Reference (Published version):
Kovler, Konstantin & Schroeyers, Wouter(2017) Special issue: Natural radioactivity in construction. In: Journal of environmental radioactivity, 168, p. 1-3

DOI: 10.1016/j.jenvrad.2017.01.007
Handle: http://hdl.handle.net/1942/23158

Special issue: Naturally Radioactivity in Construction

Konstantin Kovler[1] Wouter Schroeyers[2]

[1] *Faculty of Civil and Environmental Engineering, Technion – Israel Institute of Technology, Technion City, Haifa 32000, Israel*

cvrkost@technion.ac.il, Tel.: +972 48292971

[2] *Hasselt University, NuTeC, CMK, Nuclear Technology - Faculty of Engineering Technology, Agoralaan building H, B-3590 Diepenbeek, Belgium*

wouter.schroeyers@uhasselt.be, Tel.: +3211 292157

Keywords:

NORM (naturally occurring radioactive materials), radon, residues, building materials, construction

The current Special Issue is sponsored by the COST [1] Action TU1301 "NORM4Building". This COST Action stimulates the collaboration of scientists, industries and regulators to gather knowledge, experiences and technologies, to stimulate research on the reuse of residues containing enhanced concentrations of NORM - naturally occurring radioactive materials [2] in tailor-made building materials in the construction sector, while considering the impact on both external gamma exposure of building occupants and indoor air quality (indoor radon, mainly).

Fig. 1 represents schematically the microstructure of ceramic and concrete, which is similar. In both materials, which are considered as the main mineral building

[1] COST is an intergovernmental framework for European Cooperation in Science and Technology, allowing the coordination of nationally-funded research on a European level.
[2] NORM - radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides.

materials in most of the countries, aggregates and mineral additives are incorporated in a matrix that constitutes the binding phase. On a macroscopic scale concrete consists out of a mixture of cement paste and aggregates. The cement matrix consist mainly of silica (SiO_2), alumina (Al_2O_3), lime (CaO) and iron oxide (Fe_2O_3). The main compounds of ordinary Portland cement are tri-calcium silicate, di-calcium silicate, tri-calcium aluminate, and tetra-calcium aluminoferrite. Currently efforts are undertaken to replace both the binder and aggregates of concrete and ceramics with alternative secondary resources. The latter often include by-products and residues of different industries, while the construction industry is the biggest one, which can successfully incorporate them in building materials. Materials used include fly ash (from the burning of coal and peat), blast furnace slag and phosphogypsum. These materials may have enhanced concentrations of radionuclides of natural origin through concentration processes taking place during the generation of the residues [1]. Therefore, the successful incorporation in the construction of the industrial by-products and residues with enhanced concentrations of naturally occurring radionuclides is conditioned by the legislation and standards regulating the quality and environmental safety of the finished construction products.

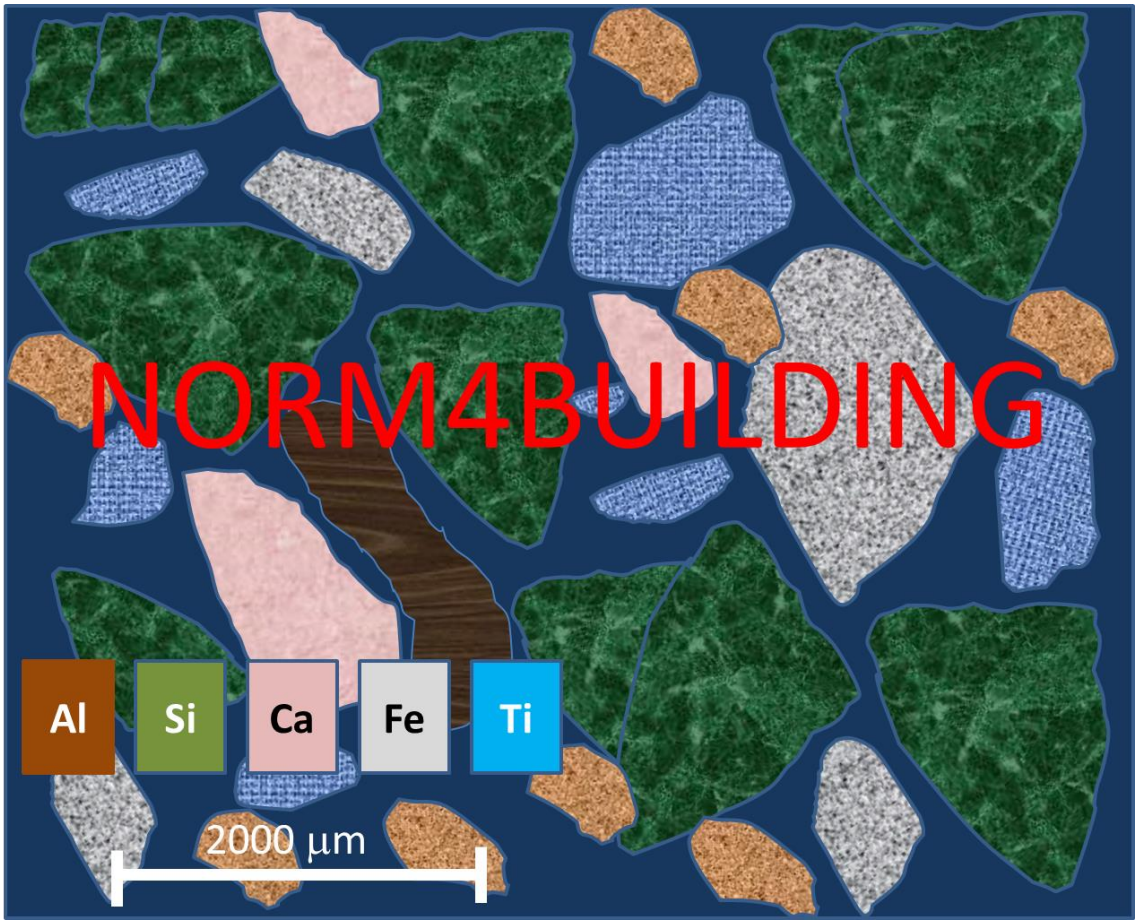

Fig. 1. Schematic simplified illustration of the microstructure of ceramic and concrete building materials considered by the experts of the COST TU1301 Action "NORM4Building"

By improving radiological impact assessment models for the reuse of NORM-containing residues in building materials we hope to further stimulate justified uses of NORM residues in different types of newly developed building materials. Based on these models, we aim at investigating realistic legislative scenarios so that the authorities concerned can allow reuse pathways for NORM that can be accepted from a radiation protection point of view in concordance with the Lead Marked Initiative (LMI) and sustainable construction.

In the COST Action TU1301 "NORM4Building" around 120 experts from 28 European countries, the Russian Federation and the US collaborate in order to investigate the reuse of NORM-containing by-products in construction. The focus of the COST Action is on building materials (in particular, on new types of building

binders – both cement and non-cement binders, concrete and ceramics) that are currently under research and that will enable the reuse of larger mass fractions of industrial by-products, such as fly ash, metallurgical slag, phosphogypsum, red mud and residues from steel production. The NORM4building network aims to generate research, in which both non-radiological and radiological aspects of the reuse and recycling of specific by-products in construction are covered. In the COST network engineers, that are developing new types of construction materials, collaborate with among others experts on gamma-ray spectrometry, radon, dosimetry, modelling of the environmental impact and public perception.

The objectives of the COST Action include the following:

- To deliver a practical evaluation of develop options for new tailor-made types of building materials to reuse NORM residues.
- To develop a data base with best practices for reuse of NORM residues in building materials.
- To evaluate and develop practical measurement protocols, if possible in situ measurement methods, to determine the indicators for the verification of the radiological impact of newly developed building materials containing NORM. A complementary secondary objective is to support standardization efforts of measurement protocols, which is especially needed for in situ measurement methods.
- To develop realistic radiological impact assessment models for the reuse of NORM residues in building materials.
- To evaluate the concordance and applicability of current radioprotection legislations with usage of NORM residues in building materials and the related impact on both gamma radiation exposure and indoor air quality.
- To disseminate this knowledge to construction and NORM processing industry, consumers, national governments as well as to international agencies such as WHO and IAEA.
- To develop a practical guidance for industry to address questions and comments regarding the EU-BSS linked to the processing of NORM in building materials. This Action aims at providing answers, double-checked with the European Commission.

The involved experts are active in the following four working groups (WGs) with a specific scientific focus:

(1) WG1 develops a database of NORM containing by-products and their reuse options in construction materials that soon will be available on the Action website (www.norm4building.org);
(2) New reuse options for NORM containing by-products in construction materials are being engineered by WG2;
(3) Since for the characterisation of NORM containing construction materials there is a lack of standardised radiological measurement procedures, WG3 is optimizing the measurement procedures for the determination of the activity concentration of naturally occurring radionuclides and studying options for pre-standard materials;
(4) Finally, WG4 focusses on the dosimetric evaluation of the newly developed construction materials involving a number of building scenarios.

The current special issue aims to give the scientific community insight regarding the radiological impact of building materials containing high concentrations of naturally occurring radionuclides. In the special issue, major attention is given to the methodology for radiological characterization by presenting several papers that focus on the characterization aspects, methodology for a national survey or the intercomparision of measurement procedures between laboratories.

These papers were presented in the two scientific workshops, both supported by the COST TU1301 Action “NORM4Building”. These events took place in October 2015: NORM4Building Workshop "Residue valorization in construction materials considering chemical and radiological issues" (Leuven, Belgium, 8-9 October 2015) and Italian Radon and NORM Workshop, "Research Advances on Radon and NORM Applications" (Salerno, Italy, 15-17 October 2015).

The Special Issue opens with the paper by G. Xhixha et al. entitled “First intercomparison among laboratories involved in COST Action TU1301 “NORM4Building”: Determination of natural radionuclides in ceramics”. This

work describes the outcomes of the COST Action-TU1301 “NORM4Building” intercomparison performed in 22 laboratories evaluated for their performance using robust statistics. The laboratories were requested to report complete characterization of natural radionuclide composition. The results of this exercise could be the basis for quality control procedures.

The paper by N. Todorović et al. “Concentrations of ^{226}Ra, ^{232}Th and ^{40}K in industrial kaolinized granite” reports activity concentrations of natural radionuclides in 120 kaolinized granite samples imported in Serbia and their frequency distributions, and estimates the absorbed dose rate and annual effective doses for Serbian workers in the ceramic industries processing kaolinized granite.

T. Kovacz et al. in their paper “Radon exhalation study of manganese clay residue and usability in brick production” describe the uses of manganese clay, which is a residue of manganese ore processing generated in large amounts. In this study, the authors try to estimate the radon emanation features and the massic exhalation rate of the heat-treated manganese clay determined with regard to brick production. The changes in the internal microstructure and the radon emanation coefficient at heating in the oven were reported and discussed.

The study by T. Croymans et al. “Radiological characterization and evaluation of high volume bauxite residue alkali activated concretes” involves the radiological characterization of different types of concretes containing bauxite residue (also known as red mud) from Ukraine. It can be used as an aggregate in concrete products. The authors measured activity concentrations of natural radionuclides, used different types of indexes to evaluate the public exposure and RP122 to evaluate the occupational exposure.

Another type of alkali-activated concrete was a subject of the investigation by C. Nuccetelli et al. “Alkali-activated concrete with Serbian fly ash and its radiological impact”. Five mixtures with different types of coal fly ash and one type of blast furnace slag were designed and tested. Experimental results were compared by

using the activity concentration assessment tool for building materials - the activity concentration index, as introduced by the EU Basic Safety Standards. Finally, the index was compared with the results of the application of a more accurate index, which accounts for thickness and density of building materials.

The main goal of research presented by I. Ignjatovic et al. in the paper "Radiological and material characterization of high volume fly ash concrete", was the characterization of high volume fly ash concrete (HVFAC), namely its natural radionuclide content, radon emanation and exhalation coefficient. All investigated concrete samples were made in the lab with fly ash content between 50% and 70% of the total amount of cementitious materials. Physical and mechanical properties of concrete were tested, as well as the radionuclide composition (^{226}Ra, ^{232}Th and ^{40}K) and radon massic exhalation. The activity concentration index of different HVFAC samples was compared with the limit recommended for the controls. Suitability of the concrete compositions for structural and non-structural applications, both from material and radiological points of view was discussed.

In contrast to previously listed papers, which dealt with concrete manufactured in the laboratory, the paper by K. Kovler "The national survey of natural radioactivity in concrete produced in Israel" concludes the results of testing industrially manufactured concrete. The tests of 109 representative concrete compositions commercially manufactured by more than 50 ready-mix concrete plants in Israel for the years 2012-2014 were analysed. The average, maximum and minimum values of the radon emanation coefficient of concrete, as well as the indexes of both total radiation (addressing gamma radiation and radon together), and gamma radiation only, of the averages of the two sub-populations of concrete mixes: with and without fly ash, were compared, while the differences were estimated from the statistical point of view.

The Special Issue ends with the paper by C. Nuccetelli et al. "Radiological characterization of the ancient Roman tuff-pozzolana underground quarry in Orvieto (Italy): a natural laboratory to revisit the interactions between radionuclides and aerosols" deals with studying tuff and pozzolana, which have

enhanced natural radioactivity and therefore are interesting from the radiation protection point of view, since they are still used as building materials. It was found that the radiological characteristics of Orvieto underground quarry make it a perfect site for "in field" intercomparison of different measurement and dose assessment methods.

To conclude, we consider the publication of the current Special Issue as a step forward in free exchanging of the information (including problems, challenges, solutions, experience) within the community of experts representing different fields, such as industry operators and industry associations that are dealing with natural radioactivity in their raw materials, processes and residues, governmental and regulatory authorities in the field of radiation protection, service providers such as laboratories and consultants, and finally researchers and scientists. The main objective of the experts in this community is to ensure that NORM is managed in compliance with European and international standards and legislation, and according to best practice so that legal/regulatory uncertainty for industry and authorities is minimised, and humans and the environment are protected in an optimised way that is acceptable to society.

Wishing to all the readers of this Special Issue a pleasant reading experience!

Acknowledgements

This special issue is all about the results of the COST Action NORM4building TU1301 (www.norm4building.org) and we would sincerely like to thank the European Cooperation in Science and Technology (COST) framework for making this research and free discussion of the research results in the meetings of the COST Action NORM4building TU1301 possible. We would like also to thank Dr. Steve Sheppard, Editor-in-Chief, Journal of Environmental Radioactivity, and Elsevier Science Ltd. for making this Special Issue possible.

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