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Marie Curie Research Fellow

By-BM Project H2020-MSCA-IF-2015

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Queen's University Belfast (QUB)

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H2020-MSCA-IF-2015

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MARIE CURIE ACTIONS

Queen's University Belfast

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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)

"The project leading to this application has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 701932"

CHALLENGES AND SOLUTIONS

2016 Rio

norm VIII

Eighth International Symposium on Naturally Occurring Radioactive Material – NORM VIII

Rio de Janeiro, Brazil, October 18 -21, 2016

INTRODUCTION OF REUSE OF BY-PRODUCTS IN BM PRODUCTION

- **The depletion of raw materials** and development **of low CO_2 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 assesment method are necessary**

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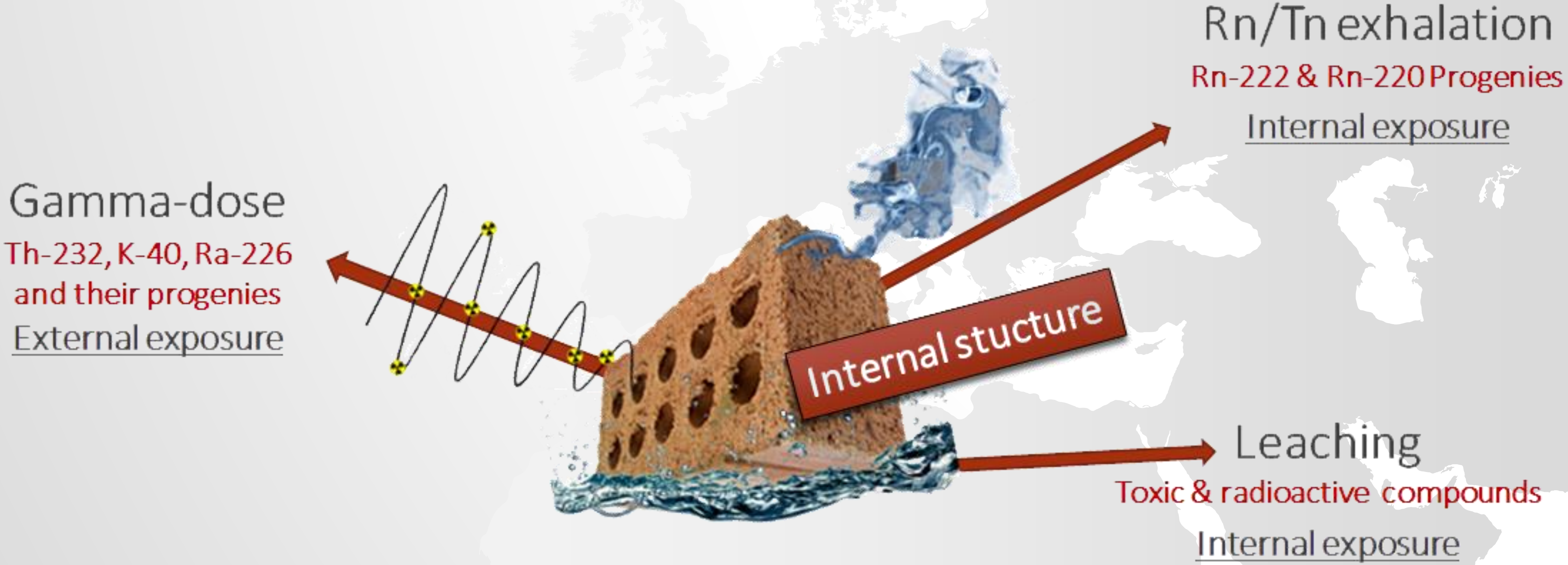
INTRODUCTION OF **BY-BM PROJECT**



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Geopolymer team in SPACE

- Experience geopolymer preparation & characterization
- Excellent university and infrastructure

universiteit hasselt KNOWLEDGE IN ACTION

NuTec in UHasslet

- Great experience in NORMs
- Excellent infrastructure for radiological characterization
- Leader of COST TU1301 NORM4Building Action

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By-BM GEOPOLYMERS

By-products and samples
CKD; PFA; GGBS

Full material character.
Mechanical and iternal structure

Radiological character.
Gamma spect.; I-index; Rn-222 em/ex

NORM4BUILDING

cost

Dissemination

Public

Academic

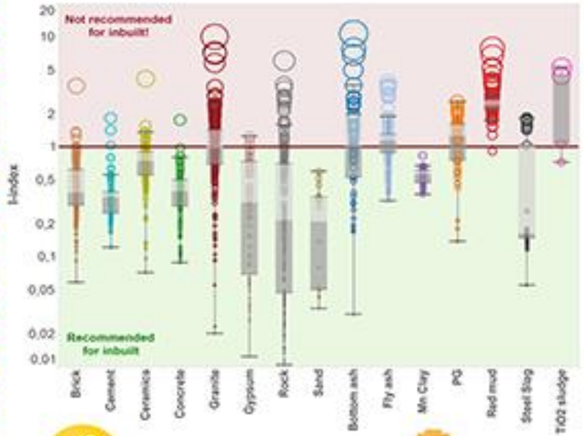
Industry

Reuse of industrial by-products

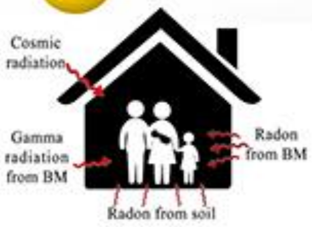
The depletion of raw materials requires innovative solutions to develop new eco-innovative building materials from industrial by-products

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

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

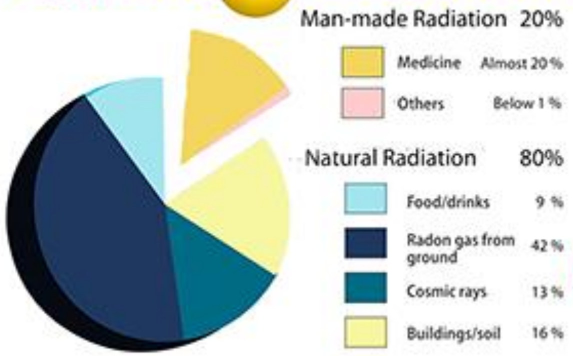


As result of elevated indoor time, the isotopes found in can significantly contribute to radiation exposure in two ways:



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 exhale and accumulate in badly aerated spaces e.g. in buildings



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.

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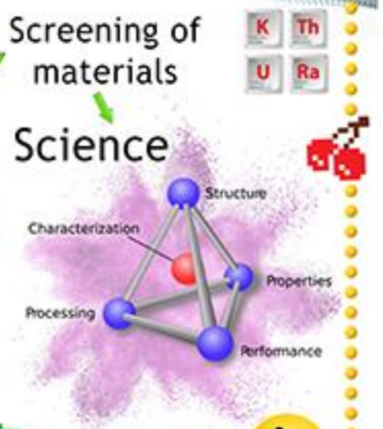
Screening of materials



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

The geopolymers are very promising for replacing traditional building materials

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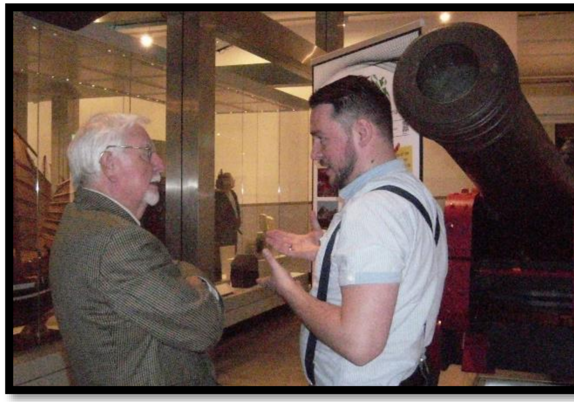
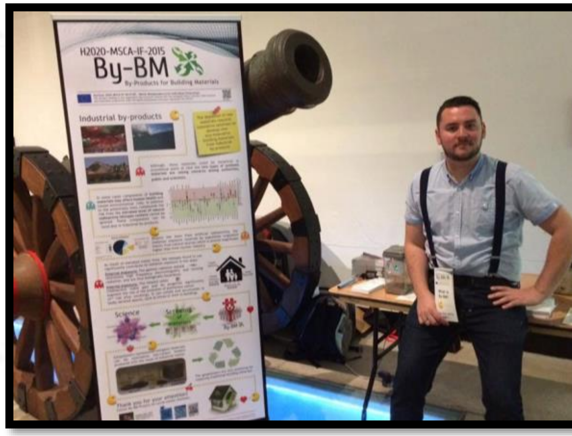
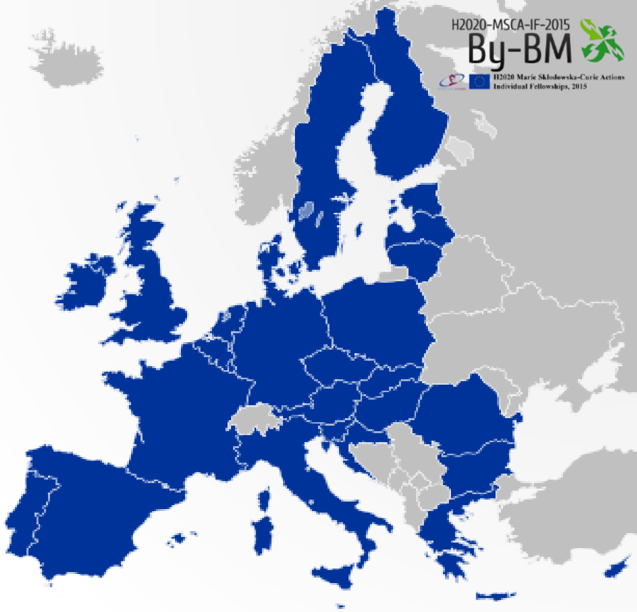




DATAMINING FOR **BY-BM DATABASE**

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

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

- 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 calculation methods based on the model of Markkanen
  - The reference level of 1 mSv/a used for buildings is defined as due to the 'excess exposure' caused by these materials above the exposure due to normal background levels of radiation

MARKKANEN, M., Radiation Dose Assessments for Materials with Elevated Natural Radioactivity, Publication STUK-B-STO 32, Finnish Centre for Radiation and Nuclear Safety, Helsinki (1995)0

The I-index (RP112)

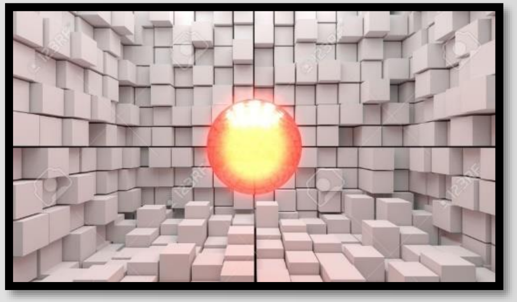
- Fixed parameters of concrete building
  - Density and thickness of the walls are 2350 kg/m^3, 20 cm, respectively
  - Room dimension: 4 m x 5 m x 2.8 m
  - Dose conversion factors: 0.7 Sv/Gy
  - Background dose rate 50 nGy/h
  - Annual exposure time: 7000 hours
  - Makes possible the **screening**

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 ASSESSEMENT 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 m^3

IAEA SSG32 DOSE ASSESSEMENT METHOD

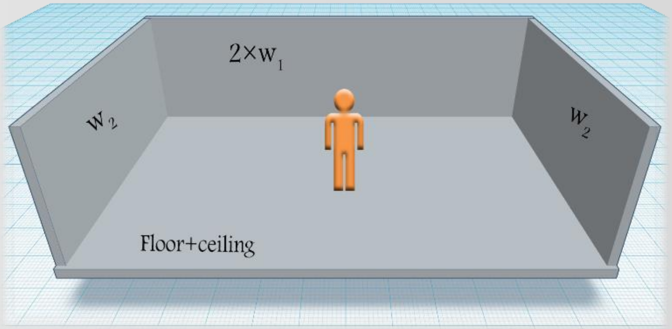
- The gamma dose rate is calculated in the middle of the **standard sized room** shown in Figure

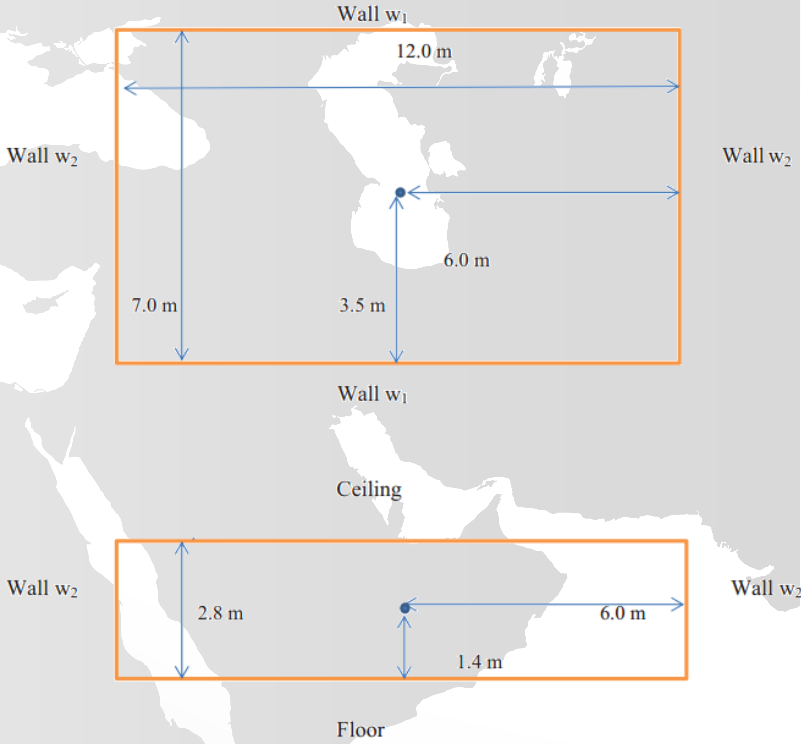
- The effects of doors and windows will lower the dose rate by only a minor amount and so for simplicity doors and windows are not considered in the calculation

- 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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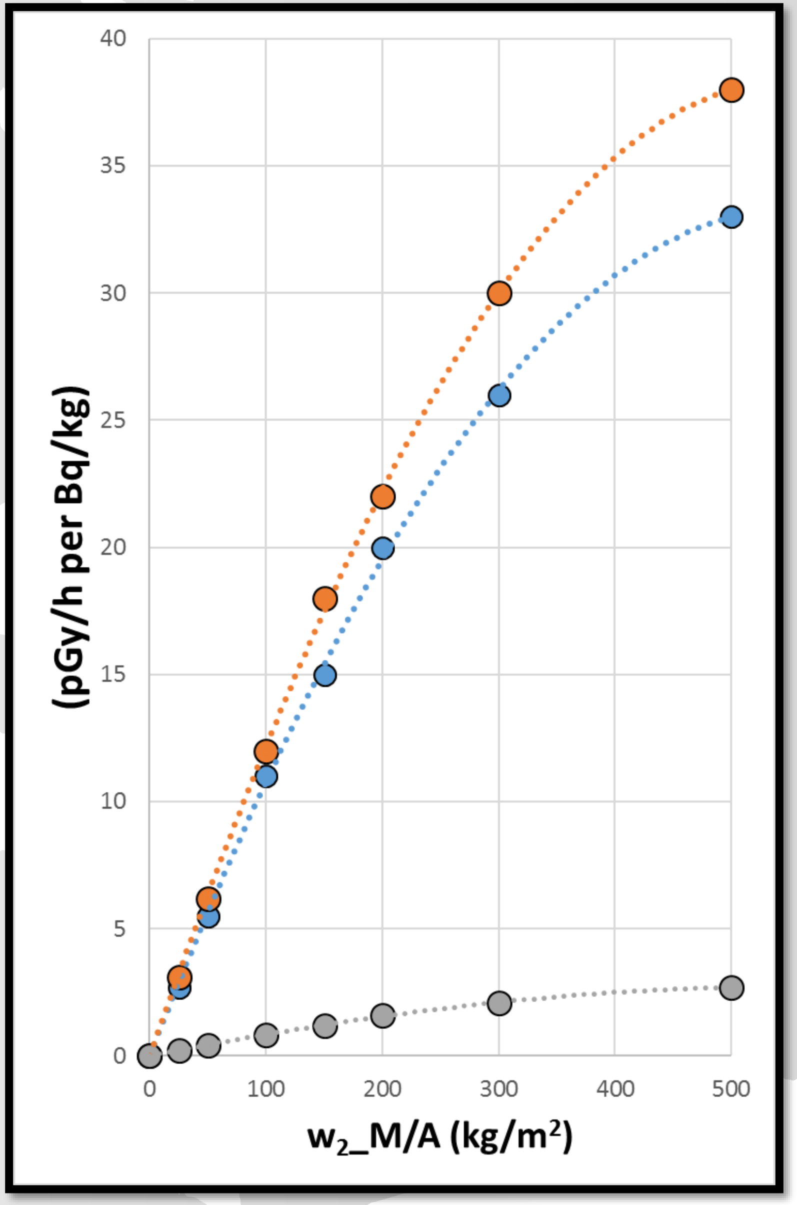

RESULTS

Material name	#	Density kg/m^3	Material name	#	Density kg/m^3
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

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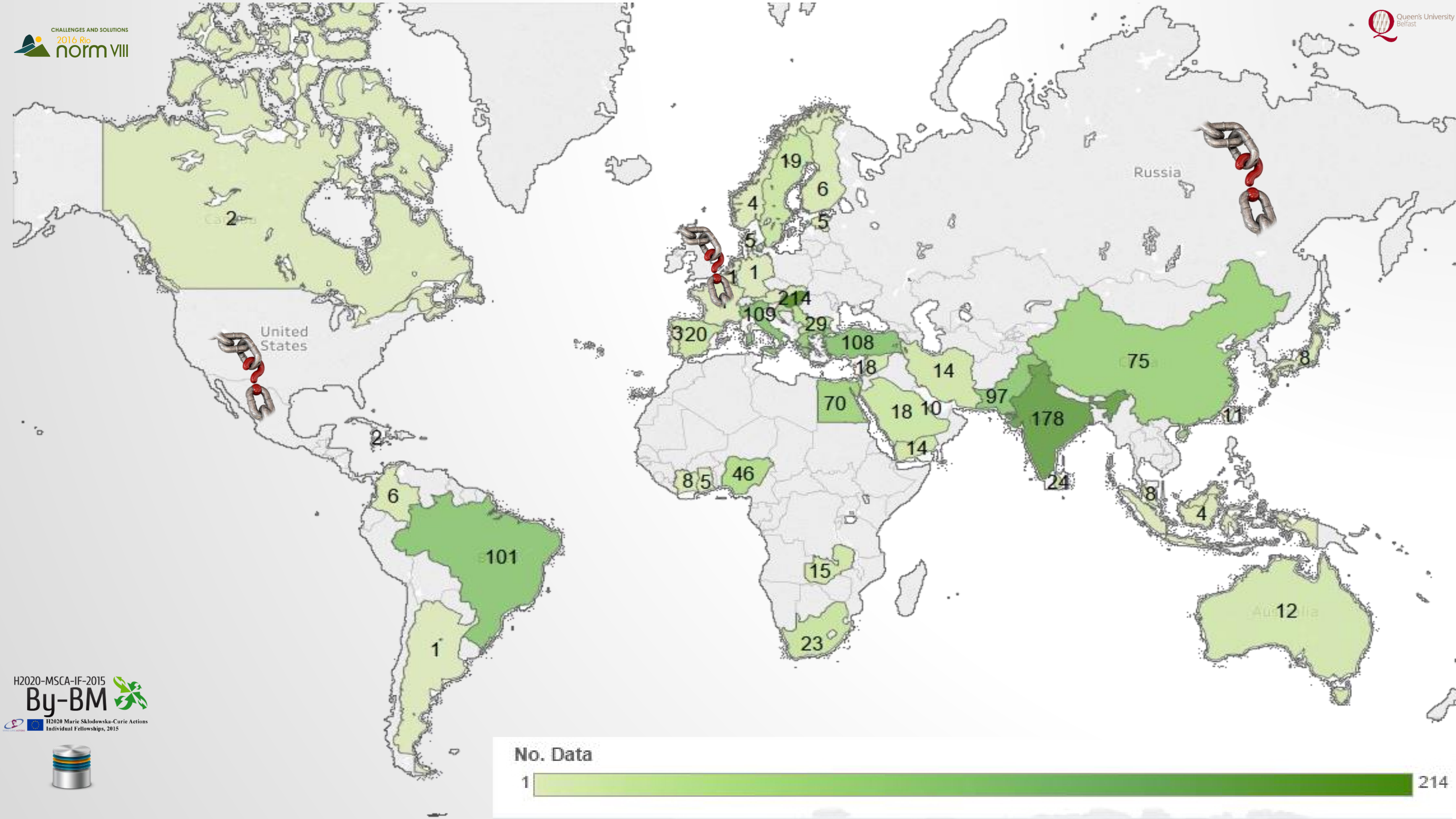

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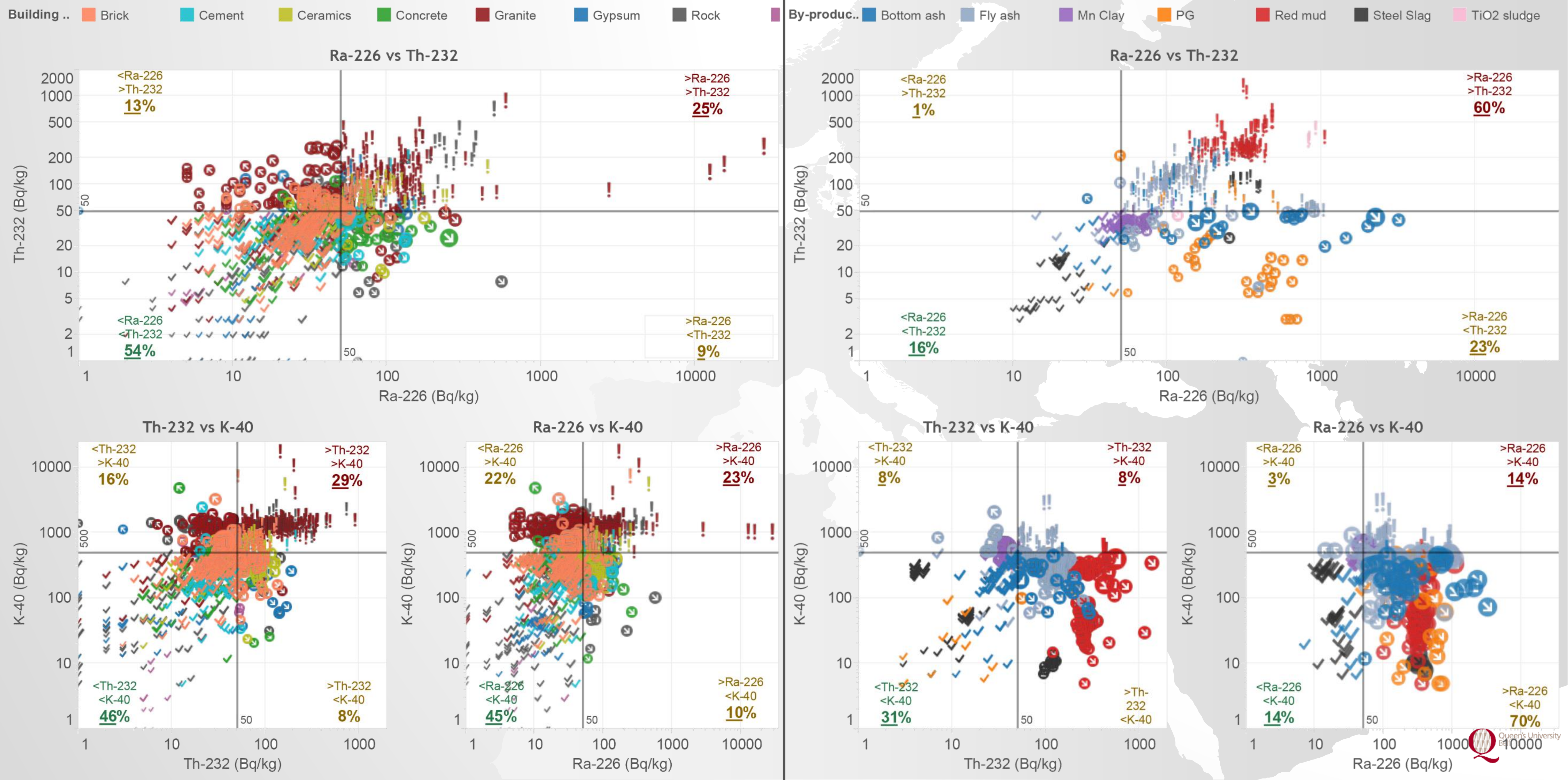
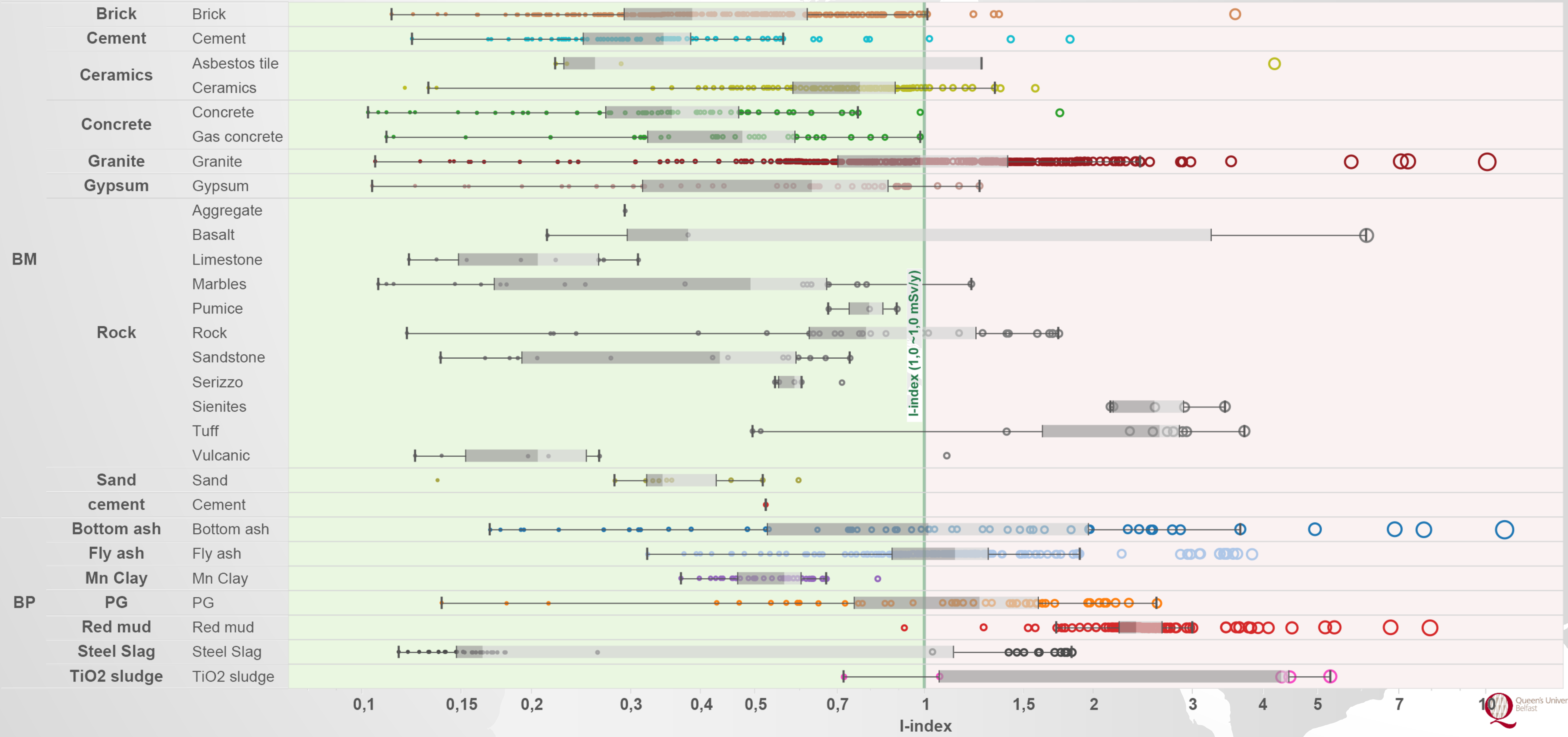
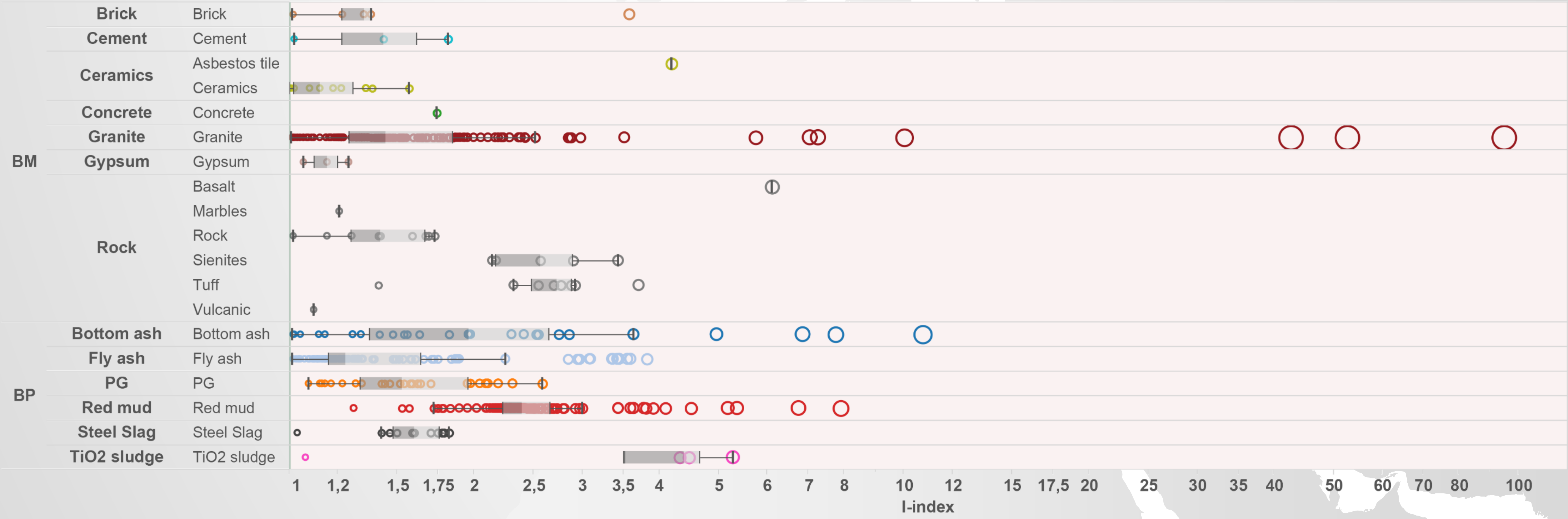


I-INDEX



Brick
Brick
Cement
Cement
Ceramics
Asbestos tile
Ceramics
Concrete
Concrete
Gas concrete
Granite
Granite
Gypsum
Gypsum
BM
Rock
Aggregate
Basalt
Limestone
Marbles
Pumice
Rock
Sandstone
Serizzo
Sienites
Tuff
Vulcanic
Sand
Sand
cement
Cement
BP
Bottom ash
Bottom ash
Fly ash
Fly ash
Mn Clay
Mn Clay
PG
PG
Red mud
Red mud
Steel Slag
Steel Slag
TiO2 sludge
TiO2 sludge
I-index (1,0 ~1,0 mSv/y)
0,1
0,15
0,2
0,3
0,4
0,5
0,7
1
1,5
2
3
4
5
7
10
I-index

I-INDEX >1.0



BM
BP
Brick
Cement
Ceramics
Asbestos tile
Concrete
Granite
Gypsum
Rock
Basalt
Marbles
Sienites
Tuff
Vulcanic
Bottom ash
Fly ash
PG
Red mud
Steel Slag
TiO2 sludge
1
1,2
1,5
1,75
2
2,5
3
3,5
4
5
6
7
8
10
12
15
17,5
20
25
30
35
40
50
60
70
80
100
I-index

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I-INDEX VS. IAEA SSG32

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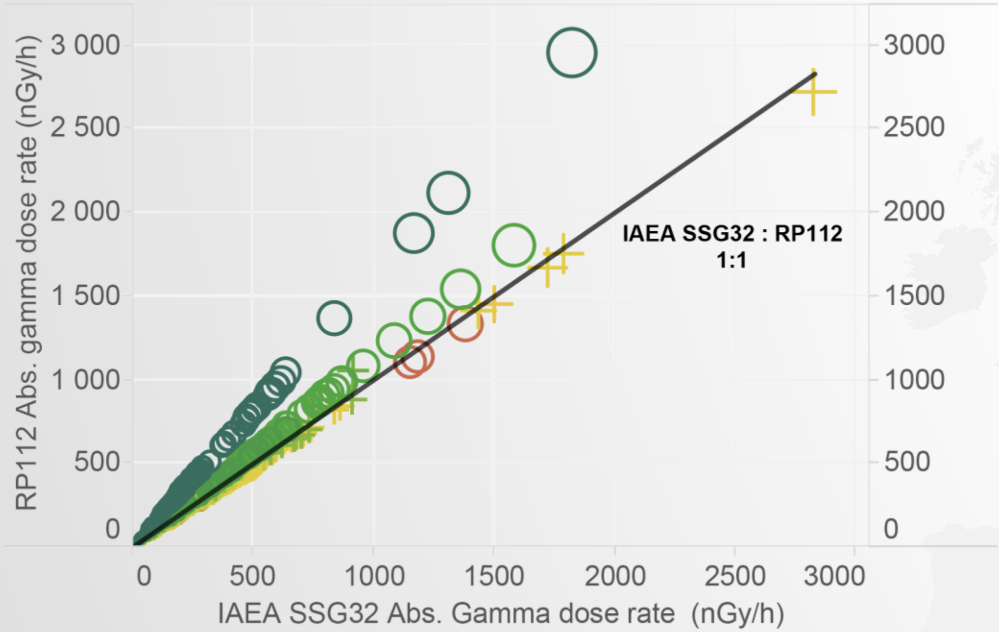
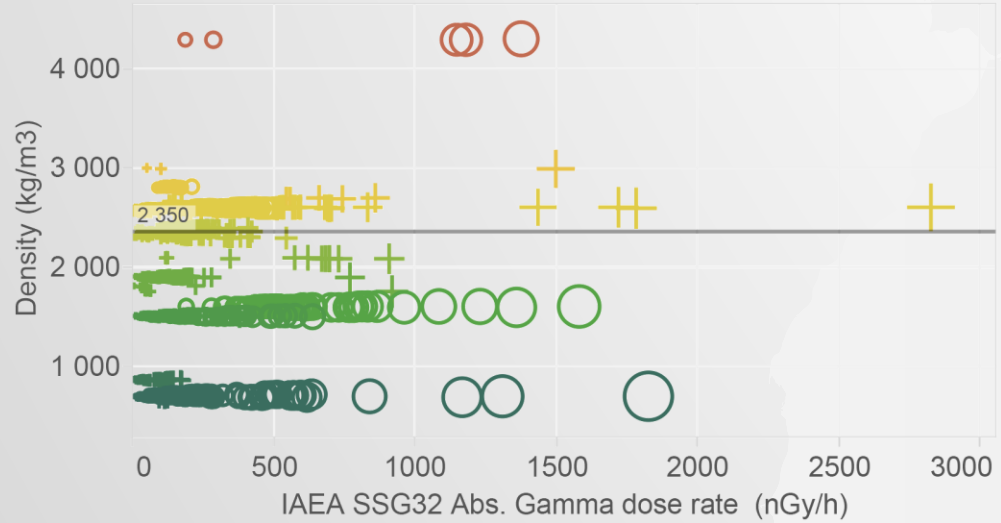
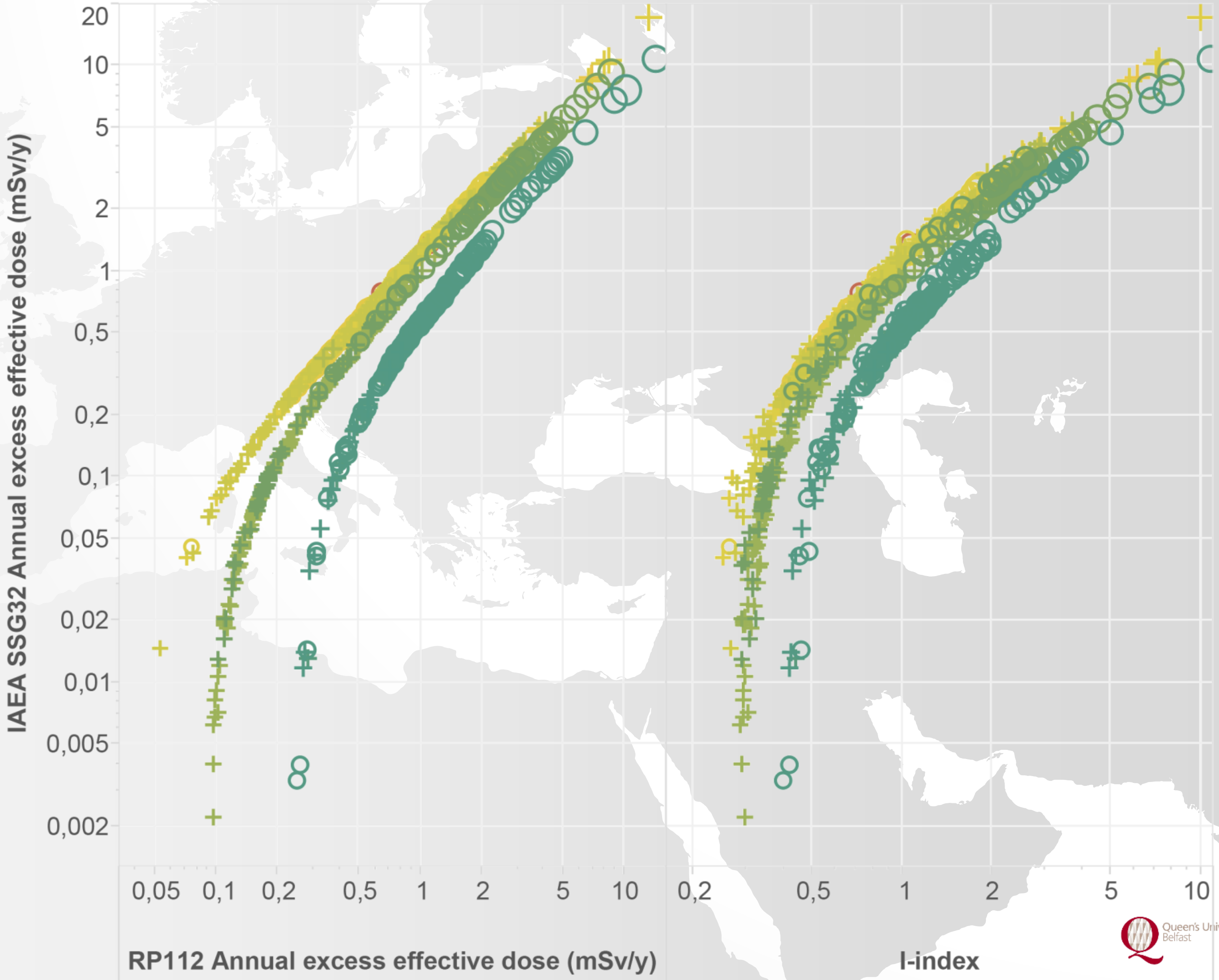
Density (kg/m3)
650 — 4300

Category
+ BM
O BP







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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 assesment
- In the case of low density range (<800 kg/m^3) 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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