The use of portable equipment for the Activity Concentration Index determination of building materials

Methodology and first results

M. Stals; S. Verhoeven; V. Pellens; B. Boeckx;
W. Schroeyers; S. Schreurs

XIOS – NuTeC

EAN NORM Conference
Hasselt – 01 December 2011

met steun van het Agentschap Ondernemen

Overview

- Introduction
  - The B-NORM project
  - NORM in building materials
  - Euro-BSS
- Method
  - The portable equipment
  - Software efficiency calculations
  - ACI calculation
- First results
  - Geometry considerations
  - ACI determination
- Conclusion

NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg

Introduction

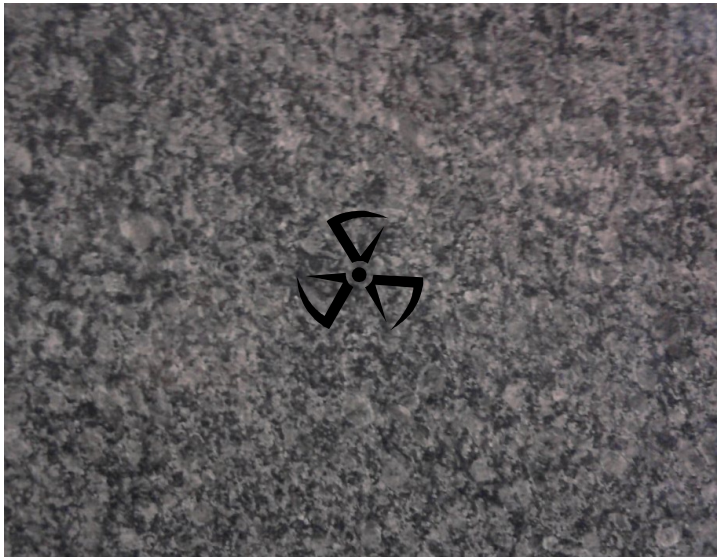
Introduction

- B-NORM: study for NORM nuclides in Belgian Building industry
- Funded by EFRO, Hermes and XIOS
- In co-operation with Belgian building industry
- Goals
  - Knowledge diffusion
  - Building material ACI inventory
  - Measurement method evaluation

NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg

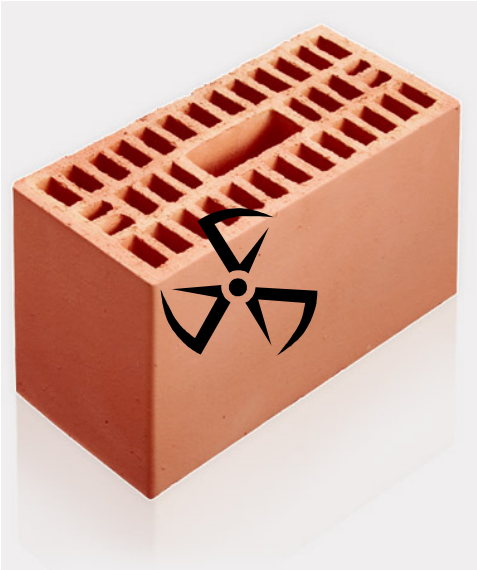
Introduction

- Building materials that are made from natural materials from the earth crust generally contain NORM
  - Minimal or only mechanical processing



Introduction

- Building materials that are made from natural materials from the earth crust generally contain NORM
  - Mechanical and thermal processing



Introduction

- Building materials that are made from natural materials from the earth crust generally contain NORM
  - Mechanical and thermal processing and / or mixing with other materials

Introduction

- Synthetic building materials usually do not contain radioactivity
  - Insulation foam, plastics,…
- Building materials based on glass or glassfibres usually do not contain radioactivity
  - Foamglass, fibre glass, windows,…

Introduction

- The new Euro-BSS will explicitly mention building materials to be checked for NORM
- It is expected that the new guidelines will be ratified by the member states by 2015

A large number of NORM measurements will be required

Introduction

- It is needed to determine the activity concentration index:

$$I = {C_{Ra-226}}/{300Bq \cdot kg^{-1}} + {C_{Th-232}}/{200Bq \cdot kg^{-1}} + {C_{K-40}}/{3000Bq \cdot kg^{-1}}$$

- *C:* activity concentration of the respective nuclide (Bq/kg)

Introduction

- Criterium:

	Category (corresponding default dose)	
Use	A (≤ 1 mSv)	B (> 1 mSv)
(1) materials used in bulk amounts	A1 I≤1	B1 I>1
(2) superficial and other materials with restricted use.	A2 I≤6	B2 I>6

- If category B: limited use of the material

Method

Method

- Current practice:
  - In a lab
  - HPGe detector with heavy lead shield
  - With a relative small sample size
  - Use only well known and predefined geometry
  - Respect 21 days delay for secular equilibrium to settle
- Accepted and high quality method
- But slow and not readily accessible to anyone

Method

- NuTeC:
  - In any room with a determinable background radiation field
  - With a portable device: inspector 1000 with $LaBr_3(Ce)$ probe
  - Large sample size or bulk samples
  - Virtually any geometry possible
  - Measure immediately the sample during 8-20 h
- Highly flexible method

Method

- Portable device:
  - Inspector 1000
  - With stabilized $LaBr_3(Ce)$ probe

Method

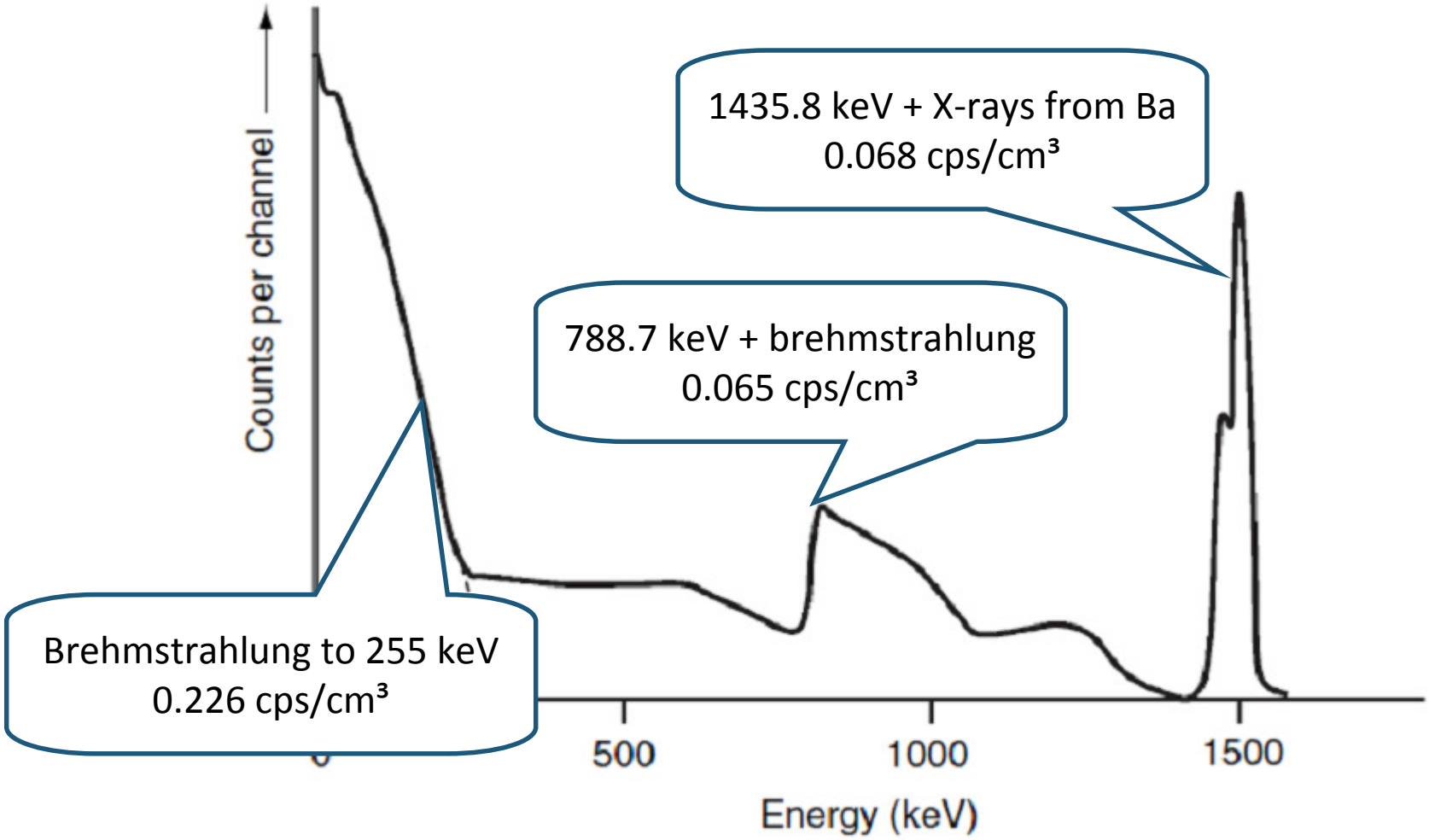
- Stabilized
  - Built-in correction for temperature change (we are measuring outside a lab)
- $LaBr_3(Ce)$
  - Good resolution compared to NaI(Tl): ~3.0% vs. ~6.7%
  - Good light yield: 160% rel. eff
  - Drawback: intrinsic activity of 138-La

NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg

Method

- Intrinsic La-138 contamination
  - Undesired, it adds extra peaks to the spectrum
  - But it is well documented and can be corrected for

Method



G. Gilmore, Practical Gamma-ray spectroscopy second edition, J. Wiley and sons, 2008

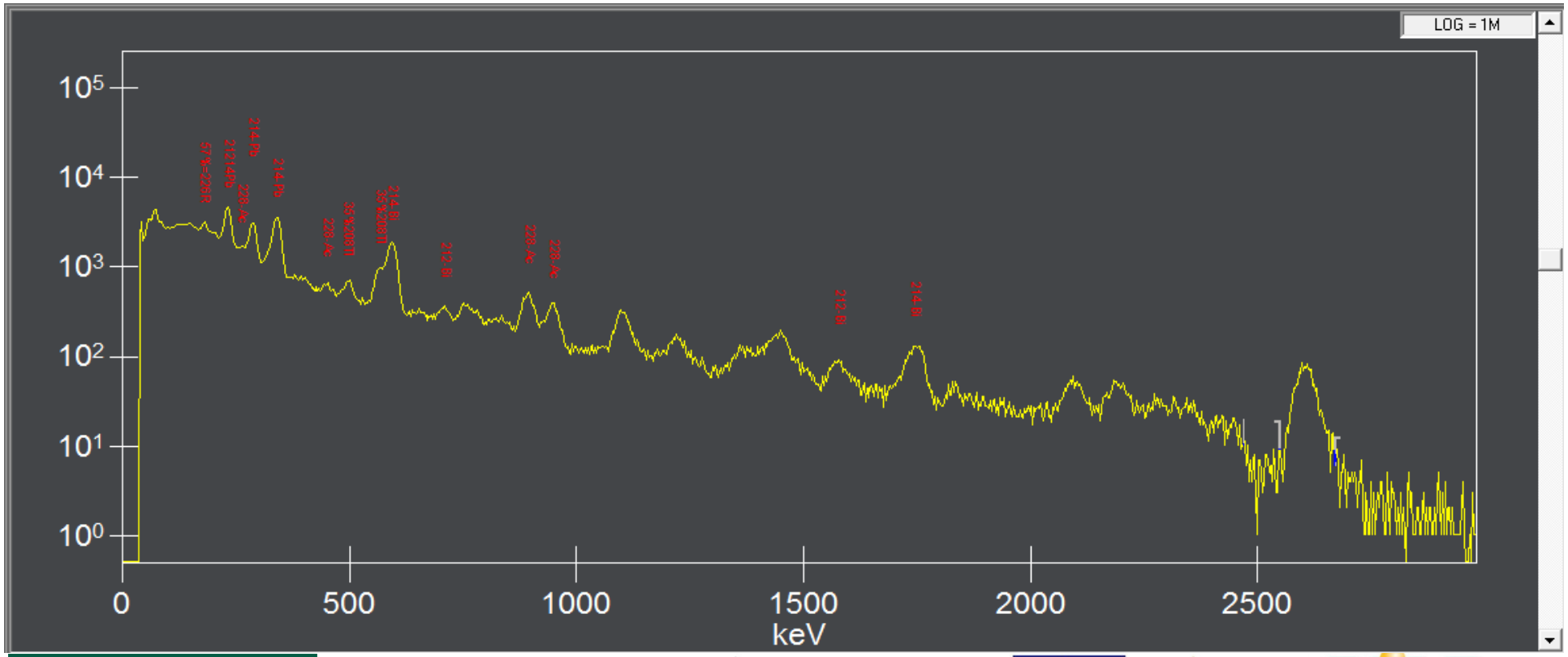
Method

- Drawback: intrinsic activity of La-138
  - This is well-documented
  - It can be corrected for with a peaked background subtraction

- The good resolution (3%) allows for measurement of NORM
- Example: Ra-226 and Th-232 encapsulated source (secular equilibrium)

Method

- The good resolution allows for measurment of NORM



Method

- Software efficiency calculations
  - In-Situ Object Counting Software (ISOCS)
  - The geometry can be drawn with a PC; use of templates
  - The software applies a finite element method Takes into account, from both the sample and possible absorbers:
    - Elemental composition of the sample
    - Density
    - Environment parameters
    - Gamma energy
    - Position and type of the detector

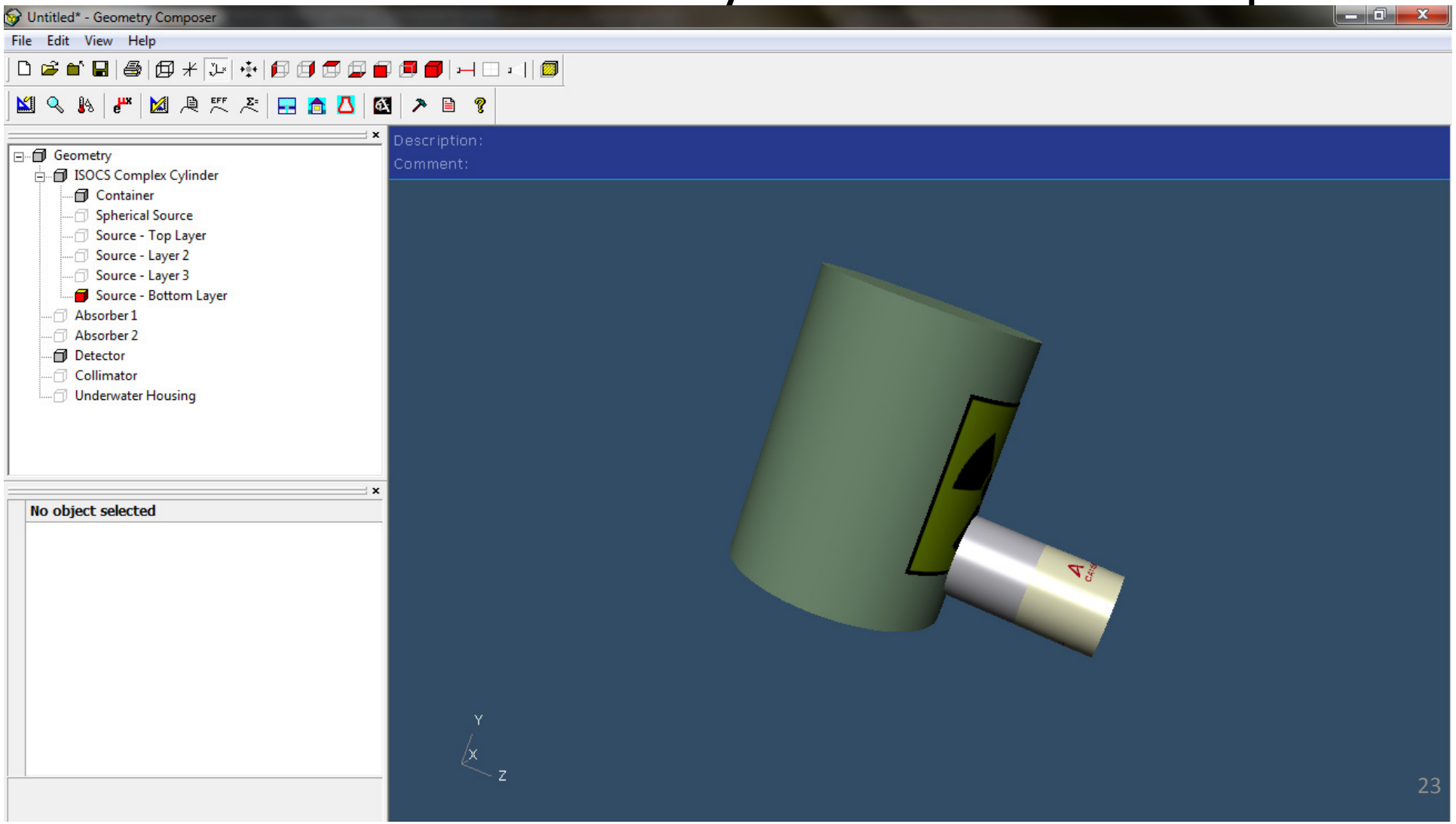
Method

- Software efficiency calculations
  - In-Situ Object Counting Software (ISOCS)
  - The detector characteristics need to be known and loaded into the program
  - The efficiency curve for the actual measurement setup is calculated and loaded into the Genie cam-file.

- Very flexible: a lot of geometries can be modelled

Method

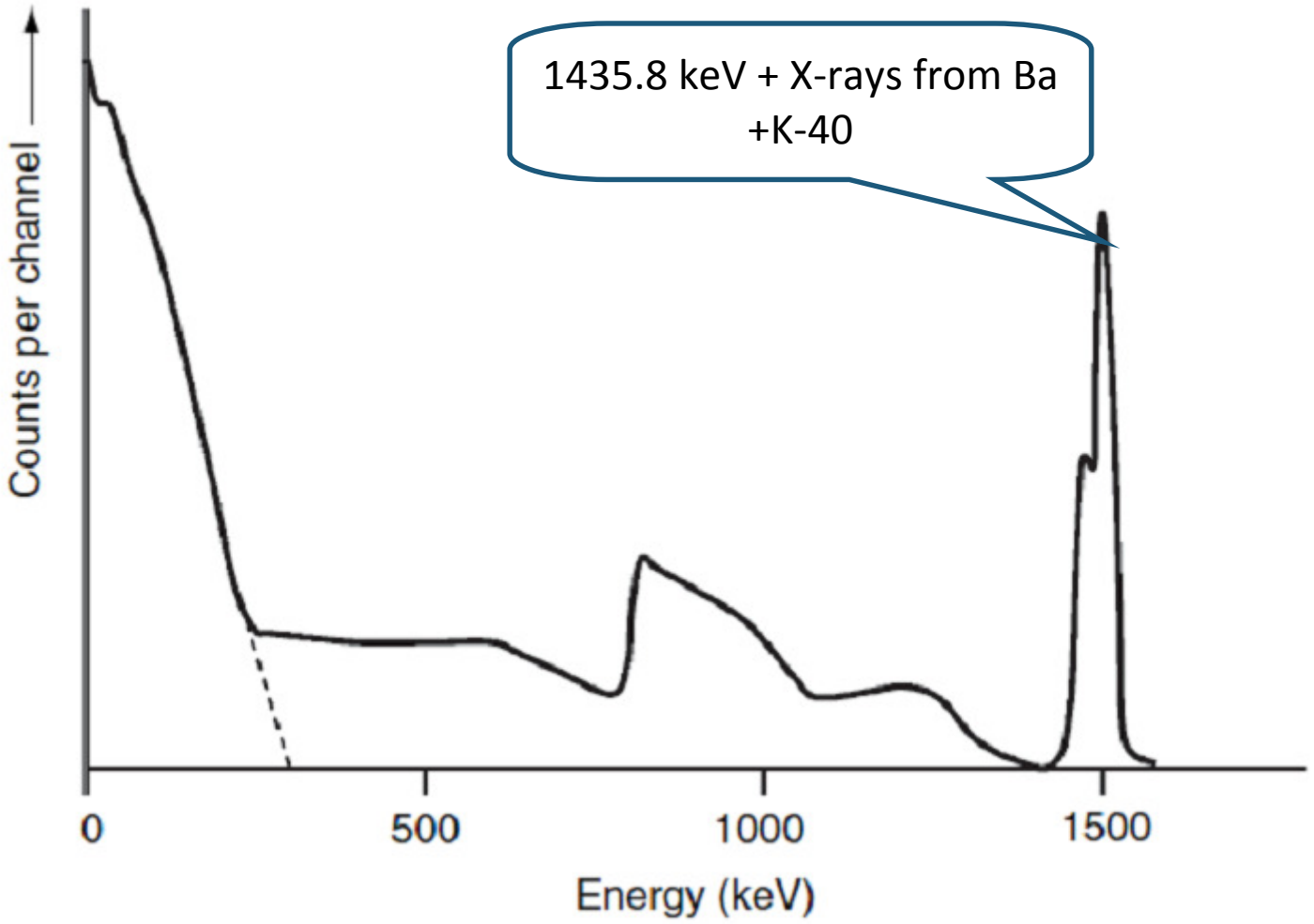
- Software efficiency calculations: examples



Method

- Calculating the ACI
  - Ra-226
    - Via daughters
    - Via Ra-226 at 186 keV
  - Th-232
    - Via daughters
  - K-40
    - Integrate whole area of K-40 + interference from intrinsic radiation from La-138 and subtract background

Method



n

met steun van het Agentschap Ondernemen

Method

- Calculating the ACI
  - The different calculation ways provide a sort of "internal QC"
  - It is expected that the different calculation ways provide similar results
- Taking into account a value of measurement + 2 SD yields "safe overestimation"

Method

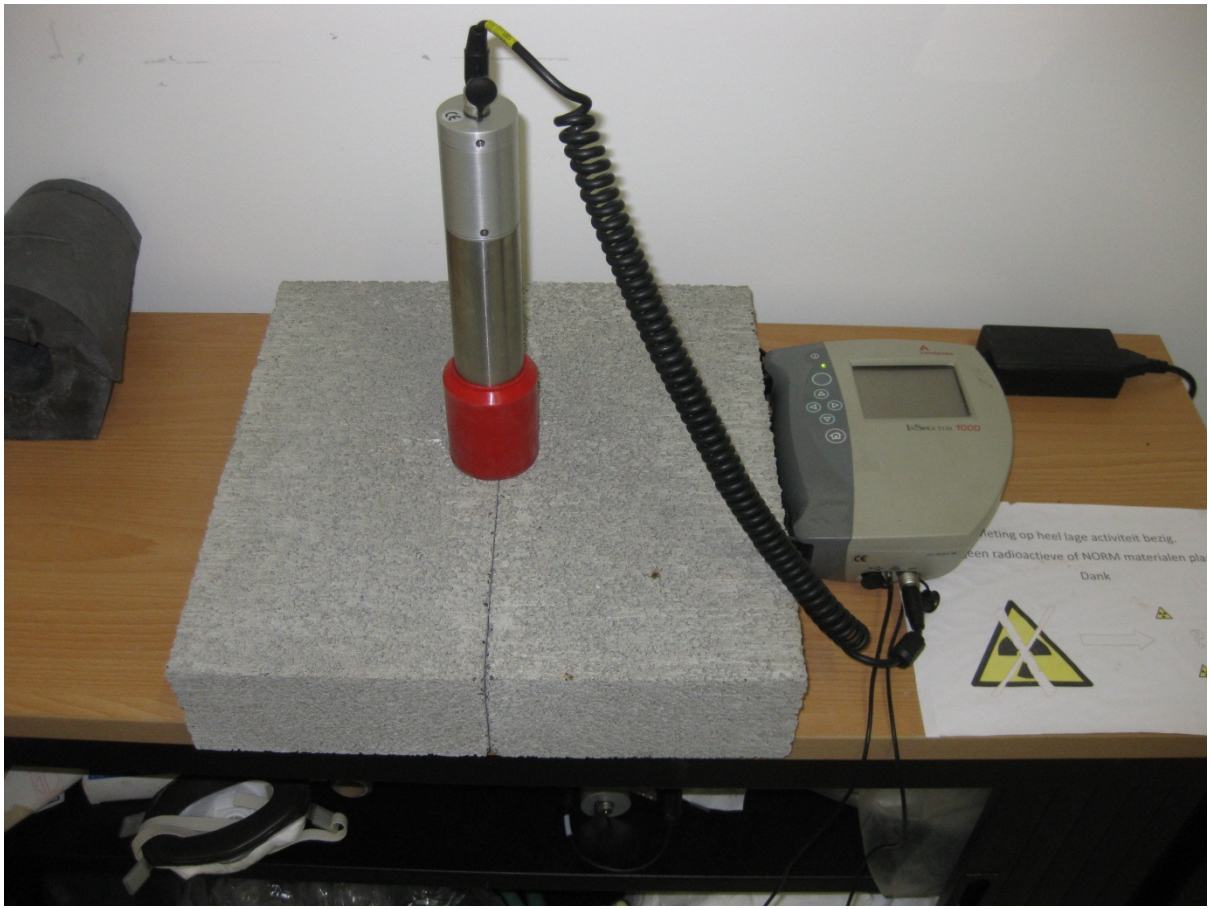
- Calculating the ACI
  - Wait for Radon ?
  - Usually, we do not find large difference between determination of Ra-226 via direct measurement at 186 keV and via daughters
  - This may indicate that equilibrium is set

Method

- Method summary:
  - Select proper room for measurement (evaluate background radiation)
  - Measure background radiation
  - Build geometry with your sample and draw the software model
  - Set acquisition for 8-20 h
  - Perform gamma analysis
  - Evaluate ACI

Method

- Example: measuring concrete bricks



Method

- Example: on-site measurement of tiles

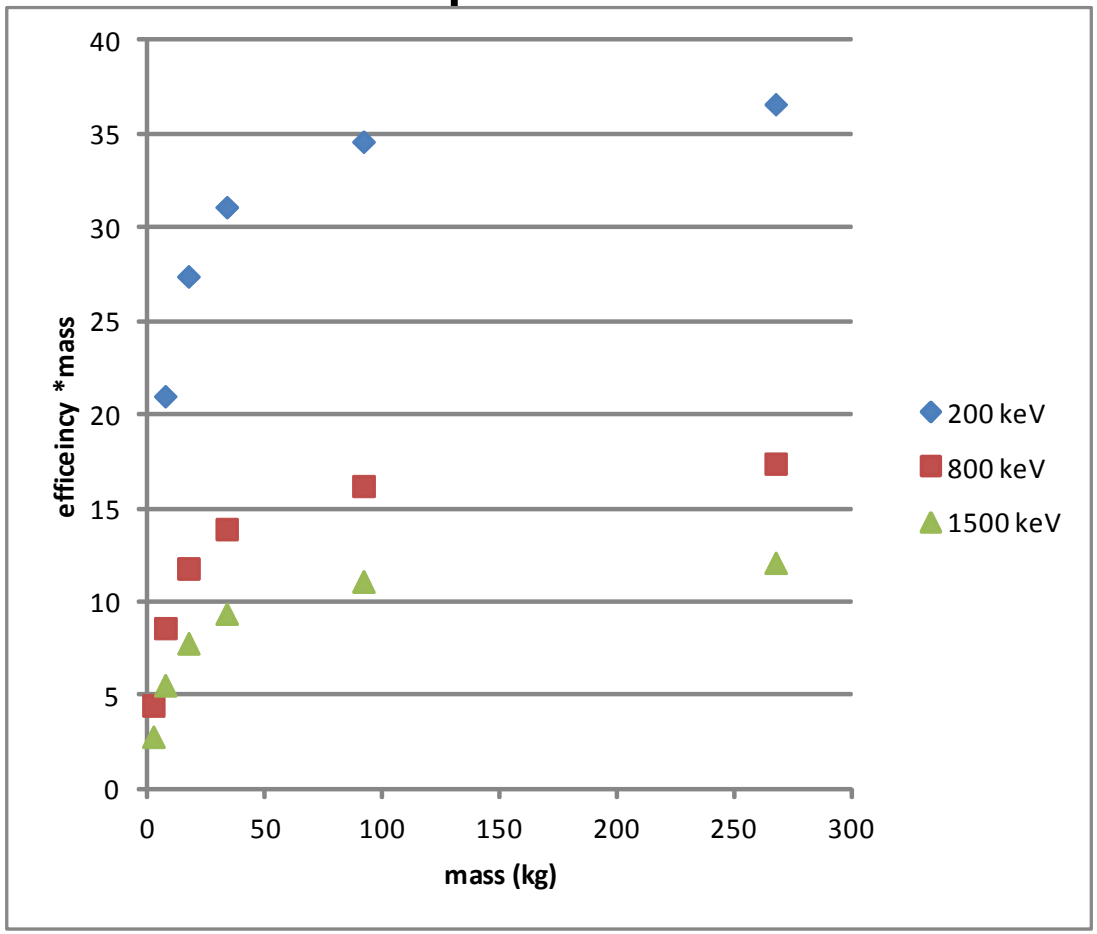
Results

Results

- Geometry considerations
  - How much sample do we need?
  - Example: flat plane geometry
    - 10 cm thickness
    - 2.1 – 267 kg

Results

- How much sample do we need ?



Results

- How much sample do we need ?
  - Once a sample size of 25 – 50 kg is reached, the efficiency gain from adding more sample strongly decreases
  - 200 keV is more efficiently detected than higher energies
    - Our detector is not a “large” detector, therefore high energy gamma’s have a lower photopeak yield

Results

- Geometry considerations
  - Eg. sample = 6 tiles; eg. Sample = 4 bricks
  - How to set them up ?

Results

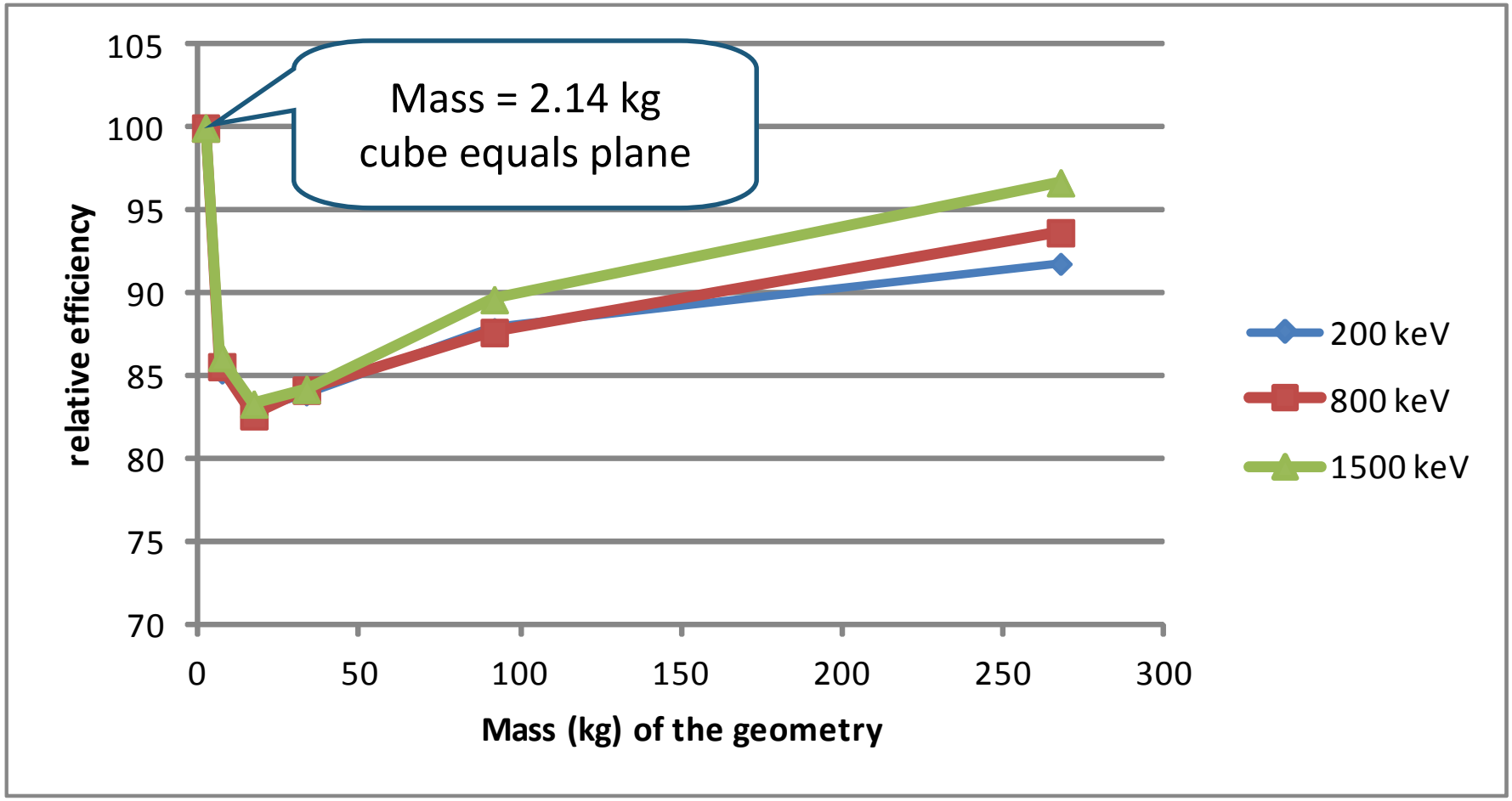
- Geometry considerations - Example
  - Case 1: try to stack the samples like a cube (shorter distance to detector, but gammas need to travel via a long path through dense material)
  - Case 2: try to stack the samples like a flat rectangular plane
    (larger distance to detector, but gammas do not need to travel via a long path through dense material)

Results

- Geometry considerations - Example
  - The example is calculated for actual concrete bricks
  - For gamma energies of 200, 800 and 1500 keV
  - The flat plane has a thickness of 10 cm
  - The graph displays for each energy

$$\frac{efficiency/mass(cube)}{efficiency/mass(plane)}$$

Results



met steun van het Agentschap Ondernemen

Results

- Geometry considerations - Example
- Especially at lower sample mass:
  Flat plane geometry is more efficient than cube geometry
  - Note that for other materials, results may vary

- We will strive for a relative flat geometry, taking practical circumstances into account

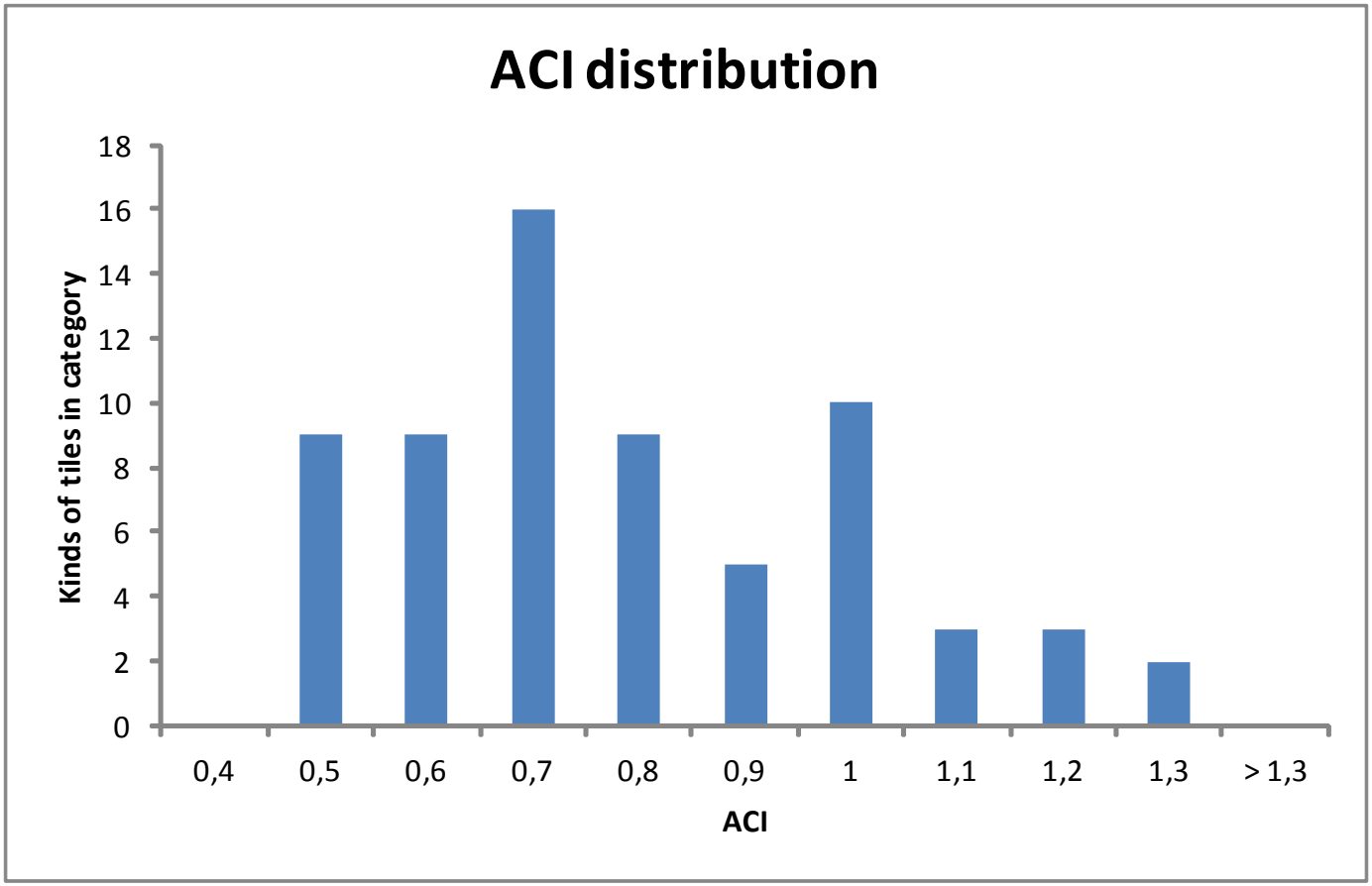
NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg

Results

- ACI determination: Tiles
  - Tile production is a precision manufacturing process
  - Application of zircon may lead to increased gamma dose
    - Nowadays largely replaced by Alumina
  - Mainly Ra-226
  - Some tiles exceed “ACI < 1” level
  - No problem: tiles are used as surface material

Results

- Tiles: 66 kinds analyzed



Results

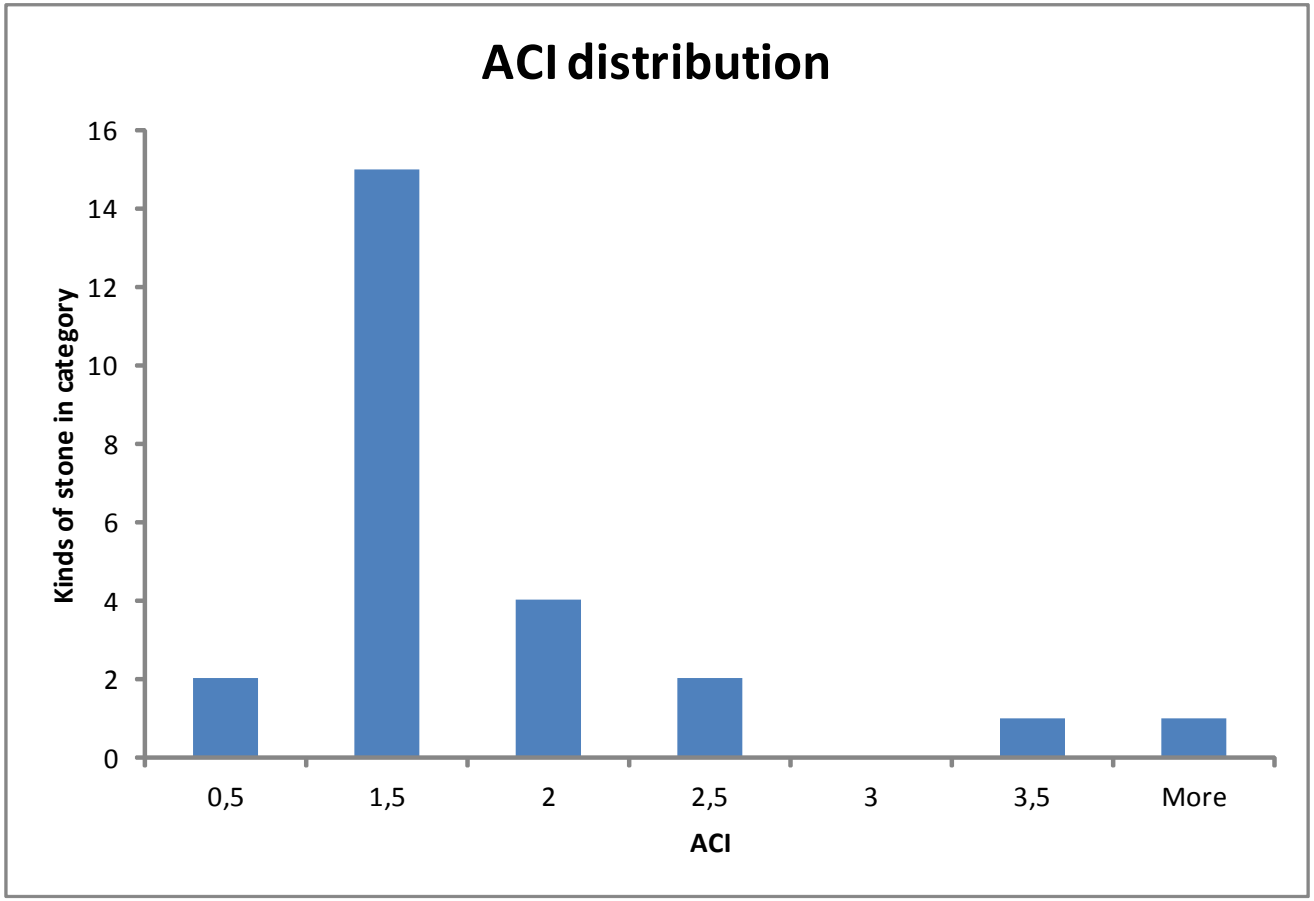
- Stone
  - Igneous stone appears to have higher gamma dose than sediment stone
  - Igneous eg. Granite, basalt
  - Sediment eg. Marble, sandstone
  - Gamma dose mainly due to Th-232

- Origin of stone ?

Stone

Results

- Stone: 24 kinds analyzed



Results

- Stone
  - Relatively high ACI found
  - But surface material allows ACI up to 6
  - Some high ACI kinds are no longer sold

Results

- Bricks - façade bricks
  - 5 types analyzed
  - ACI 0.56-0.79
- Bricks - thermal insulating bricks
  - 3 types analyzed
  - ACI 0.51-0.70

Results

- Concrete: high-density concrete
  - 3 kinds analyzed
  - ACI 0.31-0.50

- Gypsum and gypsum blocks
  - 5 types analyzed
  - ACI 0.50-0.98
  - It seems that Ra-226 bearing phosphate gypsum is no longer found in DIY (Belgium)

Results

- We did not yet found bulk materials with ACI > 1
- We did not yet found surface materials with ACI > 6

NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg

Future perspectives

Future perspectives

- Results are loaded in a database
- This allows for easy data retrieval and display
- Under construction

Future perspectives

- We are currently validating our method against numerous laboratory analyses
- The need to take into account the 21 day delay in order to set equilibrium is also evaluated

- Measuring more materials and more kinds of materials

Conclusion

Conclusion

Conclusion

- The NuTeC approach on determining building material ACI simplifies and speeds up ACI determination

- If method verification turns out right, cost reduction and enhanced speed in ACI determination is possible

NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg

The use of portable equipment for the Activity Concentration Index determination of building materials

Methodology and first results

Thank you for your attention

EAN NORM Conference
Hasselt – 01 December 2011

met steun van het Agentschap Ondernemen

Mogelijke vragen

wat is de eenheid van de ACI?
De EU-BSS vermeld niet expliciet de eenheid, maar uitgaande van de begeleidende tekst van een *ander* artikel uit de BSS kan men afleiden dat het mSv/a is.

Wie draagt de eindverantwoordelijkheid?

- Fabrikanten of verdelers ?
- Leveranciers grondstoffen?

Welke methode(n) wordt als standaard methode bepaald ?

NuTeC Nucleair Technologisch Centrum
Vlaanderen In Actie
met steun van het Agentschap Ondernemen
Europese Unie
EFRO Europa investeert. Vlaanderen groeit.
xios Hogeschool Limburg