serizzo | 5 | 2650
Brick | 243 | 1900 | Sienite | 5 | 2700
Cement | 87 | 1500 | Asbestos tile | 4 | 1750
Ceramics | 94 | 2400 | Travertine | 9 | 2300
Concrete | 63 | 2350 | Tuff | 10 | 2100
Gas concrete | 37 | 700 | Volcanic | 7 | 1800
Granite | 297 | 2600 | Bottom ash | 59 | 700
Gypsum | 66 | 865 | Fly ash | 145 | 720
Limestone | 16 | 2600 | Manganese clay | 44 | 2800
Marble | 72 | 2550 | Phosphogypsum | 45 | 1500
Pumice | 3 | 650 | Red mud | 92 | 1600
Rock | 31 | 2300 | Steel slag | 41 | 2600
Sand | 19 | 1500 | Residue of TiO² | 5 | 4300

**Database content:**

- 48 countries
- 23 building materials (1095)
- 7 type of by-products (431)
- In case of the BMs the natural isotope content varied widely (Ra-226: <DL-27851 Bq/kg; Th-232: <DL-906 Bq/kg, K-40: <DL-17922 Bq/kg)
- More so than the BPs (Ra-226: 7-3152 Bq/kg; Th-232: <DL-1350 Bq/kg, K-40: <DL-3001 Bq/kg).
- **But the mean value of Ra-226, Th-232 and K-40 content of reported by-products were 2.52, 2.35 and 0.39 times higher in case of the BPs than the BMs, respectively**
I-INDEX >1.0
SUMMARY

• 48 countries → 23 building materials (1095); 7 type of by-products (431)
• The mean value of Ra-226, Th-232 and K-40 content of reported by-products were 2.52, 2.35 and 0.39 times higher in case of the BPs than the BMs, respectively
• Lot of data available but usually the range is reported
  • Missing information from developed countries
• Visualization of data is practical tool for demonstration of data
• To design BMs the I-index is not suitable
• The density consideration is indispensable for dose assessment
• In the case of low density range (<800 kg/m³) 60 % overestimation is expectable
SYMPOSIUM

“Use of by-products in construction: dealing with natural radioactivity”

FINAL Symposium COST NETWORK “NORM4Building”

More info @ www.norm4building.org

Venue: National Institute of Health Rome
Dates: 06-08th June 2017

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“The project leading to this application has received funding from the European Union’s Horizon 2020 research and innovation programme under the Marie Skłodowska-Curie grant agreement No 701932.”