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REM 2020 proficiency test on naturally occurring radionuclides in building materials

Proficiency testing report

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Contents

Abstract

The Joint Research Centre of the European Commission organised a proficiency test (PT) on the measurements of natural radioactivity (^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{228}Ra, ^{228}Th and ^{40}K) in building materials. This PT was an integral part of the European Commission's work of realising verifications of Member States' obligations towards Article 35 of the Treaty establishing the European Atomic Energy Community (Euratom Treaty). In addition, it also constitutes the JRC's obligations towards the European Commission (the Commission) following Article 39 of the Euratom Treaty. The work was part of the quality control programme[1], which JRC-Geel is coordinating in order to assess the quality of the radioactivity results reported by member state laboratories and authorities to the Radioactivity Environmental Monitoring (REM) database[2].

The PT test items were prepared from two types of commercially available building materials; cement and expanded clay blocks. The test items were shipped to 105 laboratories of which 96 laboratories submitted results. The results of the PT were evaluated according to ISO 13528:2015. The percentage difference (*D%*), *z* and *zeta (ζ)* scores were calculated.

Out of the 1586 reported results (for all radionuclides in all three materials), 94.7% of the *z* scores and 73.1% of the *zeta* scores were satisfactory. This indicates a good precision of measurements in general but in some cases a somewhat underestimated uncertainty. A general conclusion is that no major general analytical problems were encountered by the participating laboratories. The large amount of data generated in this PT will be used by different actors for identifying underperforming laboratories, discovering measurement errors, investigating training needs and making suggestions for possible improvements to international standards.

[1] (https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/Proficiency-Tests

[2] (https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/REMdb

Foreword

This proficiency test (PT) ran under JRC's programme REM, Radioactivity Environmental. Monitoring (https://remon.jrc.ec.europa.eu/), which constitutes an essential part of JRC's work in support of Article 39 of the Euratom Treaty supporting the European Commission in its tasks linked to Chapter 3 (Articles 30-39 on health and safety) of the Euratom Treaty. JRC's work on the REM PT programme began in 2003. This was formally the 12th REM PT since 2003[3]. Note also that over the years the formal name of the REM PT exercises have slightly changed[4]. With increasing awareness of the complexity of radioactive environmental monitoring combined with extension of accreditation programmes, the number of participants have increased over the years. Based on feedback from radioactivity monitoring laboratories and Article 35 experts we have learnt that there is a great need for reference materials that mimic the type of materials actually measured in monitoring laboratories. It is also essential that radionuclides that are typical for important scenarios (e.g. nuclear accident or natural disasters) are used and not simply the radionuclides that are used for calibrating detectors. The decision on which materials to use and which radionuclides to include are taken by DG ENER based on input from JRC (what can be produced) and from Member States (what is most needed). This is the first exercise that involved building materials. Although building materials are formally not mentioned in Chapter 3 of the Euratom Treaty, recent extensions to the BSS (Basic Safety Standards, Council Directive 2013/59/Euratom) broadens the scope of radiation protection to cover also building materials (Article 75).

[3] Note that other interlaboratory comparisons (ILCs) have been conducted by JRC in this this time period in support of the European Member State's monitoring laboratories (like Pilot-PTs, collaborative trials and method testing) but were formally not included in the REM PT scheme.

[4] In 2003 the scheme was formally called ICS-REM (International Comparison Scheme – Radioactivity Environmental Monitoring). Later it was also called EC lnterlaboratory Comparison and EC Proficiency Test. Since 2018 it is called REM XXXX PT where the XXXX is the year of announcing the exercise. There is often the addition of the radionuclide and matrix (e.g. radon-in-water).

Acknowledgements

First of all the authors wish to thank all participating laboratories listed in Annex 27. This work would not have been possible without their active participation in this proficiency test.

The authors are indebted to laboratories that contributed to the reference values: CEA-LNHB (Paris, France), IAEA (Monaco), SCK CEN (Mol, Belgium), AGES (Vienna, Austria), Environmental Board (Estonia), ARPA (Milan, Italy), IJS (Ljubljana, Slovenia), TENMAK (Ankara, Türkiye) for their contributions to the reference value determination.

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Many thanks to Jan Paepen and Raf Van Ammel for assisting in the cleaving of the expanded clay blocks and to the JRC-Geel, F.6 Reference Materials Unit: Irma Huybrechts, Diana Vernelen, Heidi Dierckx, Jean Charoud-Got, Silvia García Ruiz and John Seghers for material processing, packing and providing storage rooms.

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The work of Raf Van Ammel and Jan Paepen on organising a collaborate trial for validating the precision of the draft standard WD EN 17216 (natural radionuclides in building materials) impacted very positively on this PT and many synergies were found. The authors further thank Jan Paepen for reviewing this report and for providing data on the short-term stability of the materials.

This report was authorised by Dr. Arjan Plompen, Head of Unit JRC.G.II.6.

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Head of Unit, Arjan Plompen; ISO/IEC 17043 Quality management, Petya Malo; Project Leader, Katarzyna Sobiech-Matura/Mikael Hult; Statistical advisors, Stefaan Pommé and Jan Paepen; External technical advisors: Piotr Robouch from JRC-Geel Directorate F.5 Food & Feed Compliance Unit and Håkan Emteborg from JRC-Geel Directorate F.6 Reference Materials Unit.

Executive summary

Policy context and concept

European Commission Directorate-General (Commission DG) Joint Research Centre in Geel (JRC-Geel) on request of the Commission DG for Energy (DG ENER) organised a proficiency test (PT) on the measurements of natural radioactivity (^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{228}Ra, ^{228}Th and ^{40}K) in building materials. This PT was an integral part of the Commission's work of realising verifications of Member States' obligations towards Article 35 of the Treaty establishing the European Atomic Energy Community (Euratom Treaty). In addition, it also constitutes the JRC's obligations towards the Commission following Article 39 of the Euratom Treaty. The work was part of the quality control programme that JRC-Geel is coordinating in order to assess the quality of the radioactivity results reported by member state laboratories and authorities to the Radioactivity Environmental Monitoring (REM) database (https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/REMdb).

Results

The PT test items (reference materials) were prepared from two types of commercially available building materials; cement and expanded clay blocks. The test items were shipped to 105 laboratories of which 96 laboratories submitted results. The results of the PT were evaluated according to ISO 13528:2015. The percentage difference (*D%*), *z* and *zeta* (ζ) scores were calculated. Out of the 1586 reported results (for all radionuclides in all three materials), 94.7% of the *z* scores and 73.1% of the *zeta* scores were acceptable.

Main findings and conclusions

The results indicate that Member State laboratories generally measure these materials (cement and expanded clay blocks) with acceptable to good precision of measurements but in some cases with a somewhat underestimated uncertainty. A general conclusion is that no major general problems were encountered. The vast amount of data generated in this PT will be used by different actors for important actions like identifying underperforming laboratories, discovering measurement errors, investigating training needs and making suggestions for possible improvements to international standards.

Related and future JRC work

Following several consultations with Member State experts (Article 35 Experts) and Member State laboratories monitoring radioactivity, it is concluded that there is a great need for radioactive reference materials and international proficiency tests in order to (i) validate methods, (ii) perform quality control (iii) test new methods, (iv) show proficiency towards accreditation bodies, (v) establish international equivalence and (vi) work on emergency preparedness. Seeing that radioactivity monitoring is a necessity whether a country has nuclear power within its borders or not, it is essential and a legal obligation to continue the national radioactivity monitoring schemes. Several countries are modernizing their instrumentation for radioactivity monitoring, highlighting further the need for comprehensive quality control schemes. Certain Member States and associated Member States have a need to catch up with those countries having more advanced monitoring systems. These facts in combination with a general increase in nuclear activities and nuclear threats outside EU borders highlight the need for strengthening JRC's work on provision of SI-traceable radioactive reference materials and proficiency tests for environmental radioactivity.

Quick guide

In support of Articles 35 and 39 of the Euratom Treaty, The JRC organised a proficiency test (PT) amongst 105 Member State laboratories that are involved in national measurement programmes of environmental radioactivity. Following the advice of the Article 35 Experts the first PT (within JRC's REM programme) on building materials was carried out. Seven naturally occurring radionuclides in three materials were tested. The materials were (i) cement, (ii) expanded clay blocks and (ii) pulverised expanded clay blocks.

Out of the 1586 reported results (for all radionuclides in all three materials), 94.7% of the *z* scores and 73.1% of the *zeta* scores were acceptable. This indicates a good precision of measurements in general but in some cases with a somewhat underestimated uncertainty. A general conclusion is that no major problems were encountered. The vast amount of data generated in this PT will be used by different actors for important actions like identifying underperforming laboratories, discovering measurement errors, investigating training needs and making suggestions for possible improvements to international standards.

1 Introduction

Within the framework of the European Atomic Energy Community (Euratom) Treaty and derived European legislation, Member States (MS) of the European Union (EU) are obliged to perform measurements of the radioactivity levels in their environment. The results shall be reported to the European Commission (the Commission). The Radioactivity Environmental Monitoring (REM) group of the Commission's Joint Research Centre (JRC) collects, validates and publishes the reported data. In order to verify the performance of the monitoring laboratories and to ensure comparability of reported results, regular proficiency tests (PTs) are organised by the JRC since 2003. This was the 12th PT organised by JRC-Geel in support of Article 35. The first ten PTs are summarised in a report by Hult *et al*. (2019). The full reports are also available from the REMON website: https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/Proficiency-Tests. The physical properties as well as the radioactivity levels of JRC-Geel PT test items (reference materials) are generally closer to the real samples measured routinely in monitoring laboratories than calibration standards like point sources, gels or liquid solutions. Therefore, the REM PTs provide a realistic estimate of the performance of these laboratories in their routine monitoring tasks.

This was the first REM PT dealing with building materials as those are not mentioned in Article 35[5]. However, at two consecutive Article 35/36 Experts' meetings (2016 and 2018) there have been requests from the Experts that JRC should organise PTs on building materials. The reasons for this are several; one is that the BSS[6], Basic Safety Standards, (EUCO, 2013) includes and broadens the range of exposure situations to building materials. It explicitly says "*the new requirements for building materials should allow for the free circulation of building materials*". Furthermore, Article 75 in the BSS includes five paragraphs on building materials. Paragraph 2 says: "*For identified types of building materials, the industries placing such materials on the market shall (i) determine the concentration of the radionuclides specified in Annex VII and (ii) Provide information to the competent authority on the results of measurements and the corresponding activity concentration index, as defined in Annex VII.*" For practical screening purposes, the activity concentration index, *I*, is defined in the following way:

$$I = \frac{C_{Ra226}}{300}+\frac{C_{Th232}}{200}+\frac{C_{K40}}{3000} \qquad (1)$$

Where C_{Ra226} , C_{Th232} and C_{K40} are the massic activities (in Bq/kg) of the three primordial radionuclides ^{226}Ra, ^{232}Th ("or its decay product ^{228}Ra") and ^{40}K, respectively.

All building materials contain natural (primordial[7]) radionuclides. Building materials that are based on rock and soil contain radionuclides in the ^{238}U and ^{232}Th decay chains as well as the omnipresent primordial radionuclide ^{40}K (Cinelli *et al*., 2019). These three radionuclides have half-lives in the order of billions of years (~10^9 a). In the ^{238}U decay chain, the decay chain segment starting with ^{226}Ra (half-life 1600 a) is radiologically most important (e.g. via production of radioactive radon-gas, ^{222}Rn) and therefore reference is often made to radium instead of uranium. World-wide average massic activities are about 40 Bq·kg^{-1}, 40 Bq·kg^{-1} and 400 Bq·kg^{-1} for ^{226}Ra, ^{232}Th and ^{40}K, respectively (EC, 2000). These are also typical massic activities encountered in materials like concrete and bricks but there is a great variation depending on the base materials. It is also common that product-types based on industrial by-products like blast furnace slag or coal fly ash have higher massic activities than the average ones. In this PT, three test items produced from two test materials were provided; cement (named NORM1), pieces of expanded clay blocks (NORM2) and the same expanded clay blocks but in pulverised form (NORM3).

Finally one may note that within the scope of nuclear decommissioning it has become important to measure radioactivity in building material although in such cases the anthropogenic radionuclides are more important

[5] Extract from EURATOM Treaty Article 35 "*Each Member State shall establish the facilities necessary to carry out continuous monitoring of the level of radioactivity in the air, water and soil and to ensure compliance with the basic standards. The Commission shall have the right of access to such facilities; it may verify their operation and efficiency*"

[6] Council Directive 2013/59/EURATOM laying down the basic safety standards for protection against the dangers arising from exposure to ionising radiation and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. Article 31 of the Euratom treaty obliges the Council to establish the BSS

[7] A long-lived radionuclide that was present when the Earth was formed

than the natural ones that are dealt with in this PT. But, for some radionuclides the measurement techniques are the same or have aspects of the measurement procedures that are similar.

This PT included large pieces of expanded clay blocks (the NORM2 test item), which the participants needed to prepare in a manner that they saw suitable. In previous REM PTs the test items have all been provided in a form like powder, filters or liquids that (at least for gamma-ray spectrometry) enables users to transfer the material directly into suitable measurement containers. As the sample preparation step is crucial when performing environmental radioactivity measurements, it was considered an important to include also a test in a REM PT that required sample preparation also for gamma-ray spectrometry. The NORM3 material came from the same batch of expanded clay bricks but had been thoroughly crushed, milled, sieved and homogenised before it was distributed to the participants. This PT thus opens for studying impact of some aspects of sample preparation used by the participants.

This report describes in detail the PT that was announced in 2020[8]. It covers the production of the PT test items (reference materials), how the assigned values were established, the treatment of the reported data and provides details regarding the procedures used for the evaluation and comparison of the individual results with the assigned values. The performance of individual laboratories was evaluated according to ISO 13528:2015. Finally, the large amount of data (1586 results plus responses to questionnaire) that was collected from 96 laboratories gives possibilities of looking for best practices or identifying less accurate procedures that eventually can give input to new or updated international standards. In this context one must note that the three test items (together with three additional test items) were used in a collaborative trial to assess the precision of a draft European standard WD EN 17216: “Construction products: Assessment of release of dangerous substances – Determination of activity concentrations of radium-226, thorium-232 and potassium-40 in construction products using semiconductor gamma-ray spectrometry”. This draft is intended to be published as the reference method in support of CE-declaration of the performance of construction products with respect to emission of radiation.

2 Project management and organisation details

2.1 Responsibilities and roles

The REM 2020 PT was organised by the Joint Research Centre of the European Commission (JRC-Geel), Belgium. The communication between the organiser and the participants was mainly done using the functional mail account: JRC-GEE-REM-COMPARISONS@ec.europa.eu. The responsibilities amongst the involved staff of the organiser can be seen in Annex 28. The G.II.6 unit[9] of JRC-Geel is accredited for organisation of proficiency tests according to ISO/IEC 17043:2010. As the new version (ISO/IEC 17043:2023) was not available at the onset of this exercise the 2010 version was used throughout this project although the symbols from the 2023 version have been used as they also appear in ISO 13528:2015 that is applied in this work..

2.2 Subcontractors and collaborators

The G.II.6 unit of JRC-Geel subcontracted some of the tasks to external expert institutes in the field. The main contacts and the name of each collaborating entity contributing to the assigned value are listed in Annex 29.

Furthermore, through JRC in-house collaboration the following tasks were done.

- Production of PT test items (reference materials): Reference Materials Unit, JRC.F.6, accredited to ISO 17034 for the production of reference materials..
- PT data analysis: Food & Feed Compliance Unit, JRC.F.5, accredited to ISO/IEC 17043 for organisation of PTs.

[8] and consequently subject to delays due to the Covid pandemic.
[9] Note that the unit identifier changed in June 2024 from JRC.G.II.5 to JRC.G.II.6.

2.3 Participating organisations, participation fee

The participation in the PT was based predominantly on nominations by national regulatory authorities and voluntary inscription following the announcement. Priority was given to the environmental radioactivity monitoring laboratories nominated by the EU Member States' Euratom article 35/36 contact points and authorities. In total 105 laboratories registered to this PT. They were from 25 EU countries (102 laboratories), 2 Horizon-Europe associated countries (HEAC) and 1 non-EU affiliated country[10]. JRC-Geel received a number of participation requests by e-mail that were rejected because they were either received after the registration deadline or the participation requests were coming from outside Europe (USA, African or Asian countries) where other financial or logistics issues could have emerged (e.g. customs). The full list of all registered European laboratories with their affiliations is presented in Annex 27. In total 96 laboratories (93 from EU MS, 2 from HEAC and 1 from non-EU) reported results. The distribution between the number of laboratories submitting results per country is given in Table 1. Since anonymity is a requirement the identity of the laboratories is not shown in this compilation of the results. The laboratory numbers used throughout the data evaluation in this report are not related to the order of listing the participants in Annex 27 or any other list.

Participation in this PT was free of charge. All costs regarding the PT organisation were covered by the JRC.

Table 1 Number of laboratories that submitted results, listed per country.

Country	Number of labs that submitted results	Country	Number of labs that submitted results
Austria	**2**	Korea, Rep. of	**1**
Belgium	**2**	Latvia	**1**
Bulgaria	**7**	Lithuania	**1**
Croatia	**2**	Luxembourg	**1**
Cyprus	**1**	Netherlands	**1**
Czech Republic	**2**	Poland	**7**
Estonia	**2**	Portugal	**2**
Finland	**1**	Romania	**8**
France	**2**	Serbia	**1**
Germany	**2**	Slovakia	**4**
Greece	**3**	Slovenia	**2**
Hungary	**1**	Spain	**19**
Ireland	**1**	Sweden	**2**
Italy	**17**	Türkiye	**1**
		SUM:	**96**

2.4 Timeline and announcements

Table 2 shows the REM 2020 PT time line.

[10] A special permission was obtained to accept one non-EU laboratory as it supports international equivalence in which the laboratory carries out important work on environmental radioactivity directed towards building materials within the auspices of ICRM (International Committee for Radionuclide Metrology) and CCRI(II) (Consultative Committee for Ionising Radiation at BIPM).

Table 2. Timeline of the REM 2020 PT exercise.

September 2018	Commission DG ENER and Euratom Treaty Art. 35-36 experts' meeting: Building materials were amongst the materials requested to be included in a PT
January 2020	DG ENER approved the plan of JRC-Geel to conduct a PT on natural radioactivity in building materials
30 April 2020	Invitation letter sent to the nominated/interested laboratories
16 June 2020	Nominations from the national representatives collected
30 May 2021	Initial registration deadline
30 June 2021	Extended deadline for registration
23 and 24 November 2021	Shipment of PT material to participants
15 February 2022	Initial submission deadline for laboratories' results and questionnaire
10 March 2022	New submission deadline for laboratories' results and questionnaire following extension requests
15 march 2023	The assigned values and participants' results and scores sent to participants using the REMPES tool.
24-26 September, 2024	Follow-up workshop at JRC-Geel

The announcements and communication documents are presented in Annexes**.**

2.5 PT materials

Commercially available building materials were used in this study (cement and expanded clay blocks), see Figure 1. Materials were packed in containers containing no less than 1000 g of powder or in a plastic bag (for the expanded clay block pieces). Details on the test item production and determination of assigned values can be found in Chapter 3.

Figure 1. The three test materials. From left: cement, expanded clay block and pulverised expanded clay block.

2.6 Logistics: packaging and shipment

The PT test items in powder form (NORM1 and NORM3) were filled into regular acid proof 1 L high-density polyethylene (HDPE) sample storage laboratory bottles. Crimp films (not shown in Figure 3) were used to cover the screw caps serving as anti-tamper seal. They were in two different colours to facilitate visual identification of the two different PT samples.

The individual PT test items assigned to different studies (homogeneity, stability and reference value) were selected using a random stratified selection strategy covering the whole batch. The selection was made using the Sample Number Assignment Program (SNAP) developed and validated by JRC.F.6. The selected individual units of PT reference materials (NORM1 + NORM3) were split in the following way:

- 336 units were shipped to 105 laboratories (one unit per material and laboratory but some laboratories requested extra supply).
- 10 units per PT sample were assigned for the homogeneity study and assigning reference value.
- 6 units per PT sample were used in the stability study.
- The remaining units served as back-up.

The samples were packed in the standard cardboard boxes used by the courier (DHL) and standard filling material (starch chips) were used inside each box.

2.7 Reporting of the results

Participants were instructed to report the results and the associated measurement uncertainty as massic activity[11] normalised to dry mass (Bq/kg d.m.). The organiser recommended performing the moisture determination on small[12] subsamples that shall not be used for the radionuclide analysis. Participants were instructed to take these subsamples from the bottles at the same time as the samples for radionuclide analysis. The recommended method for moisture content determination was the oven-drying procedure described in the sample accompanying letter (Annex 3).

The reference date for all results was **1 November 2021 00:00:00 UTC**. The Monographie BIPM-5 (https://www.bipm.org/en/publications/monographies) was recommended as source of nuclear decay data to be used in the analysis. This data arise from the Decay Data Evaluation Project (DDEP), which is recommended by the ICRM (International Committee for Radionuclide Metrology) as the first choice of decay data to be used in radiometric analyses. The data is incorporated in the "Table of data" made available online by Laboratoire National Henri Becquerel, (LNHB, 2021).

The results were reported via a web-based tool called MILC (Management of ILCs, developed by JRC-Geel). Participants were asked to answer all relevant questions regarding the measurement procedures used.

Participants had the opportunity to report results obtained by different analytical methods following the organiser's instructions including:

- the measurement technique used,
- one mean value per measurement technique,
- associated measurement uncertainty and the coverage factor of *k*.

[11] As the expression "activity concentration" is mainly taken to refer to activity per unit volume, it is useful to talk about "massic activity" as that is always activity per unit mass. However, as it is not clear whether it is dry mass (d.m.) or wet mass (w.m.) this has to be specified.

[12] The instruction from the organiser (Annex 3) said: *"Use small aliquots of test items (1-2 g is sufficient, max 20 g) to prepare each subsample*."

2.8 Questionnaires

Participants were asked to fill in a questionnaire when registering (see Annex 4) in which questions about the laboratory and its experience with building materials were asked. At the time of submitting the results, the laboratories were confronted with a second questionnaire (see Annex 5) about how the laboratory handled the measurements of the three test items in this PT.

Information provided by participants in the questionnaires enables a more detailed evaluation of the PT results. It helps also to discover sources of possible discrepancies and gives an overview of the methods used among the laboratories.

2.9 Data treatment

All results were treated confidentially; the link between the identities and the submitted results will not be disclosed by JRC. However, the results and performance of <u>each nominated laboratory</u> will be made available on request to its national representative(s) (the nominating authority) and to the relevant services of the European Commission at Directorate General for Energy as announced in the invitation e-mail.

Participants had to agree with our data treatment and privacy policy during the registration to comply with the European General Data Protection Regulation (GDPR).

2.10 Providing assigned values and scores

All relevant values, scores and results were distributed to the participants in March 2023 (registration number ARES(2023)1879445) in the form of an MS Excel file (named REMPES – Radioactivity Environmental Monitoring Performance Evaluation Spreadsheet) and with an accompanying letter (Annex 30). REMPES contained the 21 assigned values (7 radionuclides in 3 test items) together with associated uncertainties and standard deviation for the PT (σ_{PT}). Furthermore, there was global participants' data for each of the 21 results including number of reported values, median and MAD. By entering its lab-code, a lab obtained an overview of its own reported results and the corresponding scores. In addition there were plots of the percentage difference and the so-called PomPlots (Spasova *et al.*, 2007). Figure 2 shows a snapshot of the top of the first page of the REMPES tool.

Figure 2. Snapshot of the top of the first page of the REMPES tool used for distributing all results, values and scores to the participants.

European Commission

Directorate G - Nuclear Safety and Security (Geel)

Unit G.II.5 Nuclear Data and Measurement Standards

Results of the REM 2020 PT on natural radioactivity in building materials

Radioactivity **E**nvironmental **M**onitoring **P**erformance **E**valuation **S**preadsheet **(REMPES)**

My lab code:

Reference values, in Bq/kg dry mass

Sample	Measurand	Ref Date	Activity x_{pt} Bq/kg	$u(x_{pt})$, (k=1) Bq/kg	defined σ_{pt} rel.	$u(x_{pt})$ >0.3*σ_{pt}?	
JRC-NORM-01 Cement	K-40	01-11-21	182	4	20%	No	
JRC-NORM-01 Cement	Pb-210	01-11-21	23,5	2,2	30%	Yes	z' is us
JRC-NORM-01 Cement	Ra-226	01-11-21	85,8	2,4	20%	No	
JRC-NORM-01 Cement	Ra-228	01-11-21	50,0	1,0	20%	No	
JRC-NORM-01 Cement	Th-228	01-11-21	51,0	0,8	20%	No	
JRC-NORM-01 Cement	Th-232	01-11-21	50,3	1,0	20%	No	
JRC-NORM-01 Cement	U-238	01-11-21	82,3	3,7	30%	No	
JRC-NORM-02 Expanded clay block (piece)	K-40	01-11-21	315	10	20%	No	
JRC-NORM-02 Expanded clay block (piece)	Pb-210	01-11-21	33,5	1,6	30%	No	
JRC-NORM-02 Expanded clay block (piece)	Ra-226	01-11-21	32,4	1,0	20%	No	
JRC-NORM-02 Expanded clay block (piece)	Ra-228	01-11-21	22,9	0,6	20%	No	
JRC-NORM-02 Expanded clay block (piece)	Th-228	01-11-21	23,6	0,7	20%	No	
JRC-NORM-02 Expanded clay block (piece)	Th-232	01-11-21	23,1	0,6	20%	No	
JRC-NORM-02 Expanded clay block (piece)	U-238	01-11-21	33,6	1,3	30%	No	
JRC-NORM-03 Expanded clay block (powder)	K-40	01-11-21	313	5	20%	No	
JRC-NORM-03 Expanded clay block (powder)	Pb-210	01-11-21	32,7	1,7	30%	No	
JRC-NORM-03 Expanded clay block (powder)	Ra-226	01-11-21	32,7	1,1	20%	No	
JRC-NORM-03 Expanded clay block (powder)	Ra-228	01-11-21	22,7	0,6	20%	No	
JRC-NORM-03 Expanded clay block (powder)	Th-228	01-11-21	23,0	0,5	20%	No	
JRC-NORM-03 Expanded clay block (powder)	Th-232	01-11-21	22,7	0,5	20%	No	
JRC-NORM-03 Expanded clay block (powder)	U-238	01-11-21	33,8	1,2	30%	No	

2.11 Use of proficiency testing results by participants and accreditation bodies

The results and scores of a proficiency testing exercise should be used as described in Clause C.4 and C.5 of the ISO/IEC 17043:2010. The aforementioned clauses warn the laboratories and accreditation bodies to use proficiency testing (especially results from only one PT) as the only tool in the accreditation processes to determine competence. Performance scores from a PT are momentary evidence of competence for that particular exercise and may not necessarily reflect general long-term competence of a laboratory.

3 PT test items

Three reference materials (PT test items) were prepared for this study – cement, expanded clay block (piece) and expanded clay block powder. They were given the short names NORM1, NORM2 and NORM3, respectively[13]. Each participant received one sample container of each of the materials NORM1 and NORM3 and one piece of material NORM2.

[13] In some places you may find the alternative (longer) names: JRC-NORM-01, JRC-NORM-02 and JRC-NORM-03 or NORM-01, NORM-02 and NORM-03. In this PT they refer to the same materials.

Figure 3. The three test items as shipped to the participants.

3.1 "NORM1"-Cement

Commercially available blast-furnace cement (type CEM-III) originating from a single production batch was delivered to JRC-Geel in a big-bag. The material is a fine powder and did not require further milling (Figure 1). The material was processed in the JRC's reference materials production facility (see e.g. https://visitors-centre.jrc.ec.europa.eu/virtual-tour/refmat/en/index.html). First, it was mixed/homogenised and then filled in sample containers (high-density polyethylene wide-mouth sample containers with a volume of 1.3 L, brand Packo CurTec). The cement material was named "NORM1".

3.2 "NORM2" – Expanded clay block (piece)

Expanded clay blocks from a single production batch were delivered to JRC-Geel. A series of blocks was cleaved (see Figure 1 and Figure 3**Error! Reference source not found.**) in pieces by JRC-Geel staff, packed i n plastic bags and sent to the participating laboratories as "NORM2".

3.3 "NORM3" – Expanded clay block (powder)

A number of blocks from the same batch of expanded clay blocks as used for NORM2 was first manually cut by JRC-Geel staff and then crushed to a size below 20 mm. The material was sent to an external company who crushed it further to <3 mm and then milled and sieved it to a particle size below 250 µm. JRC.F.6 then mixed/homogenised the material and distributed it over sample containers that were of the same type as those used for NORM1. The pulverised expanded clay blocks is material "NORM3".

3.4 Characterisation

3.4.1 Homogeneity and stability

The (in)homogeneity and short-term stability (under transport conditions) of the six radionuclides ^{238}U, ^{226}Ra, ^{210}Pb, ^{228}Ra, ^{228}Th and ^{40}K in the test items was studied using gamma-ray spectrometry at JRC-Geel. In addition, a homogeneity study using alpha-particle spectrometry of U-isotopes (^{234}U, ^{235}U and ^{238}U) and Th-isotopes (^{228}Th, ^{230}Th and ^{232}Th) was performed by SCK CEN, Belgium. The data obtained from the study at JRC-Geel were used in the evaluation as the data from SCK CEN supported the findings from JRC-Geel regarding homogeneity. The alpha-particle spectrometry measurement was an important control as ^{232}Th cannot be measured using gamma-ray spectrometry. As described in Chapter 3.4.3, there is strong indication that ^{228}Ra and ^{228}Th are in equilibrium in the materials, which would indicate that they are in secular equilibrium with ^{232}Th. The data from SCK CEN supported this assumption as there was agreement in massic activities between ^{232}Th, ^{228}Ra and ^{228}Th. Furthermore, due to the low energy gamma-ray of ^{234}Th (daughter of

^{238}U), at 63.3 keV (meaning it suffers from self-attenuation in the sample) that was used for studying the homogeneity of ^{238}U it was valuable to obtain information from an independent method regarding ^{238}U homogeneity.

Ten bottles of the PT test items were randomly selected for the homogeneity study. Three samples were prepared from each bottle. These samples were measured on a HPGe detector under the same conditions.

Results were evaluated according to ISO 13528:2015. The contribution from homogeneity (u_{hom}) to the standard uncertainty of the assigned value ($u(x_{pt})$) was calculated using single-factor ANOVA. The one-way ANOVA calculations were performed using SoftCRM software (Bonas, *et al*., 2003). The relative uncertainty contribution due to inhomogeneity (u_{hom}) is listed in Column 5 of Table 4, Table 5 and Table 6, respectively for the three test items.

Table 3. The gamma-ray peaks used in the homogeneity study. When more than one peak was used, the conservative approach to select the peak with the highest u_{bb} was taken.

	Gamma-ray energy (keV)	**Comment**
U-238	63.3	
Ra-226	351.9 and 609.3*	
Pb-210	46.5	
Th-232	See ^{228}Ra and ^{228}Th	The maximum value of ^{228}Th and ^{228}Ra
Ra-228	911.2	
Th-228	238.6, 583,2, 2614.5	
K-40	1460.8	

**Also the 186.2 keV line was also studied as a quality control tool. It showed a high degree of homogeneity, but it was not used in the evaluation due to the interference from the 185.7 keV line from ^{235}U.*

The test of short-term stability was conducted such that it assessed the stability under expected conditions of transport, assumed to be between 4 °C and 60 °C. This exercise included synergies with the NORMCONSTRUCT project (see Chapter 1 of this report and Paepen *et al*., 2023a and 2023b) as the three test items NORM1, NORM2 and NORM3 were used in both exercises. The short-term stability of the PT reference material was tested at two temperatures (4 °C and 60 °C). The room temperature (20 °C) was used as a reference. Three bottles (identical to those used for the material sent to participants) were randomly selected and stored during three weeks at 4 °C, 20 °C and 60 °C. After 0, 1, 2 and 3 weeks, a subsample was taken, left to obtain room temperature and then measured using gamma-ray spectrometry on the same HPGe-detector. The sample was centred on the detector endcap by the same sample holder at the same sample-to-detector distance. For each material and for each individual peak, the count rate divided by the sample mass (g) was calculated. Then, the ratio of the massic count-rate at 4 °C and 60 °C, respectively, was divided by the massic count-rate from the 20 °C data. A linear regression was applied to the measurement results for each of the two test-temperatures and the intercept and the slope were obtained from the regression equation. Then, a regression analysis and statistical tests were performed to detect outliers (Grubbs singles and doubles test according to ISO 5725-2 (ISO, 2019a) and to test if the slope of the linear regression (ratios versus time) significantly differs from zero (ISO, 2017). For the materials and all peaks, no outliers were detected and the slope of the regression analysis (ratios of massic activities between tested temperature and room temperature versus time) did not differ from zero (both at a 99% confidence level). Following ISO/IEC

17043:2010 Chapter 4.4.3.4, the uncertainty components due to stability could be omitted in the uncertainty budget as the concerned building materials were shown to be sufficiently stable over the duration of the exercise. Because the stability of the milled expanded clay blocks (NORM3) was assessed, the stability of the pieces of expanded clay blocks (NORM2) has not been verified, but as it is the same materials as NORM3 it is not a radical assumption that also NORM2 is stable under these conditions..

3.4.2 Assigned values

Eight laboratories accredited according to ISO/IEC 17025 for the measurement technique they used and selected based on previously proven satisfactory proficiency, contributed to establishing the assigned values, see Annex 29. Two techniques were used: gamma-ray spectrometry and alpha-particle spectrometry. For alpha-particle spectrometry, two independent methods of sample preparation were used: (i) complete dissolution of the material using borate fusion with Katanax© X300 device and (ii) dissolution using a mixture of acids followed by microwave digestion. The assigned values and its uncertainty were calculated using the PMM, Power-Moderated Mean (Pommé and Keighley, 2015). Note that values for ^{232}Th obtained from gamma-ray spectrometry, where calculated as arithmetic mean of the ^{228}Ra and ^{228}Th values[14].

Table 4. The assigned values for NORM1 (cement). The uncertainty is given with a coverage factor of k=1. Massic activity is per kg dry mass at the reference date of 1 November 2021 00:00:00 UTC. For symbols see Chapter 9. Subscript "rel" means a relative value.

	Number of values in PMM	Assigned value, x_{PT} (Bq/kg)	$u_{char, rel.}$ (%)	$u_{hom, rel.}$ (%)	$u(x_{pt})_{rel}$ (%)	$u(x_{pt})$ (Bq/kg)*
U-238	11	82.3	3.1	3.2	4.5	3.7
Ra-226	9	85.8	2.8	0.5	2.8	2.4
Pb-210	8	23.5	8.8	2.9	9.2	2.2
Th-232	10	50.3	2.0	0.3	2.0	1.0
Ra-228	9	50.0	1.5	0.4	1.5	1.0
Th-228	10	51.0	2.0	0.4	2.0	0.8
K-40	9	182	2.3	0.3	2.4	4

**Rounded up to one significant digit when the value (without decimals) is equal or above 40 and rounded to two significant digits when the value (without decimals) is below 40.*

[14] For all laboratories, the ^{228}Ra and ^{228}Th activities agreed.

Table 5. The assigned values for NORM2 (bricks of expanded clay blocks). The uncertainty is given with a coverage factor of k=1. Massic activity is per kg dry mass at the reference date of 1 November 2021 00:00:00 UTC. For symbols see Chapter 9. Subscript "rel" means a relative value.

	Number of values in PMM	Assigned value, x_{PT} (Bq/kg)	$u_{char,\ rel}$ (%)	$u_{hom,\ rel}$ (%)	$u(x_{pt})_{rel}$ (%)	$u(x_{pt})$ (Bq/kg)*
U-238	7	33.6	3.5	1.2	3.7	1.3
Ra-226	8	32.4	2.6	1.4	2.9	1.0
Pb-210	8	33.5	4.5	1.5	4.8	1.6
Th-232	8	23.1	1.9	2.1	2.8	0.6
Ra-228	8	22.9	1.8	2.1	2.8	0.6
Th-228	8	23.6	2.1	1.8	2.8	0.7
K-40	8	315	2.6	2.1	3.3	10

**Rounded up to one significant digit when the value (without decimals) is equal or above 40 and rounded to two significant digits when the value (without decimals) is below 40.*

Table 6. The assigned values for NORM3 (pulverised expanded clay blocks). The uncertainty is given with a coverage factor of k=1. Massic activity is per kg dry mass at the reference date of 1 November 2021 00:00:00 UTC. For symbols see Chapter 9.**Error! Reference source not found.**. Subscript "rel" means a relative value.

	Number of values in PMM	Assigned value, x_{PT} (Bq/kg)	$u_{char,\ rel.}$ (%)	$u_{hom,\ rel.}$ (%)	$u(x_{pt})_{rel}$ (%)	$u(x_{pt})$ (Bq/kg)*
U-238	10	33.8	3.0	2.2	3.7	1.2
Ra-226	9	32.7	3.1	1.5	3.5	1.1
Pb-210	8	32.7	4.6	2.9	5.1	1.7
Th-232	10	22.7	1.9	1.0	2.1	0.5
Ra-228	9	22.7	2.3	0.7	2.4	0.6
Th-228	10	23.0	2.0	1.0	2.3	0.5
K-40	9	313	1.5	0.4	1.6	5

**Rounded up to one significant digit when the value (without decimals) is equal or above 40 and rounded to two significant digits when the value (without decimals) is below 40.*

3.4.3 Equilibrium

The PT-exercise concerned natural decay chains where often the activity of progeny is determined to establish the values for the parent radionuclides. Therefore, the state of equilibrium was investigated for NORM1 and NORM3. Seeing that NORM2 (block) is based on the same materials as NORM3 (powder) it was considered sufficient to study NORM3[15]. The homogeneity study could be used to extract information about the state of equilibria in decay chains. The approach taken was to assume secular equilibrium and calculating activities at the start of each measurement (thus neglecting decay during measurement). Then the measurement results from different dates over a period of about 1 years were compared. The time from (i) cement or clay-block production to (ii) test item processing to (iii) filling measurement containers and (iv) start of a measurement has also been taken into account when drawing conclusions on the state of equilibrium.

3.4.3.1 Equilibrium within NORM1

- **^{238}U:** It is measured in gamma-ray spectrometry using the progeny ^{234}Th and ^{234m}Pa. The 24-days half-life of ^{234}Th means the there was plenty of time for secular equilibrium to be established from cement production to start of measurements. No change of massic activity linked to a 24-day half-life was detected and therefore secular equilibrium is most likely. Furthermore, the massic activity determined using alpha-particle spectrometry (of ^{238}U) agreed with that determined using gamma-ray spectrometry (of ^{234}Th and ^{234m}Pa)

- **^{226}Ra**: In gamma-ray spectrometry it is well-known that laboratories that use the radon-progeny, ^{214}Pb and ^{214}Bi for quantifying ^{226}Ra must take into account the inert gas ^{222}Rn, which has 3.8 days half-life, can escape. It is part of this PT for laboratories to correct adequately for this by for example allowing sufficient time from sample preparation to measurement to enable secular equilibrium between ^{226}Ra, ^{222}Rn and its short-lived progeny. Also, the measurement container should either be completely filled with the sample material, or the material should be sealed in a way that prevents radon from accumulating in volumes above the sample.

The massic activities of ^{238}U and ^{226}Ra did not differ significantly (see Table 4). It is, however, not critical for this report to establish whether there is equilibrium between ^{238}U and ^{226}Ra as both radionuclides have long half-lives and therefore decay corrections are negligible.

- **^{228}Ra and ^{228}Th:** Over a period of about 1 year, no change of massic count-rate with time that can be linked to the 5.75-year half-life of ^{228}Ra or the 1.91-year half-life of ^{228}Th was observed. In addition, the massic activities of ^{228}Ra and ^{228}Th agreed very well (see Table 4). Furthermore, the massic activities determined from gamma-ray spectrometry of ^{228}Ra and ^{228}Th agreed with the massic activity for ^{232}Th determined using alpha-particle spectrometry. We therefore, assume there is equilibrium in the ^{232}Th decay chain.

- **^{210}Pb:** No change of massic count-rate linked to the 22-year half-life of ^{210}Pb was observed. The massic activity of ^{210}Pb was 3.7 times lower than the ^{226}Ra massic activity (see Table 4) indicating that there is no secular equilibrium between ^{226}Ra and ^{210}Pb. In one year, there will be in-growth of ^{210}Pb from ^{226}Ra of about 2.5 Bq/kg[16], whilst the decay of ^{210}Pb leads to a loss of 0.8 Bq/kg.

3.4.3.2 Equilibrium within NORM3

- ^{238}U: Same comment as for NORM1

- ^{226}Ra: Same comment as for NORM1

- ^{228}Ra and ^{228}Th: Same comment as for NORM1

- ^{210}Pb: No change of massic count-rate linked to the 22-year half-life of ^{210}Pb was seen. Unlike the NORM1 material, the massic activity for NORM3 of ^{210}Pb was very close to the assigned values for ^{238}U and

[15] It was anyhow necessary for participants to grind NORM2.
[16] On the condition that ^{222}Rn is not lost from the container.

^{226}Ra. There is a strong indication that there is secular equilibrium within the ^{238}U decay chain as could be suspected from a clay-material.

4 Scoring

The scoring, includes symbols and definition following the international standards ISO/IEC 17043:2010 and ISO 13528:2015. The symbols are listed in Chapter 9, but a selection are also given here for ease of reading:

$u(x_i)$	standard uncertainty of laboratory result (k=1)
$U(x_{pt})$	expanded uncertainty of assigned value
$u(x_{pt})$	standard uncertainty of assigned value (k=1)
x_{lab}	mean value (massic activity) reported by a laboratory
x_{pt}	assigned value of massic activity
σ_{pt}	the standard deviation for proficiency assessment

4.1 Standard deviation for the proficiency test assessment, σ_{pt}

For all three test items (NORM1, NORM2 and NORM3) the relative standard deviation for proficiency assessment, σ_{pt}, was set to 20% for the five radionuclide ^{232}Th, ^{228}Ra, ^{228}Th, ^{226}Ra and ^{40}K.

For ^{238}U and ^{210}Pb, σ_{pt} was set to 30% for all three test items. The reasons for having a higher σ_{pt} for ^{238}U and ^{210}Pb are:

- With gamma-ray spectrometry, ^{210}Pb is determined using the 46.5 keV line. In relatively massive environmental samples (contrary to point sources), it is very difficult to obtain good accuracy for gamma-rays below 100 keV. It is linked to the high attenuation of the gamma-rays with low energy, which makes quantification extra sensitive to inhomogeneities in a sample, measurement container, detector, deadlayer etc. Furthermore, there are labs that do not calibrate below 59 keV. Additionally, considering the low activities encountered in these samples, background subtracting of this common background line can lead to significant counting statistical uncertainties. Finally, due to the above mentioned problems, also decay data suffer and have high uncertainties for low-energy gamma-ray emitters (used e.g. for calibration).
- With gamma-ray spectrometry, ^{238}U can be determined using the 1001 keV and 766.4 keV lines from the decay of ^{234m}Pa. However, in environmental samples containing the complete ^{238}U and ^{232}Th decay chains there is interference of the 766.4 keV line[17]. Seeing that emission probabilities are low (0.323% and 0.847%, for the 766.4 keV and 1001 keV line, respectively) it is often not practically possible to use these lines as they are swamped by signals from the other radionuclides in the natural decay chains. The emission probabilities of the 63.3 keV line and the 92.5 keV line of ^{234}Th are higher; 3.75% and 4.33%, respectively, and therefore better to use when analysing environmental samples. However, these low energies suffer from the same problems as mentioned above for the 46.5 keV line of ^{210}Pb. Furthermore, the 92.5 keV line is in fact a doublet (92.38 keV + 92.80 keV) with almost equal emission probabilities (2.18% and 2.15%, respectively) so the FWHM of this peak (if fitted as one peak) is different from adjacent peaks. There is also interference from X-rays from ^{228}Ac-decay[18] at 93.35 keV (Th $K_{\alpha 1}$). For completeness, it must also be mentioned that the 63.3 keV line of ^{234}Th is also a doublet (62.88 keV + 63.30 keV) with highly differing emission probabilities (0.0164% and 3.75%, respectively). All-in-all, the combination of these facts augments the difficulty to determine ^{238}U accurately using gamma-ray spectrometry (Hult et al., 2012).

[17] Main interference from 768.4 keV line from ^{214}Bi (4.89%), but also 766.7 keV ^{211}Pb (0.62%, 763.5 keV, ^{208}Tl (1.8%)

[18] This thorium X-ray also follows the decay of ^{227}Ac in the ^{235}U decay chain, but when there is natural isotopic abundance of uranium isotopes and activities in the same order of magnitude of ^{232}Th and ^{238}U (as in the samples in this report), this line is very small in comparison to that from the ^{228}Ac decay.

4.2 Percent difference

The percentage difference from the reference activity value for the i_{th} participant was calculated with the following formula:

$$D_{i,\%} = 100 \times \frac{x_i - x_{\mathrm{pt}}}{x_{\mathrm{pt}}} \qquad (2)$$

4.3 *z* scores and *zeta* score (*ζ*)

The *z* score is defined as

$$z_i = \frac{x_i - x_{\mathrm{pt}}}{\sigma_{\mathrm{pt}}} \qquad (3)$$

When the uncertainty of the assigned value, $u(x_{pt})$, is greater than 0.3 times the σ_{PT}, then, according to ISO 13528:2015 Chapter 9.5.1 (ISO, 2015), the z' score must be used. This was the case for ^{210}Pb in NORM1. The *z'* score is defined in the following way:

$$z_i' = \frac{x_i - x_{\mathrm{pt}}}{\sqrt{\sigma_{pt}^2 + u^2(x_{pt})}} \qquad (4)$$

It takes into account the standard uncertainty of the assigned value. For the rest, the performance is evaluated like for the *z* score.

The *zeta* score, *ζ*, is calculated as follows:

$$\zeta_i = \frac{x_i - x_{\mathrm{pt}}}{\sqrt{u^2(x_i) + u^2(x_{pt})}} \qquad (5)$$

The difference between a participant's value and the assigned value is evaluated against the combined standard uncertainty of the participant's value and the assigned value.

The interpretation of the *z*, *z'* and *ζ* scores is done according to ISO 13528:2015.

$\lvert \text{score} \rvert \leq 2$	satisfactory performance ("S")	(green in Table 8 and in Annexes 6-26)
$2 < \lvert \text{score} \rvert < 3$	questionable performance ("Q")	(yellow in Table 8 and in Annexes 6-26)
$\lvert \text{score} \rvert \geq 3$	unsatisfactory performance ("U")	(red in Table 8 and in Annexes 6-26)

5 Participants' Results

A detailed presentation of all the participants' results, covering three materials (NORM1, NORM2 and NORM3) and seven radionuclides (^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{228}Ra, ^{228}Th and ^{40}K) are given in Annexes 6 – 26.

Table 7 shows an excerpt from the REMPES file that was sent to the participants containing the assigned values and the participants' scores. In Table 7 is presented the assigned value, the median and MAD[19] of the participants' reported values and the difference between median and the assigned value. The relative

[19] MAD = Median absolute deviation between participant's submitted value and the assigned value; median ($|x_i - x_{PT}|$)

difference between the medians and assigned values is for each of the 21 cases below 6%. On average the absolute relative difference between the median and the assigned value is 1.7%, 2.4% and 2.5% for NORM1, NORM2 and NORM3, respectively. A shallow analysis of the data shows that NORM1 has a relative difference (between median and assigned value) that is smaller compared to the other materials. One reason is probably linked to the low moisture content compared to NORM2 and NORM3. Another is that, except for ^{210}Pb and ^{40}K, the massic activities were higher. The extra sample preparation step included in the analysis of NORM2 (compared to NORM3) seems not to have added much extra difficulty.

Table 8 shows and overview of participants' scores. One can note that the number of reported results were lower for NORM2 than for the other materials (560 for NORM1, 471 for NORM2 and 555 for NORM3). This was expected as some laboratories may have judged that they had no time or resources for the extra sample preparation step. The good results for NORM2 shown in Table 7 could probably be affected by the fact that laboratories that experienced problems may have refrained from reporting results for that material.

Table 7. Global participants' data comparing the medians with the assigned values. In addition, the MAD (Median Absolute Deviation) is shown.

Sample	Radionuclide	Assigned value, massic activity x_{pt} (Bq/kg)	Median massic activity $\tilde{M}$ (Bq/kg)	*MAD* (Bq/kg)	Absolute difference (Bq/kg)	Relative difference (%)
NORM1 - Cement	K-40	182	185	10.2	2.8	1.5
NORM1 - Cement	Pb-210	23.5	23.2	5.0	-0.3	-1.3
NORM1 - Cement	Ra-226	85.8	83.4	4.4	-2.4	-2.8
NORM1 - Cement	Ra-228	50.0	51.0	2.0	1.0	2.0
NORM1 - Cement	Th-228	51.0	51.8	1.9	0.8	1.6
NORM1 - Cement	Th-232	50.3	51.2	2.2	0.9	1.8
NORM1 - Cement	U-238	82.3	83.0	8.1	0.7	0.9
NORM2 - Expanded clay block (piece)	K-40	315	324	19.1	9.4	3.0
NORM2 - Expanded clay block (piece)	Pb-210	33.5	32.1	4.5	-1.4	-4.2
NORM2 - Expanded clay block (piece)	Ra-226	32.4	32.6	2.6	0.2	0.6
NORM2 - Expanded clay block (piece)	Ra-228	22.9	23.9	1.6	1.0	4.4
NORM2 - Expanded clay block (piece)	Th-228	23.6	23.6	2.0	-0.1	-0.2
NORM2 - Expanded clay block (piece)	Th-232	23.1	24.0	2.1	0.8	3.7
NORM2 - Expanded clay block (piece)	U-238	33.6	33.9	3.9	0.3	0.9
NORM3 - Expanded clay block (powder)	K-40	313	312	17.0	-1.3	-0.4
NORM3 - Expanded clay block (powder)	Pb-210	32.7	30.8	5.3	-1.9	-5.8
NORM3 - Expanded clay block (powder)	Ra-226	32.7	32.0	2.3	-0.7	-2.1
NORM3 - Expanded clay block (powder)	Ra-228	22.7	23.3	1.1	0.6	2.6
NORM3 - Expanded clay block (powder)	Th-228	23.0	23.1	1.1	0.1	0.4
NORM3 - Expanded clay block (powder)	Th-232	22.7	23.2	1.2	0.5	2.2
NORM3 - Expanded clay block (powder)	U-238	33.8	32.4	3.6	-1.4	-4.1

Source: JRC-Geel

Table 8. Global participants' data with statistics on the number of reported results, *z* (or *z'*) scores and zeta scores.

Sample	Radio-nuclide	Number of reported values	z score: No. of submitted results			z score: % of submitted results			zeta score: No. of submitted results			zeta score: % of submitted results		
			$\|z\| \le 2$	$2<\|z\|<3$	$\|z\| \ge 3$	$\|z\| \le 2$	$2<\|z\|<3$	$\|z\| \ge 3$	$\|\zeta\| \le 2$	$2<\|\zeta\|<3$	$\|\zeta\| \ge 3$	$\|\zeta\| \le 2$	$2<\|\zeta\|<3$	$\|\zeta\| \ge 3$
NORM1 - Cement	K-40	94	92	1	1	97.9	1.1	1.1	67	7	20	71.3	7.4	21.3
NORM1 - Cement	Pb-210	75	66	4	5	88.0	5.3	6.7	56	11	8	74.7	14.7	10.7
NORM1 - Cement	Ra-226	91	87	1	3	95.6	1.1	3.3	62	13	16	68.1	14.3	17.6
NORM1 - Cement	Ra-228	77	74	2	1	96.1	2.6	1.3	62	2	13	80.5	2.6	16.9
NORM1 - Cement	Th-228	72	68	3	1	94.4	4.2	1.4	56	4	12	77.8	5.6	16.7
NORM1 - Cement	Th-232	75	71	1	3	94.7	1.3	4.0	58	5	12	77.3	6.7	16.0
NORM1 - Cement	U-238	76	73	0	3	96.1	0.0	3.9	50	14	12	65.8	18.4	15.8
NORM2 - Expanded clay block (piece)	K-40	77	74	2	1	96.1	2.6	1.3	53	10	14	68.8	13.0	18.2
NORM2 - Expanded clay block (piece)	Pb-210	64	60	3	1	93.8	4.7	1.6	51	4	9	79.7	6.3	14.1
NORM2 - Expanded clay block (piece)	Ra-226	75	68	2	5	90.7	2.7	6.7	49	9	17	65.3	12.0	22.7
NORM2 - Expanded clay block (piece)	Ra-228	65	64	0	1	98.5	0.0	1.5	48	8	9	73.8	12.3	13.8
NORM2 - Expanded clay block (piece)	Th-228	64	60	0	4	93.8	0.0	6.3	44	10	10	68.8	15.6	15.6
NORM2 - Expanded clay block (piece)	Th-232	60	54	2	4	90.0	3.3	6.7	45	5	10	75.0	8.3	16.7
NORM2 - Expanded clay block (piece)	U-238	66	62	1	3	93.9	1.5	4.5	53	6	7	80.3	9.1	10.6
NORM3 - Expanded clay block (powder)	K-40	93	93	0	0	100.0	0.0	0.0	64	7	22	68.8	7.5	23.7
NORM3 - Expanded clay block (powder)	Pb-210	75	70	2	3	93.3	2.7	4.0	50	14	11	66.7	18.7	14.7
NORM3 - Expanded clay block (powder)	Ra-226	90	84	2	4	93.3	2.2	4.4	61	15	14	67.8	16.7	15.6
NORM3 - Expanded clay block (powder)	Ra-228	77	74	1	2	96.1	1.3	2.6	58	10	9	75.3	13.0	11.7
NORM3 - Expanded clay block (powder)	Th-228	72	68	0	4	94.4	0.0	5.6	59	4	9	81.9	5.6	12.5
NORM3 - Expanded clay block (powder)	Th-232	73	67	0	6	91.8	0.0	8.2	59	7	7	80.8	9.6	9.6
NORM3 - Expanded clay block (powder)	U-238	75	73	0	2	97.3	0.0	2.7	54	13	8	72.0	17.3	10.7
Sum		**1586**	**1502**	**27**	**57**				**1159**	**178**	**249**			
Average						**94.7**	**1.7**	**3.6**				**73.1**	**11.2**	**15.7**

Source: JRC-Geel

5.1 Moisture content

Seeing that the participants were asked to report massic activity in Bq per kg dry mass, the moisture content determination was crucial to obtaining accurate values. Table 9 gives an overview of the moisture data. It is important to note that there is **no** reference moisture content as it can vary from one laboratory to another depending on the environment (e.g. temperature, humidity and pressure) in each specific laboratory where the samples are handled. Great variations from the median values are, however, unlikely and laboratories with great deviations from the median are encouraged to perform extra quality control of the measurement of moisture content. The participants reported moisture content in the tool "EU-Survey" together with the questionnaire so it was considered as auxiliary information. Four laboratories reported twice in this questionnaire and consequently one of their numbers (the one reported first) was deleted from the analysis in Table 9. Four (other) laboratories reported not to have used the prescribed method. In the case a value different from zero was reported by such a lab (two cases for NORM1, one case for NORM2 and NORM3, respectively, the value was used in the evaluation in Table 9. Two laboratories report the value 1% (without any decimals) for all three samples but were included in the evaluation. All the reported results are graphically depicted in Annex 31- Annex 33.

Table 9. Data on reported measured moisture content in the samples. Note that there is no reference value for the moisture content as it can vary from one laboratory to another depending on the environmental parameters and time in the area the samples were handled.[20]. The number of decimals for the median, min and max values are identical to what was reported by the participant, which thus varied from one laboratory to another.

Test Item	NORM1	NORM2	NORM3
No. of reported values	80	69	82
Median	0.28%	2.49%	4.3%
Mean	0.67%	2.34	3.99%
Min	0.00%	0.00%	0.38%
Max	10%	8%	9%
Standard deviation	1.31%	1.60%	1.44%

6 Information on techniques

Table 10 gives an overview of the techniques used by the laboratories.

[20] For information (not for reference), these were the values measured by JRC-Geel: NORM1: 0.153%±0.016%, NORM2: 2.37%±0.11%, NORM3: 4.10%±0.45%.

Table 10. Analytical methods reported by participants. Any reported value (i.e. when it is not a blank or a dash), also an upper limit, is counted.

	Number of reported values	Radionuclides	Comment
α-particle spectrometry	77	^{238}U, ^{232}Th, ^{228}Th	31, 33 and 13 values respectively per radionuclide by 12 labs.
γ-ray spectrometry	1449	All seven (^{232}Th indirectly)	^{232}Th determined either as mean of ^{228}Ra and ^{228}Th or identical to ^{228}Ac
ICP-MS	10	^{238}U, ^{232}Th	One lab all three materials, another lab NORM1 and NORM3
ICP-OES	9	^{238}U, ^{232}Th, ^{40}K	One lab, all three materials
Co-precipitation and solid scintillation ZnS(Ag) counting	3	^{226}Ra	One lab, all three materials
LSC	6	^{226}Ra, ^{210}Pb	One lab, all three materials
Not reported	32		
Total	1586		

As expected, gamma-ray spectrometry was the most used method. Amongst the 1449 reported values in Table 10, 23 were upper limits (13 for ^{210}Pb, 1 for ^{228}Th and 7 for ^{232}Th).

Alpha-particle spectrometry was the second most used method with 77 submitted results. Seeing that alpha-particle spectrometry is also is a routine method for determining ^{238}U, ^{232}Th and ^{228}Th it is informative to study the results separately. Figure 4, Figure 5 and Figure 6 show the relative difference in reported results (compared to the assigned values) for the ^{238}U, ^{232}Th and ^{228}Th, respectively. For NORM1 and NORM3 the ^{238}U values distribute around the assigned values. For NORM2, all values except one are lower than the assigned value, which could indicate some bias in sample preparation. For ^{232}Th, the results distribute around the assigned value for all three materials and the bias seen for ^{238}U in NORM2 is not observed. For ^{228}Th there are rather few submitted results (4-5 per material) and difficult to draw conclusions.

The moisture content determined by the laboratories that reported alpha-particle spectrometry results was investigated. No values that “stand out” were noted. It can be concluded that the moisture content is not responsible for the alpha-particle spectrometry results with large deviations.

Figure 4. The relative difference from the assigned value for ^{238}U from alpha-particle spectrometry measurements

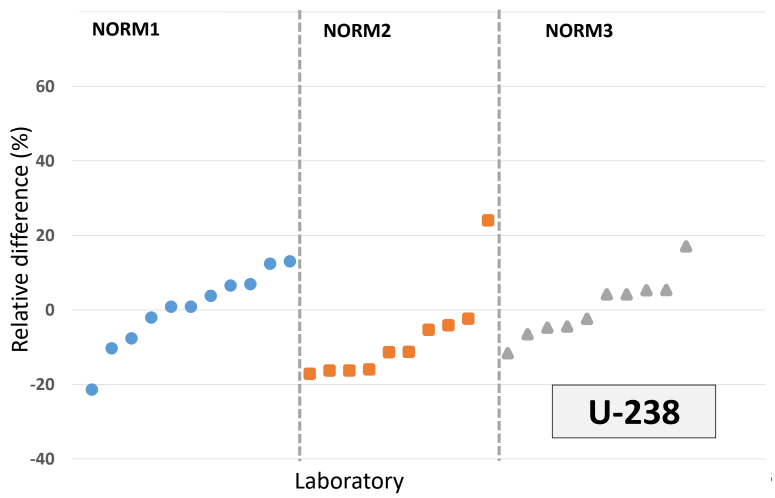


Figure 5. The relative difference from the assigned value for ^{232}Th from alpha-particle spectrometry measurements

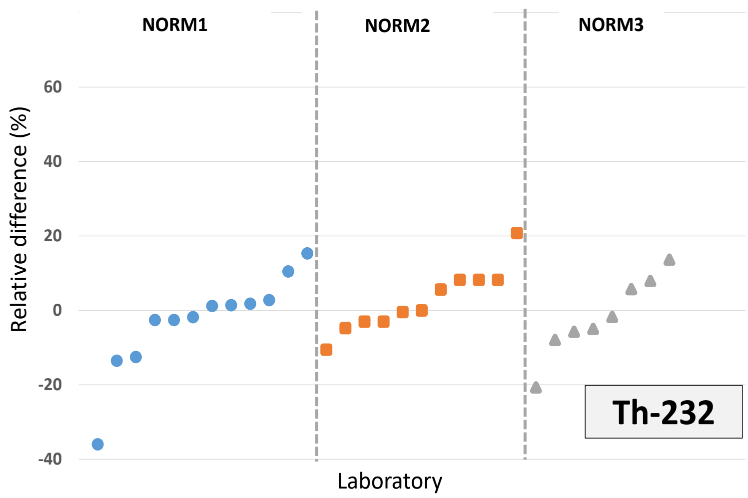
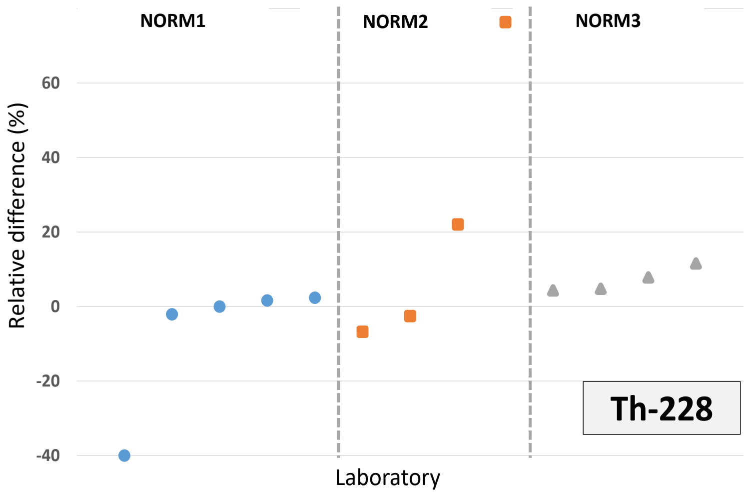


Figure 6. The relative difference from the assigned value for ^{228}Th from alpha-particle spectrometry measurements



For the remaining techniques it is difficult to make an in-depth analysis due to the few submitted results. One can, however, note the following when looking at the percent difference:

ICP-MS: Two labs submitted results (^{238}U and ^{232}Th). Judging from the *z* scores, seven out of ten submitted results were satisfactory. The three non-satisfactory ($z > 2$) ones were all for ^{232}Th (one result for each material for the same lab) and rather large (91%, 90% and 245% percent difference respectively for NORM1, NORM2 and NORM3). The satisfactory results were for ^{238}U (5 results) and ^{232}Th (2 results).

ICP-OES: Five out of nine submitted results were non-satisfactory (all three for ^{232}Th and two for ^{238}U) with percent difference ranging from 93% to 1342%.

LSC: Of the six submitted results, five were non-satisfactory ($z > 2$) with percent difference ranging between 57% and 84%.

Solid scintillation ZnS(Ag) counting of ^{226}Ra: All three results were satisfactory judging from *z* score. The percent difference was -20%, -7% and -14%, respectively for NORM1, NORM2 and NORM3.

6.1 Participants' feedback

In the questionnaire connected to the reporting of results, all participants reported to have followed their routine method of measurement. The large amount of data gathered in this PT can be further explored in order to identify good or bad practices or potential pitfalls, but, it falls outside the scope of this report.

7 Summary, discussion and conclusions

Three PT test items were prepared from two types of commercially available building materials; cement and expanded clay blocks. The test items were shipped to 105 laboratories of which 96 laboratories submitted results[21] of the massic activities (dry mass) of the seven primordial radionuclides. ^{238}U, ^{226}Ra, ^{210}Pb, ^{232}Th, ^{228}Ra, ^{228}Th and ^{40}K. The results of the PT were evaluated according to ISO 13528:2015. The percentage difference (*D%*), *z* and *zeta* (ζ) scores were calculated. Out of the 1586 reported results, 94.7% of the *z* scores and 73.1% of the *zeta* scores were acceptable.

Looking at the data on reported moisture content, one can see that some reported values are quite unlikely to appear in these materials in a normal environmental radioactivity laboratory and more likely of inadequate determination of the moisture content. Seeing that the final massic activity results is directly affected by the

[21] Not all laboratories reported results for all seven radionuclides in all three materials.

moisture content one must conclude that for a few laboratories the moisture content determination requires further quality control.

Gamma-ray spectrometry was by far the most widely used technique in this exercise with 1449 reported results followed by alpha-particle spectrometry, 77 reported results. Gamma-ray spectrometry is advantageous to use as it has the possibility to generate quantitative results for many radionuclides without necessarily having to perform complex sample preparation. Analysis of the results from this PT shows that the results obtained from gamma-ray spectrometry for ^{238}U and ^{228}Th showed similar distribution of results as alpha-particle spectrometry of the same radionuclides. For ^{238}U, alpha-particle spectrometry is generally considered more reliable due to the low energy of the gamma-rays used (63.3 keV and 92.5 keV) and interference problems encountered in gamma-ray spectrometry. But, the global results (Table 7 and Table 8) show a median value that is in good agreement with the assigned values. So, a conclusion is that gamma-ray spectrometry is a suitable method for measuring the seven radionuclides in these materials.

In Europe today, there are increasing number of nuclear decommissioning projects. Many of those involve measurements of radioactive contamination in building materials. When it comes to nuclear decommissioning, there is focus on anthropogenic radionuclides (activation products, fission products), but for radionuclides decaying in similar ways, one can possibly gain some insights from this exercise that can be useful in nuclear decommissioning.

The general conclusion is that for the materials (test items) in this PT there seems not to be any general or serious analytical problems. It is not clear whether the conclusions from this exercise can be transferred to other building materials. However, seeing the vast number of different types of building materials on the market it is essential that more studies of this type are undertaken.

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9 Symbols, acronyms, abbreviations and definitions

9.1 General names and concepts

a	Annum, recommended symbol for the unit year
activity concentration	Activity per unit volume
assigned value	Value attributed to a particular property of a proficiency test item.
BIPM	Bureau International des Poids et Mesures
cpm	counts per minute
CE	Conformité Européene
DG ENER	European Commission's Directorate-General for Energy
EURATOM	European Atomic Energy Community
GUM	Guide to the Expression of Uncertainty in Measurement
HDPE	high density polyethylene
HEAC	Horizon-Europe Associated Country
ICP-MS	Inductively Coupled Plasma - Mass Spectrometry
ICP-OES	Inductively Coupled Plasma – Optical Emission Spectrometry
IEC	International Electrotechnical Commission
ILC	Interlaboratory comparison
ISO	International Standardization Organization
JRC	Joint Research Centre (of the European Commission)
LS	Liquid Scintillation
LSC	Liquid Scintillation Counting

MAD	Median Absolute Deviation
massic activity*	Activity per unit mass
MILC	Management of ILC. (JRC's online tool for reporting ILC-results)
MS	Member States of the European Union
PFA	Perfluoroalkoxy alkane
PTFE	Polytetrafluoroethylene
PT	Proficiency Test
SI	Système International d'Unités, International System of Units
Test item	ISO 13528:2015 defines a proficiency test item as a sample, product, artefact, reference material, piece of equipment, measurement standard, data set or other information used to assess participant performance in proficiency testing.
WHO	World Health Organization

9.2 Symbols linked to scoring

D	Difference between the reported and the assigned values
$D\%$	Percentage difference between the reported and the assigned values
k	Coverage factor according to GUM
$U(x_i)$	Expanded uncertainty of laboratory result
$u(x_i)$	Standard uncertainty of laboratory result, k=1
u_{char}	Standard uncertainty from characterisation, k=1
u_{hom}	Standard uncertainty from homogeneity, k=1
$U(x_{pt})$	Expanded uncertainty of assigned value
$u(x_{pt})$	Standard uncertainty of assigned value, k=1
x_i	Mean value (massic activity) reported by a laboratory
x_{pt}	Assigned value of massic activity
σ_{pt}	Standard deviation for proficiency assessment
z	The z score compares each participant's difference from the assigned value with the standard deviation of the proficiency test assessment (σ_{pt}).
z'	The modified *z* score compares each participant's difference from the assigned value with the combined value of the standard deviation of the proficiency test assessment (σ_{pt}) and the uncertainty of the reference value.
ζ	The *zeta* score (ζ) states whether a laboratory's result agrees with the assigned value considering both the reported uncertainty and the uncertainty of the reference value.

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Annexes

Annex 1. Nomination request, invitation letter and registration instructions

Ref. Ares(2020)2325096 - 30/04/2020

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE
Directorate G - Nuclear Safety and Security
Standards for Nuclear Safety, Security and Safeguards

Geel, 30 April 2020

Subject: Article 35-36 of the Euratom Treaty
Nomination request for EC Proficiency Testing on Ra-226, Th-232 and K-40 in building materials running under the ICS-REM* programme

Ms	Maria José Bação Madruga	**Mr**	Andris Abramenkovs
	Martina Dubníčková		Pål Andersson
	Sarah Fallon		Michel Baudry
	Sonia Fontani		Paul Brejza
	Rositza Kamenova-Totzeva		Ondřej Chochola
	Konstantina Kehagia		Michel Cindro
	Sanja Krca		Jurgen Claes
	Claudia Landstetter		Kasper Grann Andersson
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	Sofía Luque		Christian Katzlberger
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			Lionel Sombré
			Reimund Stapel
			Zsolt Stefánka
			Giancarlo Torri
			Michalis Tzortzis
			Martijn van der Schaaf

Dear colleague,

As you know, EU Member States are obliged under Art. 35 and 36 of the EURATOM Treaty to inform the European Commission (EC) on a regular basis of the radioactivity levels in their environment. In order to obtain more information on the measurement methods and on the quality of the values reported by the Member States, the EC Directorate-General Joint Research Centre (DG JRC) is organising Proficiency Testing (PT) exercises for the Member States (MS) laboratories. These PTs are organised under the ICS-REM* programme in which the EC is testing

*ICS-REM – International Comparison Scheme for Radioactivity Environmental Monitoring measurement capabilities as well as providing technical support to the participating laboratories.

After discussions with DG ENER.D.3 and during the Euratom Treaty Art. 35-36 meetings, it was agreed that next PT exercise will be on **Ra-226, Th-232 and K-40 measurements in building materials**.

The schedule for this PT is as follows:

- October 2020 – PT material dispatch
- February 2021 – participating laboratories requested to send their results to the JRC
- April 2021 – preliminary report available
- t.b.d. – workshop and short training course for participating laboratory practitioners

Due to the current unusual situation, the schedule may be subject to change.

I would like to encourage you to investigate which laboratories in your country would be interested in participating in this exercise or which laboratories you would like to see participating and provide us with the contact data of the nominated laboratories (responsible person, complete postal address, telephone, and e-mail). To proceed according to the plan, we require your (nationally coordinated) response by **31 May 2020**.

Please, send your replies to the functional e-mail box
JRC-GEE-REM-COMPARISONS@ec.europa.eu

Looking forward to hearing from you with the laboratory nominations,

Yours sincerely,

Katarzyna Sobiech-Matura	Petya Malo
Project Coordinator	*Logistic Assistant*

Joint Research Centre
Nuclear Safety and Security
Standards for Nuclear Safety, Security & Safeguards
Retieseweg 111
B-2440 Geel
Belgium

cc: Messrs Michael Hübel, Vesa Tanner (DG ENER.D3)
Mr Marc De Cort (JRC Ispra)
Messrs Arjan Plompen, Mikael Hult, Ms Petya Malo (JRC Geel)

EUROPEAN COMMISSION
JOINT RESEARCH CENTRE

Directorate G - Nuclear Safety and Security, Unit G.2
Standards for Nuclear Safety, Security and Safeguards

Geel, 30 April 2020

Invitation for participation in the EC-JRC REM 2020 Proficiency Test on naturally occurring radionuclides in building materials

Dear colleague,

It is our pleasure to invite your laboratory to participate in the EC-JRC REM 2020 Proficiency Test on massic activities (Bq/kg) of naturally occurring radionuclides in building materials (reference: REM 2020 PT) as part of the European Commission's verification scheme under Article 35 of the Euratom Treaty. You can find further instructions and information on the proficiency test below. Please read them carefully.

Information on the materials

The proficiency test (PT) materials are three building material samples readily available on the European market. These materials contain naturally occurring radionuclides, but they can be transported freely and handled in the laboratory without any radiological restrictions.

The PT materials will be provided in amount of not more than 1 item per material per participant, containing not less than 1 kg of sample. The moisture content of the materials was determined, but it needs to be re-measured in each laboratory, as the results shall be provided for the dry mass of the sample.

Reference values and evaluation

Reference values of the comparison samples will be established as a consensus values from measurements by expert laboratories. The participants' results will be evaluated with respect to these reference values using percentage difference from the reference value and in addition z-score and zeta-score. Therefore, a well-founded estimate of the uncertainty of the reported results is required from each participating laboratory.

Participation costs

We kindly draw your attention to the fact that the participation in this PT is free of charge. All costs regarding the PT organization are covered by JRC-Geel. However, the sample analysis related costs are covered by the participants and not by the PT organizer. The participant is responsible for possible clearance or customs fees. By registering for this PT, you accept these aforementioned policies.

Subcontracting

We would like to inform you that part of the tasks in the REM 2020 PT will be subcontracted. This includes materials processing, elemental composition analysis and (partly) materials characterisation, as the reference values will be consensus values based on results from expert laboratories (including JRC-Geel).

Protocol for the REM 2020 PT

1. Participants are requested to follow their own routine measurement methods.

2. A brief questionnaire is a part of this exercise and participants are requested to answer all relevant questions regarding the procedures that they are using. More information and the link will be distributed after the registration to the email address provided in the registration form.

3. Tentative schedule:

30 May 2021	**Registration deadline**
June 2021	PT material shipment to participants
15 September 2021	**Deadline for results reporting**
December 2021	Preliminary report
April 2022	Final report
2022 t.b.d.	Workshop and training course for PT participants organised by JRC-Geel

Please be aware that this schedule may be influenced by the current pandemic situation and therefore subject to change.

Data treatment and privacy

Each laboratory's results will be treated with confidentiality; identities will be kept anonymous and will not be disclosed to third parties. However, the results and performance of each nominated laboratory will be made available to its national representative(s) (the nominating authority) and to the relevant services of the European Commission at Directorate General for Energy.

By registering to this PT you give your consent to the PT organizer to use your measurement results anonymously for reporting and publication purposes.

Complaints

In case of complaints, please send an email to our functional mailbox immediately. We will investigate your complaint and try to resolve it.

If you have further questions, please contact us at:
JRC-GEE-REM-COMPARISONS@ec.europa.eu

We are looking forward to your participation in this proficiency testing exercise.

Yours faithfully,

Katarzyna Sobiech-Matura

Katarzyna Sobiech-Matura

PT Coordinator
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REM Proficiency Tests: https://remon.jrc.ec.europa.eu/Services/Proficiency-Tests

Ref. Ares(2021)2888160 - 30/04/2021

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE
Directorate G - Nuclear Safety and Security, Unit G.2
Standards for Nuclear Safety, Security and Safeguards

Geel, 30 April 2020

Subject: Instructions for registration in the JRC REM 2020 Proficiency Test on naturally occurring radionuclides in building materials

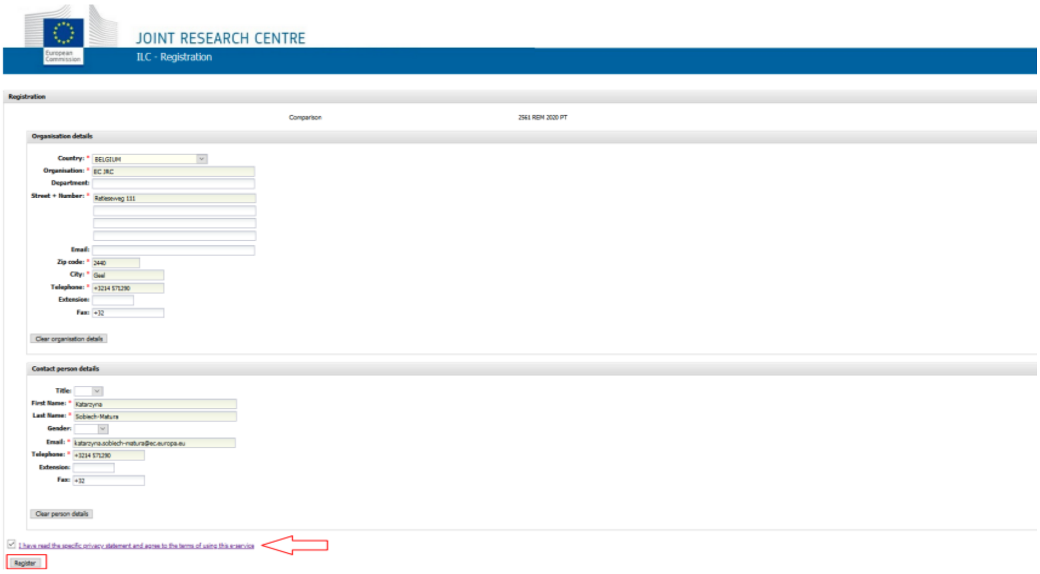
Important note: Multiple registrations are allowed only if you would like to report more than one result per radionuclide (e.g. obtained using two or more different methods).

Web link: https://web.jrc.ec.europa.eu/ilcRegistrationWeb/registration/registration.do?selComparison=2561

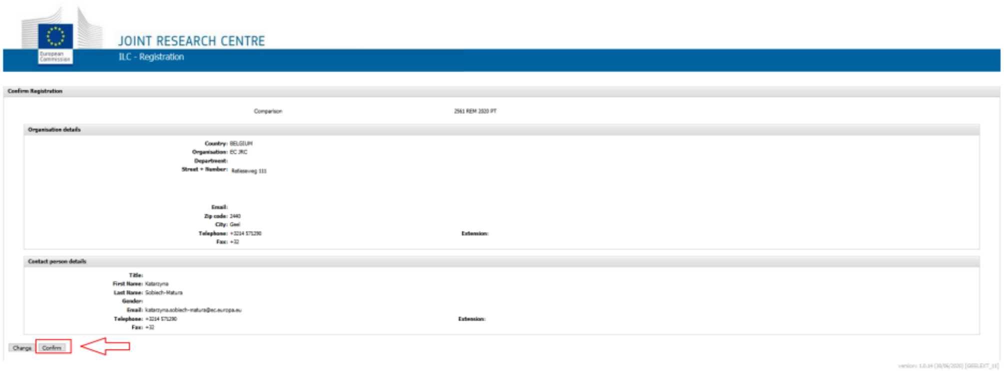
Step 1: Fill in the data, confirm that you have read the privacy statement and click "Register".

In the section "Organisation details", please provide the postal address of the laboratory which will perform the measurements (PO box is not acceptable). **The sample will be sent to that address.**

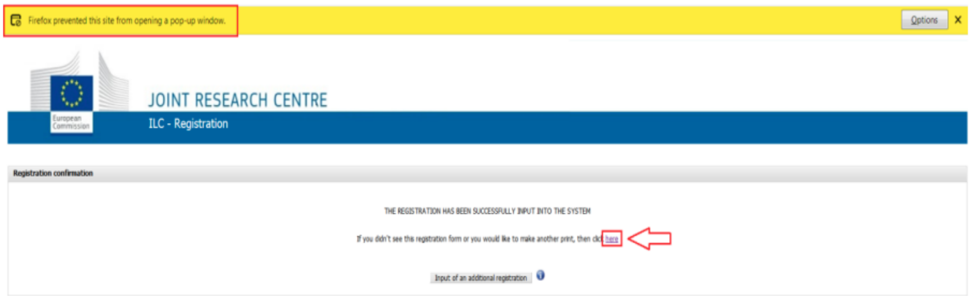
In the section "Contact person details", please provide the contact details of the person who will hold an overall responsibility for the measurements. This person will be our point of contact throughout the exercise.



Step 2: Check the data and if they are correct, click "Confirm" (if they are not correct, click "Change"). DO NOT CLOSE THE NEXT SCREEN!



Step 3: Download the registration form as proof of registration. Depending on your browser settings, the form will either open automatically or you should open it by clicking on the link "here".



It is recommended that you print the form and keep it for your records as proof of registration but it is **NOT** required to sign it and send it to us by e-mail.

After this step, your registration is complete.

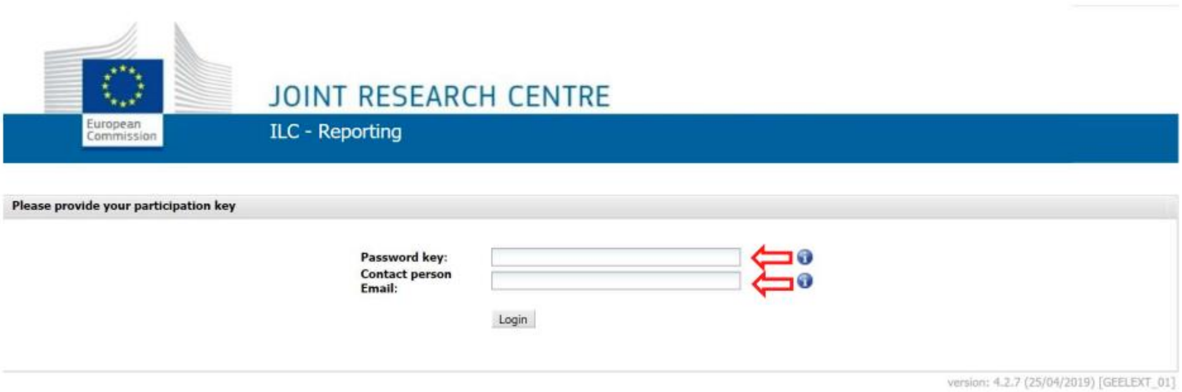
Annex 2. Reporting instructions

How to submit your results for the reporting

JRC-REM 2020 PT on naturally occurring radionuclides in building materials

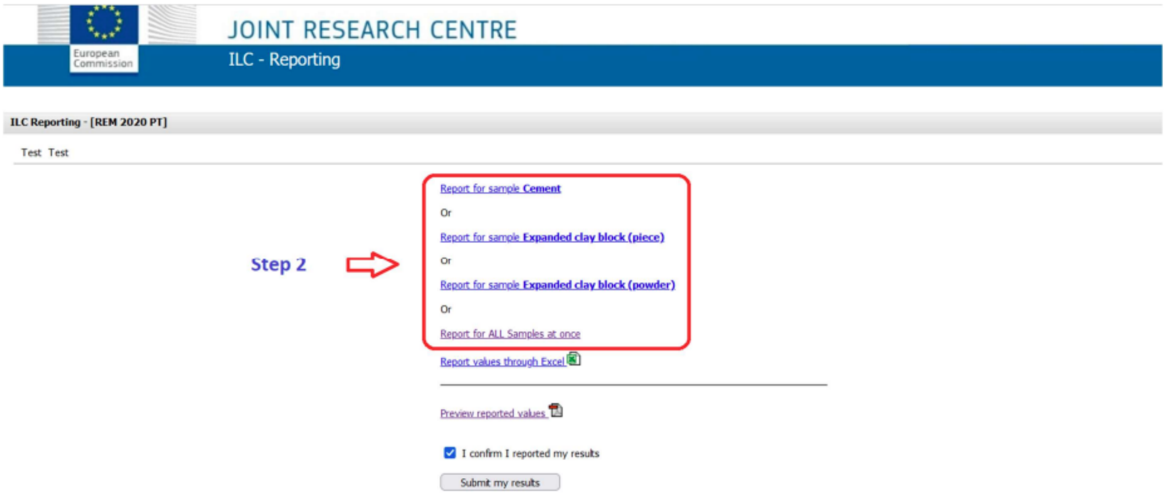
Step 1: Click on the link to the reporting module and insert your password key and e-mail used for registration.

https://web.jrc.ec.europa.eu/ilcReportingWeb



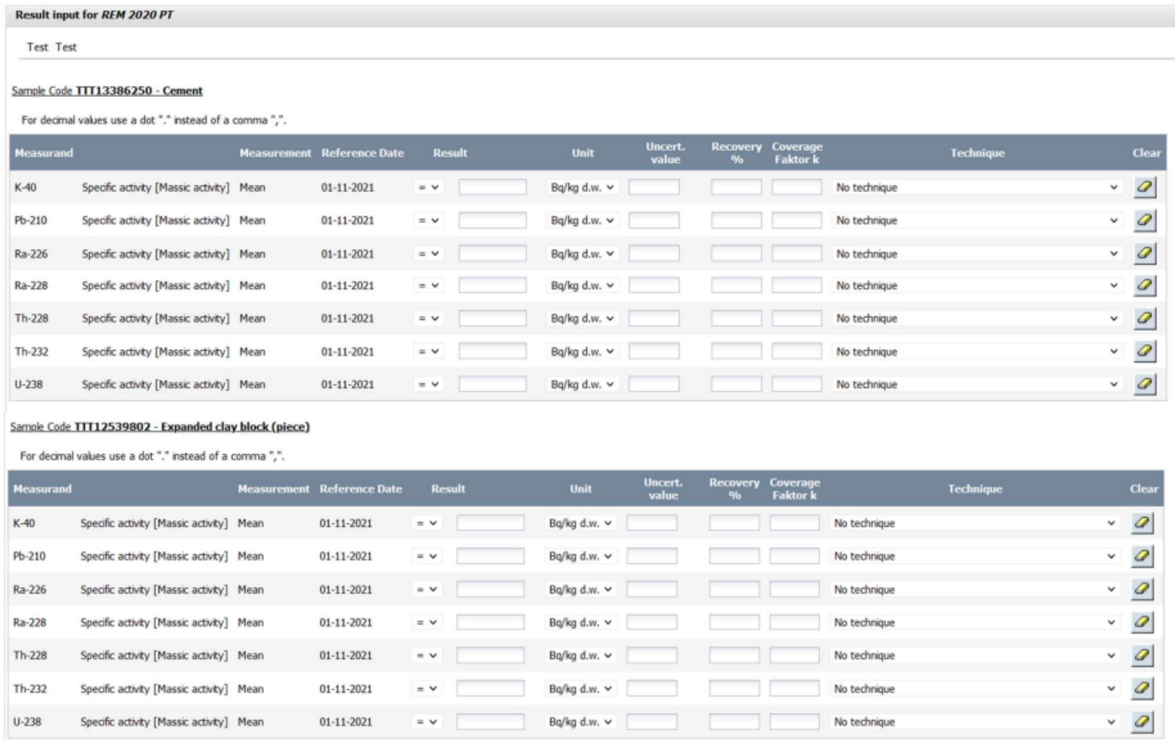
Step 2-1. Report the results for the samples **Cement**, **Expanded clay block (piece)** and **Expanded clay block (powder)**. You can report for all the samples at once or separately. For more details on Step 2, see next page.

Please DO NOT report results through Excel.



Step 2-2. Report the results for the three samples. Once you filled in the tables, you can validate and save your results then go back to the main page.

Note: The recovery is only for the methods using chemical separation and tracers. The activity and the uncertainty should be reported in Bq/kg d.w.



Result input for *REM 2020 PT*

Test Test

Sample Code **TTT13386250 - Cement**

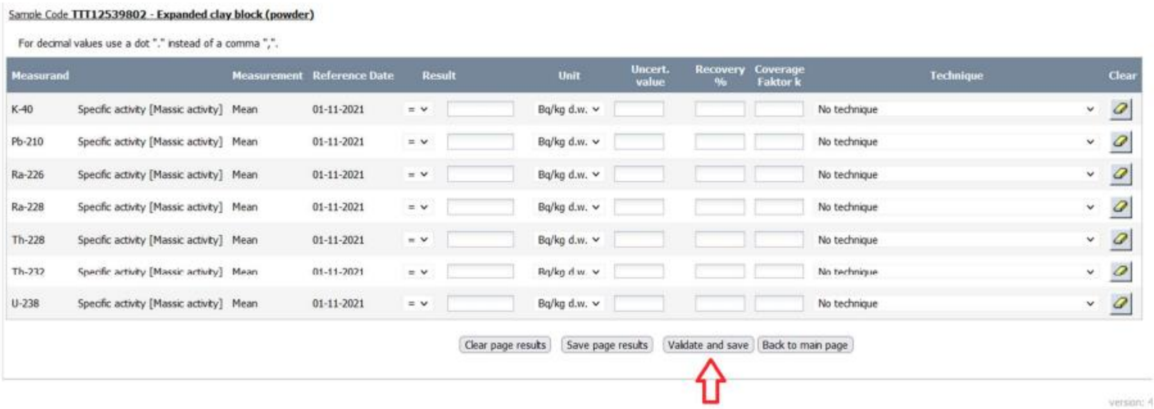
For decimal values use a dot "." instead of a comma ",".

Measurand		Measurement	Reference Date	Result		Unit	Uncert. value	Recovery %	Coverage Faktor k	Technique	Clear
K-40	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Pb-210	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Ra-226	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Ra-228	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Th-228	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Th-232	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
U-238	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	

Sample Code **TTT12539802 - Expanded clay block (piece)**

For decimal values use a dot "." instead of a comma ",".

Measurand		Measurement	Reference Date	Result		Unit	Uncert. value	Recovery %	Coverage Faktor k	Technique	Clear
K-40	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Pb-210	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Ra-226	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Ra-228	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Th-228	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Th-232	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
U-238	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	

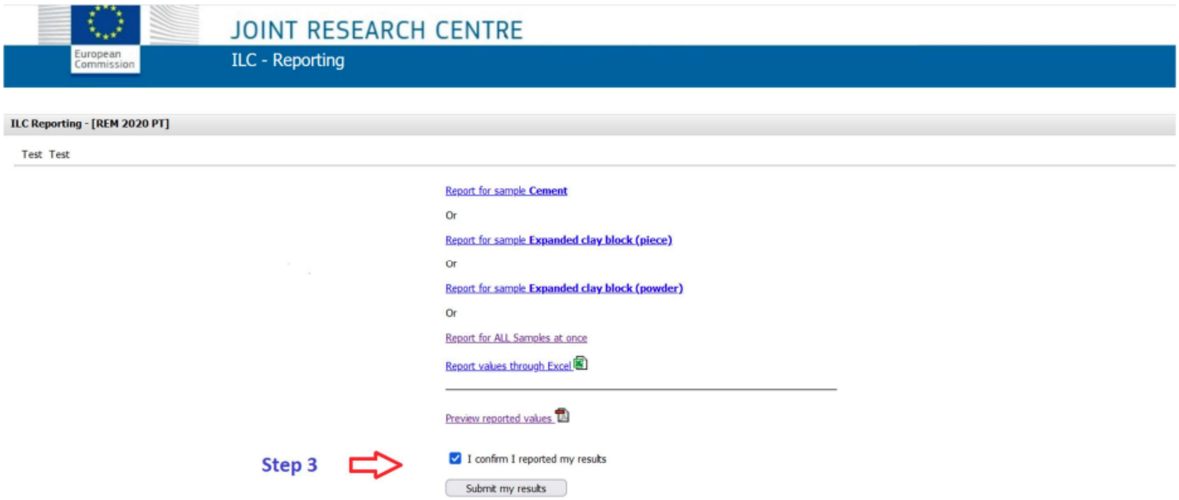


Sample Code TTT12539802 - Expanded clay block (powder)

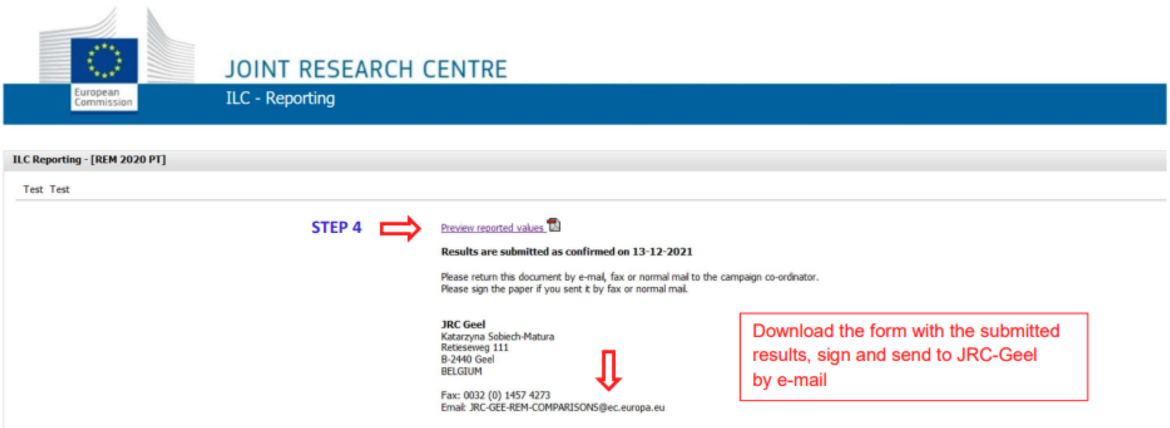
For decimal values use a dot "." instead of a comma ",".

Measurand		Measurement	Reference Date	Result		Unit	Uncert. value	Recovery %	Coverage Faktor k	Technique	Clear
K-40	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Pb-210	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Ra-226	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Ra-228	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Th-228	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
Th-232	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	
U-238	Specific activity [Massic activity]	Mean	01-11-2021	=		Bq/kg d.w.				No technique	

Step 3. Check the box next to the text "*I confirm I reported my results*" and click on "*Submit my results*".



Step 4. Click on the link to preview reported values. Print out the pdf document with the submitted values, **sign it** and send it by **e-mail** (JRC-GEE-REM-COMPARISONS@ec.europa.eu) to finalise your results submission.



Annex 3. Test item accompanying letter

Ref. Ares(2021)7119391 - 19/11/2021

EUROPEAN COMMISSION
DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE
Directorate G - Nuclear Safety and Security (Geel)
Standards for Nuclear Safety, Security and Safeguards

Geel, 15/11/2021

REM 2020 PT on Naturally Occurring Radionuclides

in Building Materials

Dear colleague,

Thank you for participating in the REM 2020 PT on naturally occurring radionuclides in building materials.

This parcel contains:

a) Three test items (each > 1000 g)
  - cement (powder) – NORM1
  - expanded clay block (piece) – NORM2
  - expanded clay block (powder) – NORM3

b) Instruction for moisture content determination

c) This accompanying letter

Important notes

1) Please confirm the receipt of the sample by e-mail to JRC-GEE-REM-COMPARISONS@ec.europa.eu, entitled SAMPLE RECIPT CONFIRMATION

2) Please check the parcel content carefully and in case of any damage or deviation from the elements described above report it to the same e-mail address.

3) **Please keep this letter for further reference**.

4) For the measurement and analysis, you should follow the procedure you routinely use.

5) Details regarding reporting will be communicated in a separate email

6) The minimum sample intake differs depending on the radionuclide:
  - For ^{40}K, ^{210}Pb, ^{226}Ra and ^{228}Ra analysis minimum sample intake is 90 g. It can be reduced down to 50 g if a correspondingly higher number of samples is analysed. Below this value, homogeneity of the material cannot be guaranteed.
  - For ^{228}Th, ^{232}Th and ^{238}U minimum sample intake is 0.5 g. Below this value, homogeneity of the material cannot be guaranteed.

7) The results must be reported for the reference date of **1 November 2021 0:00 UTC**.

8) For your calculations, we recommend to use the data provided by the Decay Data Evaluation Project (DDEP) at http://www.lnhb.fr/nuclear-data/

9) Remember to determine the moisture content of the material according to the enclosed instruction. All results are to be reported **normalized to dry mass** as Bq/kg dry mass.

10) Safety issues – please observe the pictograms, hazard and precautionary statements on the test items and in the Annex 2 of this letter. All samples contain cement and should be handled with caution.

Reporting of the results

Please report massic activities of ^{40}K, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{232}Th and ^{238}U Bq/kg dry mass.

The link to the reporting website together with the unique registration key will be send to you by email at the beginning of December 2021.

Please note that only **submitted** results will be taken into account, therefore, do not only ***Save*** your results but also click on the ***Submit*** button. Once you have submitted your results and questionnaire, please remember to send us a signed copy by e-mail to JRC-GEE-REM-COMPARISONS@ec.europa.eu

The uncertainty of the result must be reported in the same units as the activity concentration (i.e. Bq/kg) as expanded uncertainty with a relevant coverage factor.

The description of your analytical and measurement procedures will be collected via questionnaire using the same URL link as for reporting the results. We kindly ask you to answer all relevant questions regarding the procedures you employed for the measurement of the test sample. Disregard questions which are not relevant to the methods used in your laboratory.

Please, notice that during the reporting of your results the *Cancel* button serves as an exit or return button.

The deadline for reporting results and completing the questionnaire is **15 February 2022.**

Should you have any question, please do not hesitate to contact us.

I wish you success with your measurements.

Kind regards,

Katarzyna SOBIECH-MATURA
Project Coordinator

Annex 1 Moisture content determination procedure
Annex 2 Hazardous and precautionary statements

Annex 1 Moisture content determination procedure

The moisture content is to be determined in one or two small aliquots (sub-samples) that will NOT be used for the radionuclide determination.

From each test item, prepare 1-3 subsamples for the moisture content determination.

Use small aliquots of test items (1-2 g is sufficient, max 20 g) to prepare each subsample.
Each subsample should be placed in a drying/weighing container where it will remain throughout this test.
Test item material in the container should be spread out evenly to allow for water evaporation.

The subsample(s) of the test item material to be tested for moisture content should be prepared at the same time and from the same bottle as the PT sample(s) for radionuclides determination.

EQUIPMENT

- Weighing device: A balance or scale sensitive to 0.1% of the mass of the sub-sample.
- Drying device: A ventilated oven or another suitable thermostatically controlled heating chamber calibrated and capable of maintaining a temperature up to (105 ± 2) °C.

MATERIALS

- Container with a removable lid, withstanding the drying temperature and suitable to contain and spread evenly the test sample without loss while allowing for water evaporation.
- Desiccator

PROCEDURE

1) Label each container with a subsample ID.

2) Determine the mass of the container.

3) Determine the mass of the subsample and the container, subtract the mass of the container and record the remaining value mass as the "Wet mass" (m_{wet}).
The mass of the subsample should be determined immediately after preparation, as a cover on the container does not completely prevent evaporation or absorption of water.

4) Dry in the drying device at 105 °C for one hour in an opened container.

5) Close the container, remove the subsample from the drying device and cool to room temperature in a desiccator.

6) Determine the mass of the sub-sample.

   The mass of the sub-sample should be determined immediately after cooling, each time using the same time interval, e.g. 20 minutes.

7) Repeat steps 6 to 7 until constant mass is attained (three consecutive weighings should not differ by more than 0.1% of the total mass of the sample). Record the last weighing as the "Dry mass" (m_{dry}).

CALCULATION

Determine the moisture content (w) as follows:

$$w = \frac{m_{wet} - m_{dry}}{m_{wet}} * 100\ (\%)$$

PRECAUTIONS

The drying rate of subsamples will be affected by the humidity conditions and number of samples in the drying device. Avoid placing wet samples in the drying device together with nearly dry samples, to avoid possible absorption of moisture into the dry samples.

Annex 2 Hazard and precautionary statements

Signal word: Danger

Hazard statements

H318 Causes serious eye damage

H315 Causes skin irritation

H317 May cause skin irritation

H335 May cause respiratory irritation

Precautionary statements

P102 Keep out of reach of children.

P280 Wear protective gloves/protective clothing/eye protection.

P305+P351+P338+P310: IF IN EYES: Rinse cautiously with water for several minutes. Remove contact lenses, if present and easy to do. Continue rinsing. Immediately call POISON CENTER or doctor/physician.

P302+P352+P333+P313: IF ON SKIN: Wash with plenty of soap and water. If skin irritation or rash occurs: Get medical advice/attention.

P261+P304+P340+P312: **Avoid breathing dust.** IF INHALED: Remove victim to fresh air and keep at rest in a position comfortable for breathing. Call a POISON CENTER or doctor/physician if you feel unwell.

P501 Dispose of contents/container to suitable waste collection.

Annex 4. Questionnaire at the time of registration

REM 2020 PT Survey on the measurement methods

Fields marked with * are mandatory.

Dear participant of the REM 2020 PT on naturally occurring radionuclides in building materials,

We kindly ask you to answer questions regarding the procedures used in your laboratory to measure naturally occurring in building materials.
Questions marked with asterisk (*) are mandatory.

Contact details

* Contact person

---

* Full email of the contact person

test@test.com

* Name of the institution

---

* What is the type of your laboratory? (More than one answer possible)
  - [ ] Research and development
  - [x] Monitoring radioactivity in the environment
  - [ ] Monitoring nuclear facilities
  - [ ] Governmental laboratory
  - [ ] University laboratory
  - [x] Other

* Please specify

Samples of building materials containing naturally occurring radionuclides

1

* Do you measure naturally occurring radionuclides in building materials in your laboratory?
  - (•) Yes
  - ( ) No

* What kind of material do you usually measure?

---

* Approximately, how many building material samples per year do you measure?

0

* How many years of experience does your laboratory have in performing this kind of measurements?

0 years

* Do you perform moisture content determination in these samples?
  - ( ) Yes
  - (•) No

* In which form do you receive the building materials? (More than one answer possible)
  - [x] As produced (e.g. whole bricks, aggregates)
  - [ ] Pre-treated (e.g. pulverised concrete)

* What kind of processing do you apply during sample preparation? (Please choose all relevant answers, more than one aswer possible)
  - [x] Crushing
  - [x] Milling
  - [x] Sieving
  - [x] Homogenising
  - [x] Tapping/Compacting
  - [x] Other
  - [ ] None

* What kind of tools/apparatus do you use for crushing?

---

* What kind of tools/apparatus do you use for milling?

2

* What kind of tools/apparatus do you use for sieving?

---

* Please provide the mesh sizes of the sieves used

---

* Please provide the typical most representative fraction, average and end point used for sieving

---

* What kind of tools/apparatus do you use for homogenising?

---

* What kind of tools/apparatus do you use for tapping/compacting?

---

* Please provide more information

---

* Are you legally obliged to perform these measurements?
  - (•) Yes
  - ( ) No

* By whom?

---

* Please provide the legal basis for this obligation

3

Measurements methods

* Which of the following naturally occurring radionuclides are routinely measured in you laboratory (in any kind of material)? (More than one answer possible)
  - [x] K-40
  - [x] Pb-210
  - [x] Ra-226
  - [x] Ra-228
  - [x] Th-228
  - [x] Th-232
  - [x] U-238
  - [x] Other

* Please specify the radionuclide(s)

---

* Which method is used for the measurement of K-40?
  - (•) Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ( ) Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ( ) By determination of total potassium
  - ( ) LSC
  - ( ) Other

* Which method is used for the measurement of Pb-210?
  - ( ) Alpha-particle spectrometry
  - ( ) Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ( ) Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ( ) ICP-MS
  - ( ) LSC
  - (•) Other

* Please specify the method

---

* Which method is used for the measurement of Ra-226?
  - ( ) Alpha-particle spectrometry
  - ( ) Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ( ) Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ( ) ICP-MS
  - ( ) LSC

4

◉ Other

* Please specify the method

---

* Which method is used for the measurement of Ra-228?
  - ○ Alpha-particle spectrometry
  - ○ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ○ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ○ ICP-MS
  - ○ LSC
  - ◉ Other

* Please specify the method

---

* Which method is used for the measurement of Th-228?
  - ○ Alpha-particle spectrometry
  - ○ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ○ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ○ ICP-MS
  - ○ LSC
  - ◉ Other

* Please specify the method

---

* Which method is used for the measurement of Th-232?
  - ○ Alpha-particle spectrometry
  - ○ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ○ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ○ ICP-MS
  - ○ LSC
  - ◉ Other

* Please specify the method

---

* Which method is used for the measurement of U-238?
  - ○ Alpha-particle spectrometry
  - ○ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)

5

  - ○ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ○ ICP-MS
  - ○ LSC
  - ◉ Other

* Please specify the method

---

* You indicated additional radionuclide(s), not listed in the first question. Which method is used for the measurement of this radionuclide(s)?
  - ○ Alpha-particle spectrometry
  - ○ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ○ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ○ ICP-MS
  - ○ LSC
  - ◉ Other

* Please specify the method

---

* Please describe briefly the sample preparation, if any

---

* Which type of efficiency calibration do you use for gamma-ray spectrometry?
  - ○ Reference material or source
  - ○ Monte Carlo calculations only
  - ○ Combination of Monte Carlo calculations and reference material or source measurements
  - ◉ Other

* Please provide more details on the efficiency calibration used

---

* Is the measurement container for gamma-ray spectrometry completely filled with the sample?
  - ○ Yes
  - ◉ No

* Are there any fillers applied to fill the void?
  - ◉ Yes
  - ○ No

6

* Please provide additional information on the type of fillers used

---

* Do you apply any sealing material to close the measurement container for gamma-ray spectrometry?
  - ◉ Yes
  - ○ No

* What kind of sealing it do you apply to close the measurement container?

---

* Do you test the radon tightness of the measurement containers used for gamma-ray spectrometry?
  - ◉ Yes
  - ○ No

* Please provide a brief description of this method

---

* Please describe the calibration procedure(s) used for your measurement method(s) (other than gamma-ray spectrometry)

Problems encountered

* Do you encounter any difficulties while measuring the naturally occurring radionuclides in building materials?
  - ◉ Yes

7

  - ○ No
  - ○ Not applicable

* Please describe these difficulties

Contact

Katarzyna.SOBIECH-MATURA@ec.europa.eu

8

Annex 5. Questionnaire-2, at reporting date

REM 2020 PT Survey on the measurement methods

Fields marked with * are mandatory.

Dear participant of the REM 2020 PT on naturally occurring radionuclides in building materials,

We kindly ask you to answer questions regarding the procedures used during measurements of the PT reference materials.
Questions marked with asterisk (*) are mandatory.

Contact details

* Contact person

---

* Full email of the contact person

test@test.com

* Name of the institution

General information on the performed measurements

* Did you follow your standard procedure during the measurement of the PT reference materials?
- ( ) Yes
- (•) No

* What type of changes did you make?

---

* Did you determine the moisture content of the the samples according to the provided procedure?

1

- ( ) Yes
- (•) No

* What type of changes did you make?

What was the moisture content of the reference materials? (in mass %)

	Moisture content (%)
NORM1	0
NORM2	0
NORM3	0

* What kind of processing did you apply during sample preparation of NORM1? (Please choose all relevant answers, more than one answer possible.)
- [ ] Crushing
- [ ] Milling
- [ ] Sieving
- [ ] Homogenising
- [ ] Tapping/Compacting
- [x] Other
- [ ] None

* Please provide more information

---

* What kind of processing did you apply during sample preparation of NORM2? (Please choose all relevant answers, more than one answer possible)
- [x] Crushing
- [x] Milling
- [x] Sieving
- [x] Homogenising
- [x] Tapping/Compacting
- [x] Other
- [ ] None

* What kind of tools/apparatus did you use for crushing?

2

---

* What kind of tools/apparatus did you use for milling?

---

* What kind of tools/apparatus did you use for sieving?

---

* Please provide the mesh sizes of the sieves used

---

* What kind of tools/apparatus did you use for homogenising?

---

* What kind of tools/apparatus did you use for tapping/compacting?

---

* If other, please provide more information.

---

* What kind of processing did you apply during sample preparation of NORM3? (Please choose all relevant answers, more than one answer possible.)
- [ ] Crushing
- [ ] Milling
- [ ] Sieving
- [ ] Homogenising

3

- [ ] Tapping/Compacting
- [x] Other
- [ ] None

* Please provide more information

Measurements methods

* Which of the following naturally occurring radionuclides did you measure in the REM 2020 PT reference materials? (More than one answer possible)
- [x] K-40
- [x] Pb-210
- [x] Ra-226
- [x] Ra-228
- [x] Th-228
- [x] Th-232
- [x] U-238
- [x] Other

* Please specify the radionuclide(s)

---

* Which method was used for the measurement of K-40?
- ( ) Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
- ( ) Gamma-ray spectrometry with low resolution detector (e.g. NaI)
- ( ) By determination of total potassium
- ( ) LSC
- (•) Other

* Please specify the method

---

* Which method was used for the measurement of Pb-210?
- ( ) Alpha-particle spectrometry
- ( ) Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
- ( ) Gamma-ray spectrometry with low resolution detector (e.g. NaI)
- ( ) ICP-MS
- ( ) LSC
- (•) Other

4

* Please specify the method

---

* Which method was used for the measurement of Ra-226?
  - ◯ Alpha-particle spectrometry
  - ◯ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ◯ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ◯ ICP-MS
  - ◯ LSC
  - ◉ Other

* Please specify the method

---

* Which method was used for the measurement of Ra-228?
  - ◯ Alpha-particle spectrometry
  - ◯ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ◯ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ◯ ICP-MS
  - ◯ LSC
  - ◉ Other

* Please specify the method

---

* Which method was used for the measurement of Th-228?
  - ◯ Alpha-particle spectrometry
  - ◯ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ◯ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ◯ ICP-MS
  - ◯ LSC
  - ◉ Other

* Please specify the method

---

* Which method was used for the measurement of Th-232?
  - ◯ Alpha-particle spectrometry
  - ◯ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ◯ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ◯ ICP-MS

5

  - ◯ LSC
  - ◉ Other

* Please specify the method

---

* Which method was used for the measurement of U-238?
  - ◯ Alpha-particle spectrometry
  - ◉ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ◯ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ◯ ICP-MS
  - ◯ LSC
  - ◯ Other

* You indicated additional radionuclide(s), not listed in the first question. Which method was used for the measurement of this radionuclide(s)?
  - ◯ Alpha-particle spectrometry
  - ◯ Gamma-ray spectrometry with high resolution detectors (e.g. HPGe)
  - ◯ Gamma-ray spectrometry with low resolution detector (e.g. NaI)
  - ◯ ICP-MS
  - ◯ LSC
  - ◉ Other

* Please specify the method

---

* Please describe briefly the sample preparation, if any

---

* What was the volume of the measurement container for the gamma-ray spectrometric measurements? (in litres)

0 L

* What was the mass of the sample used for the gamma-spectrometric measurements? (in grams)

0 g

* Which type of efficiency calibration did you use for gamma-ray spectrometry?
  - ◯ Reference material or source
  - ◯ Monte Carlo calculations only
  - ◯ Combination of Monte Carlo calculations and reference material or source measurements

6

  - ◉ Other

* Please provide more details on the efficiency calibration used

---

* Were the measurement containers for gamma-ray spectrometry completely filled with the sample?
  - ◯ Yes
  - ◉ No

* Were there any fillers applied to fill the void?
  - ◉ Yes
  - ◯ No

* Please provide additional information on the type of fillers used

---

* Did you apply any sealing material to close the measurement container for gamma-ray spectrometry?
  - ◉ Yes
  - ◯ No

* What kind of sealing did you apply to close the measurement container?

---

* Please describe the calibration procedure(s) used for your measurement method(s) (other than gamma-ray spectrometry)

7

Please provide values for detection limits of the radionuclides measured. If one or more radionuclides was not measured in your laboratory please insert N/A.

	NORM1	NORM2	NORM3
K-40	0	0	0
Pb-210	0	0	0
Ra-226	0	0	0
Ra-228	0	0	0
Th-228	0	0	0
Th-232	0	0	0
U-238	0	0	0
Other	0	0	0

8

• Which method did you use for the calculation of the detection limits?
- ISO 11929
- Currie's method
- other

• If other calculation method, please specify

If you performed gamma-ray spectrometry, please fill in this uncertainty budget by providing a value or a typical range for each component (e.g. counting statistics, background, detector efficiency etc.). If the table contains more row than necessary please insert N/A.

	Component	Relative uncertainty (%)
1 *	---	0
2 *	---	0
3 *	---	0
4 *	---	0
5 *	---	0
6 *	---	0
7 *	---	0

Problems encountered

• Did you encounter any difficulties while processing or measuring any of the PT reference materials?
- Yes
- No

• Please describe these difficulties

Comments

Please provide your comments on the REM 2020 PT exercise

9

Which radionuclides and matrices would be useful to use in the future proficiency tests?

Contact

Contact Form

10

Annex 6: K-40 in JRC-NORM 01

x_{pt} = 182.3 $u(x_{pt})$ = 4.3 σ_{pt} = 36.5 (in Bq/kg dm)

Lab.Code	x_i	±	*k*	Technique	*D%*	*z score*	ζ score
19228	183.0	9.0	1	Direct gamma-spec.	0.4%	0.02	0.07
19229	179.591	3.078	2	Direct gamma-spec.	-1.5%	-0.07	-0.59
19230	146.6	9.6	1	Direct gamma-spec.	-19.6%	-0.98	-3.40
19231	179.04	5.1	1	Direct gamma-spec.	-1.8%	-0.09	-0.49
19232	186.0	15.0	2	Direct gamma-spec.	2.0%	0.10	0.43
19233	162.4	9.3	1	Direct gamma-spec.	-10.9%	-0.55	-1.94
19234	188.2	11.0	1	Direct gamma-spec.	3.2%	0.16	0.50
19235	187.0	11.5	1	Direct gamma-spec.	2.6%	0.13	0.38
19236	173.0	10.0	1	Direct gamma-spec.	-5.1%	-0.26	-0.85
19237	219.0	26.0	2	Direct gamma-spec.	20.1%	1.01	2.68
19238	193.0	25.0	2	Direct gamma-spec.	5.9%	0.29	0.81
19239	178.7	7.1	2	Direct gamma-spec.	-2.0%	-0.10	-0.65
19240	201.0	6.0	2	Direct gamma-spec.	10.3%	0.51	3.57
19241	184.0	12.0	1	Direct gamma-spec.	0.9%	0.05	0.13
19242	175.0	14.0	2	Direct gamma-spec.	-4.0%	-0.20	-0.89
19243	173.4	20.38	2	Direct gamma-spec.	-4.9%	-0.24	-0.81
19244	211.6	22.8	2	Direct gamma-spec.	16.1%	0.80	2.41
19245	184.0	10.0	1	Direct gamma-spec.	0.9%	0.05	0.16
19246	195.3	18.8	2	Direct gamma-spec.	7.1%	0.36	1.26
19247	185.2	5.5	1	Direct gamma-spec.	1.6%	0.08	0.42
19249	169.0	28.0	2	Direct gamma-spec.	-7.3%	-0.36	-0.91
19250	186.0	7.0	1	Direct gamma-spec.	2.0%	0.10	0.45
19251	212.0	26.0	2	Direct gamma-spec.	16.3%	0.81	2.17
19252	160.11	5.39	1	Direct gamma-spec.	-12.2%	-0.61	-3.22
19253	181.0	10.0	2	Direct gamma-spec.	-0.7%	-0.04	-0.20
19254	186.0	15.0	1	Gamma spectrometry	2.0%	0.10	0.24
19255	217.35	7.96	2	Direct gamma-spec.	19.2%	0.96	5.99
19256	204.0	20.0	2	Direct gamma-spec.	11.9%	0.60	1.99
19257	184.0	7.0	1	Direct gamma-spec.	0.9%	0.05	0.21
19258	164.0	23.0	2	Direct gamma-spec.	-10.0%	-0.50	-1.49
19259	180.84	11.23	2	Direct gamma-spec.	-0.8%	-0.04	-0.21
19260	176.4	7.2	1	Direct gamma-spec.	-3.2%	-0.16	-0.70
19261	226.1	8.6	2	Direct gamma-spec.	24.0%	1.20	7.22
19263							
19264	188.0	17.0	1	Direct gamma-spec.	3.1%	0.16	0.33

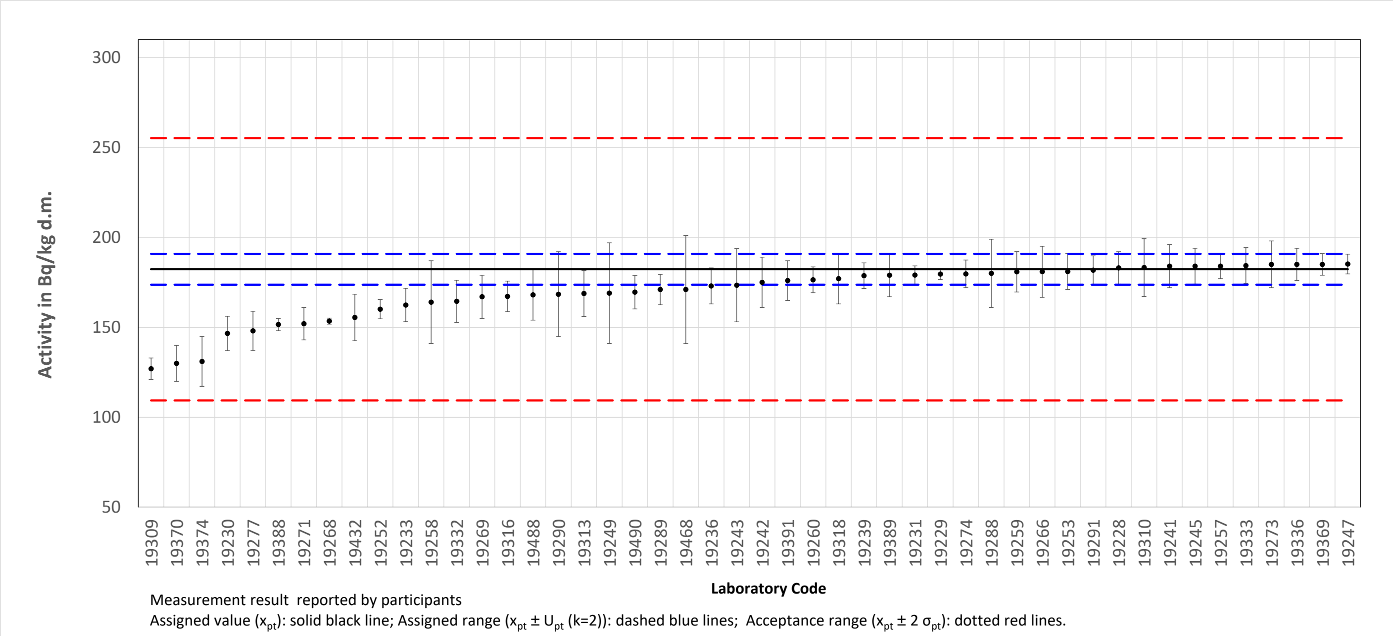
Lab.Code	x_i	±	*k*	Technique	*D%*	*z score*	ζ score
19265	190.0	13.0	1	Direct gamma-spec.	4.2%	0.21	0.56
19266	180.9	14.2	1	Direct gamma-spec.	-0.8%	-0.04	-0.09
19267	192.0	13.0	1	Direct gamma-spec.	5.3%	0.27	0.71
19268	153.476	1.688	1.05	ICP-OES	-15.8%	-0.79	-6.30
19269	167.0	12.0	1	Direct gamma-spec.	-8.4%	-0.42	-1.20
19270	200.0	16.0	2	Direct gamma-spec.	9.7%	0.49	1.95
19271	152.0	9.0	1	Direct gamma-spec.	-16.6%	-0.83	-3.04
19272	300.4	20.9	2	Direct gamma-spec.	64.8%	3.24	10.46
19273	185.0	13.0	2	Direct gamma-spec.	1.5%	0.07	0.35
19274	179.7	7.7	1	Direct gamma-spec.	-1.4%	-0.07	-0.30
19276	210.3	13.8	2	Direct gamma-spec.	15.4%	0.77	3.45
19277	148.0	11.0	2	Direct gamma-spec.	-18.8%	-0.94	-4.92
19278	188.0	16.0	2	Direct gamma-spec.	3.1%	0.16	0.63
19279	216.0	30.0	2	Direct gamma-spec.	18.5%	0.92	2.16
19281	196.0	15.0	2	Direct gamma-spec.	7.5%	0.38	1.59
19288	180.0	19.0	2	Direct gamma-spec.	-1.3%	-0.06	-0.22
19289	171.0	8.5	1	Direct gamma-spec.	-6.2%	-0.31	-1.19
19290	168.41	23.62	2	Direct gamma-spec.	-7.6%	-0.38	-1.11
19291	181.8	7.9	2	Direct gamma-spec.	-0.3%	-0.01	-0.09
19308	195.0	5.0	1	Direct gamma-spec.	7.0%	0.35	1.93
19309	127.0	6.0	2	Direct gamma-spec.	-30.3%	-1.52	-10.57
19310	183.2	16.1	2	Direct gamma-spec.	0.5%	0.02	0.10
19311	200.0	15.0	1	Direct gamma-spec.	9.7%	0.49	1.13
19313	168.769	12.74	1	Direct gamma-spec.	-7.4%	-0.37	-1.01
19314	192.47	15.0	2	Direct gamma-spec.	5.6%	0.28	1.18
19316	167.2	8.5	1	Direct gamma-spec.	-8.3%	-0.41	-1.59
19318	177.0	14.0	1	Direct gamma-spec.	-2.9%	-0.15	-0.36
19328	202.0	7.0	2	Direct gamma-spec.	10.8%	0.54	3.56
19329	242.07	3.83	2	Direct gamma-spec.	32.8%	1.64	12.73
19330	210.0	30.0	2	Gamma-spec. with chem. sep.	15.2%	0.76	1.78
19332	164.5	11.7	1	Direct gamma-spec.	-9.8%	-0.49	-1.43
19333	184.3	10.0	2	Direct gamma-spec.	1.1%	0.05	0.30
19334	193.0	5.0	1	Direct gamma-spec.	5.9%	0.29	1.62
19336	185.0	9.0	1	Direct gamma-spec.	1.5%	0.07	0.27
19368	198.0	11.7	2	Direct gamma-spec.	8.6%	0.43	2.17
19369	185.0	6.0	2	Direct gamma-spec.	1.5%	0.07	0.52
19370	130.0	10.0	1	Direct gamma-spec.	-28.7%	-1.43	-4.81
19371	194.0	6.0	1	Direct gamma-spec.	6.4%	0.32	1.59

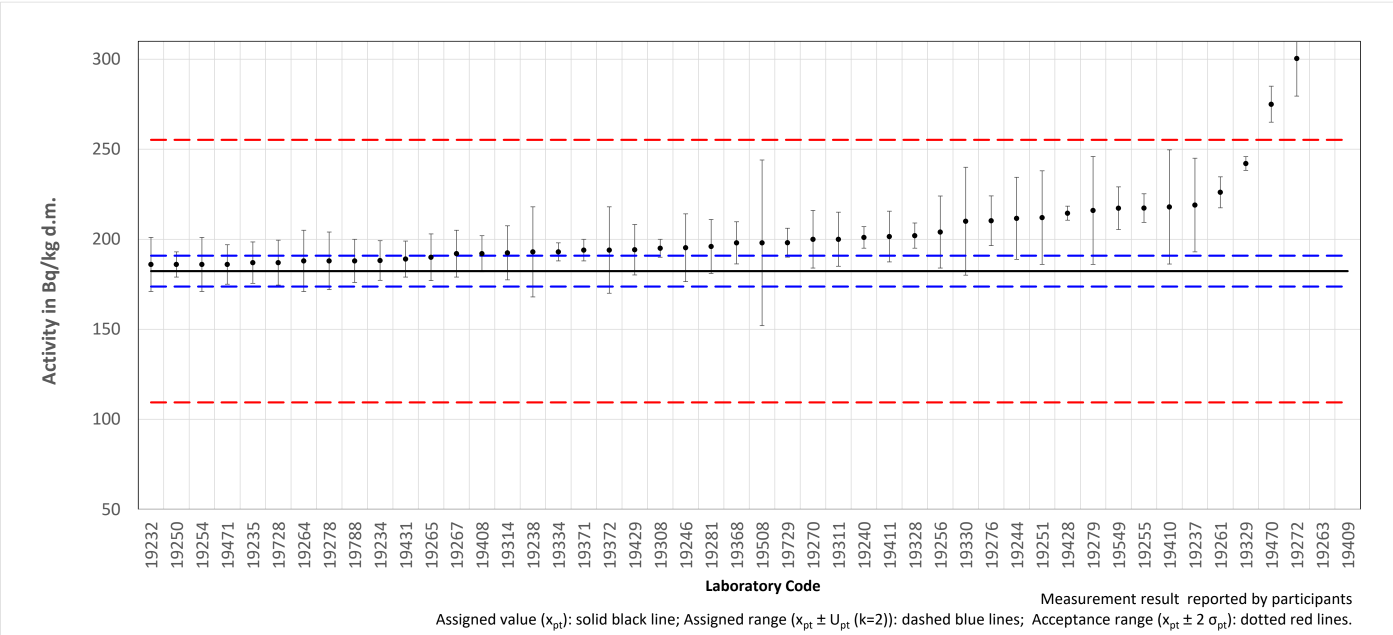
Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19372	194.0	24.0	2	Direct gamma-spec.	6.4%	0.32	0.92
19374	131.0	13.8	1.73	Direct gamma-spec.	-28.1%	-1.41	-5.67
19388	151.57	3.44	1.645	Direct gamma-spec.	-16.9%	-0.84	-6.44
19389	179.0	12.0	1	Gamma-spec. with chem. sep.	-1.8%	-0.09	-0.26
19391	176.0	11.0	1	Direct gamma-spec.	-3.5%	-0.17	-0.53
19408	192.0	10.0	1	Direct gamma-spec.	5.3%	0.27	0.89
19409							
19410	217.95	31.74	0.891	Direct gamma-spec.	19.6%	0.98	0.99
19411	201.5	14.1	2	Direct gamma-spec.	10.5%	0.53	2.33
19428	214.48	3.88	2	Direct gamma-spec.	17.7%	0.88	6.84
19429	194.169	14.031	1	Direct gamma-spec.	6.5%	0.33	0.81
19431	189.0	10.0	1	Direct gamma-spec.	3.7%	0.18	0.62
19432	155.51	12.97	2	Direct gamma-spec.	-14.7%	-0.73	-3.45
19468	171.0	30.1	2	Direct gamma-spec.	-6.2%	-0.31	-0.72
19470	275.0	10.0	1	Direct gamma-spec.	50.9%	2.54	8.52
19471	186.0	11.0	1	Direct gamma-spec.	2.0%	0.10	0.31
19488	168.0	14.0	2	Direct gamma-spec.	-7.8%	-0.39	-1.74
19490	169.57	9.32	2	Direct gamma-spec.	-7.0%	-0.35	-2.01
19508	198.0	46.0	2	Direct gamma-spec.	8.6%	0.43	0.67
19549	217.27	11.87	2	Direct gamma-spec.	19.2%	0.96	4.78
19728	187.0	12.5	1.96	Direct gamma-spec.	2.6%	0.13	0.61
19729	198.1	8.0	1	Direct gamma-spec.	8.7%	0.43	1.74
19788	188.0	12.0	2	Direct gamma-spec.	3.1%	0.16	0.77

K-40 in JRC-NORM-01

x_{pt} = 182.3 $u(x_{pt})$ = 4.3 *(k=1)* σ_{pt} = 36.5 (in Bq/kg d.m.)

z score


Activity in Bq/kg d.m.
300
250
200
150
100
50
19309 19370 19374 19230 19277 19388 19271 19268 19432 19252 19233 19258 19332 19269 19316 19488 19290 19313 19249 19490 19289 19468 19236 19243 19242 19391 19260 19318 19239 19389 19231 19229 19274 19288 19259 19266 19253 19291 19228 19310 19241 19245 19257 19333 19273 19336 19369 19247
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range (x_{pt} ± U_{pt} (k=2)): dashed blue lines; Acceptance range (x_{pt} ± 2 σ_{pt}): dotted red lines.


Activity in Bq/kg d.m.
300
250
200
150
100
50
19232 19250 19254 19471 19235 19728 19264 19278 19788 19234 19431 19265 19267 19408 19314 19238 19334 19371 19372 19429 19308 19246 19281 19368 19508 19729 19270 19311 19240 19411 19328 19256 19330 19276 19244 19251 19428 19279 19549 19255 19410 19237 19261 19329 19470 19272 19263 19409
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range (x_{pt} ± U_{pt} (k=2)): dashed blue lines; Acceptance range (x_{pt} ± 2 σ_{pt}): dotted red lines.

Annex 7: Pb-210 in JRC-NORM 01

x_{pt} = 23.5 $u(x_{pt})$ = 2.2 σ_{pt} = 7.4 (in Bq/kg dm)

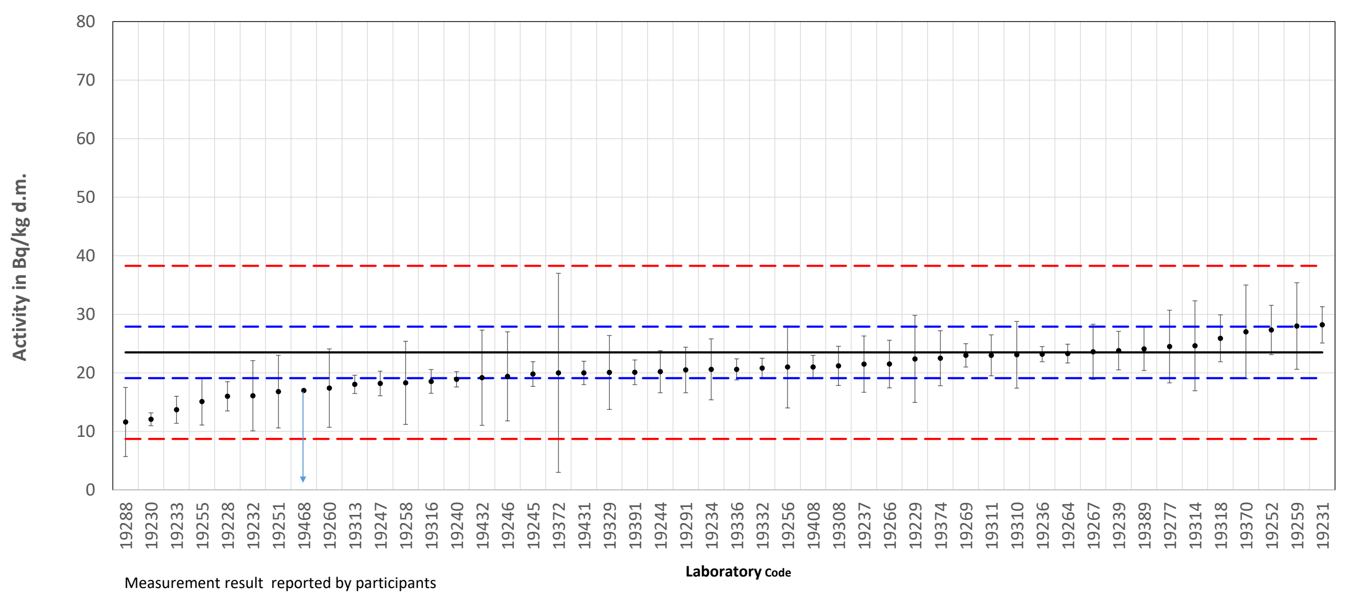
Lab.Code	x_i	±	*k*	Technique	*D%*	*z score*	ζ score
19228	16.0	2.5	1	Direct gamma-spec.	-31.9%	-1.02	-2.25
19229	22.385	7.432	2	Direct gamma-spec.	-4.7%	-0.15	-0.26
19230	12.08	1.1	1	Direct gamma-spec.	-48.6%	-1.55	-4.64
19231	28.2	3.1	1	Direct gamma-spec.	20.0%	0.64	1.24
19232	16.1	6.0	2	Direct gamma-spec.	-31.5%	-1.00	-1.99
19233	13.7	2.3	1	Direct gamma-spec.	-41.7%	-1.33	-3.08
19234	20.6	5.2	1	Direct gamma-spec.	-12.3%	-0.39	-0.51
19235	32.0	5.8	1	Direct gamma-spec.	36.2%	1.15	1.37
19236	23.2	1.3	1	Direct gamma-spec.	-1.3%	-0.04	-0.12
19237	21.5	4.8	2	Direct gamma-spec.	-8.5%	-0.27	-0.61
19238	29.4	3.4	2	Direct gamma-spec.	25.1%	0.80	2.12
19239	23.8	3.3	2	Direct gamma-spec.	1.3%	0.04	0.11
19240	18.9	1.3	2	Direct gamma-spec.	-19.6%	-0.62	-2.01
19241							
19242							
19243	29.6	7.858	2	Direct gamma-spec.	26.0%	0.83	1.35
19244	20.2	3.6	2	Direct gamma-spec.	-14.0%	-0.45	-1.16
19245	19.8	2.1	1	Direct gamma-spec.	-15.7%	-0.50	-1.22
19246	19.4	7.6	2	Direct gamma-spec.	-17.4%	-0.56	-0.93
19247	18.2	2.1	1	Direct gamma-spec.	-22.6%	-0.72	-1.74
19249	< 75.0		2	Direct gamma-spec.			
19250	29.7	2.0	1	Direct gamma-spec.	26.4%	0.84	2.09
19251	16.8	6.2	2	Direct gamma-spec.	-28.5%	-0.91	-1.76
19252	27.33	4.21	1	Direct gamma-spec.	16.3%	0.52	0.81
19253							
19254	40.0	8.0	1	Gamma spectrometry	70.2%	2.23	1.99
19255	15.1	4.0	2	Direct gamma-spec.	-35.7%	-1.14	-2.83
19256	21.0	7.0	2	Direct gamma-spec.	-10.6%	-0.34	-0.60
19257							
19258	18.3	7.1	2	Direct gamma-spec.	-22.1%	-0.70	-1.25
19259	28.0	7.39	2	Direct gamma-spec.	19.1%	0.61	1.05
19260	17.4	6.7	1	Direct gamma-spec.	-26.0%	-0.83	-0.87
19261	43.44	10.86	2	Liquid-scint. counting	84.9%	2.70	3.40
19263							
19264	23.3	1.6	1	Direct gamma-spec.	-0.9%	-0.03	-0.07
19265	66.0	14.0	1	Direct gamma-spec.	180.9%	5.75	3.00

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19266	21.51	4.06	1	Direct gamma-spec.	-8.5%	-0.27	-0.43
19267	23.6	4.7	1	Direct gamma-spec.	0.4%	0.01	0.02
19268							
19269	23.0	2.0	1	Direct gamma-spec.	-2.1%	-0.07	-0.17
19270							
19271	30.0	5.0	1	Direct gamma-spec.	27.7%	0.88	1.19
19272				Direct gamma-spec.			
19273	32.4	9.0	2	Direct gamma-spec.	37.9%	1.21	1.78
19274	32.2	4.8	1	Direct gamma-spec.	37.0%	1.18	1.65
19276	206.0	97.9	2	Direct gamma-spec.	776.6%	24.71	3.72
19277	24.5	6.2	2	Direct gamma-spec.	4.3%	0.14	0.26
19278	47.0	11.0	2	Direct gamma-spec.	100.0%	3.18	3.97
19279							
19281	56.0	6.0	2	Direct gamma-spec.	138.3%	4.40	8.74
19288	11.6	5.9	2	Direct gamma-spec.	-50.6%	-1.61	-3.23
19289	33.0	3.9	1	Direct gamma-spec.	40.4%	1.29	2.12
19290	31.28	10.27	2	Direct gamma-spec.	33.1%	1.05	1.39
19291	20.5	3.9	2	Direct gamma-spec.	-12.8%	-0.41	-1.02
19308	21.2	3.34	1	Direct gamma-spec.	-9.8%	-0.31	-0.58
19309	29.6	3.6	2	Direct gamma-spec.	26.0%	0.83	2.15
19310	23.1	5.7	2	Direct gamma-spec.	-1.7%	-0.05	-0.11
19311	23.0	3.5	1	Direct gamma-spec.	-2.1%	-0.07	-0.12
19313	18.045	1.56	1	Direct gamma-spec.	-23.2%	-0.74	-2.02
19314	24.63	7.68	2	Direct gamma-spec.	4.8%	0.15	0.26
19316	18.54	2.03	1	Direct gamma-spec.	-21.1%	-0.67	-1.66
19318	25.9	4.0	1	Direct gamma-spec.	10.2%	0.32	0.53
19328							
19329	20.07	6.32	2	Direct gamma-spec.	-14.6%	-0.46	-0.89
19330	29.0	16.0	2	Gamma-spec. with chem. sep.	23.4%	0.74	0.66
19332	20.8	1.7	1	Direct gamma-spec.	-11.5%	-0.37	-0.97
19333							
19334							
19336	20.6	1.8	1	Direct gamma-spec.	-12.3%	-0.39	-1.02
19368	< 45.5			Direct gamma-spec.			
19369							
19370	27.0	8.0	1	Direct gamma-spec.	14.9%	0.47	0.42
19371							
19372	20.0	17.0	2	Direct gamma-spec.	-14.9%	-0.47	-0.40
19374	22.5	4.7	1.73	Direct gamma-spec.	-4.3%	-0.14	-0.29

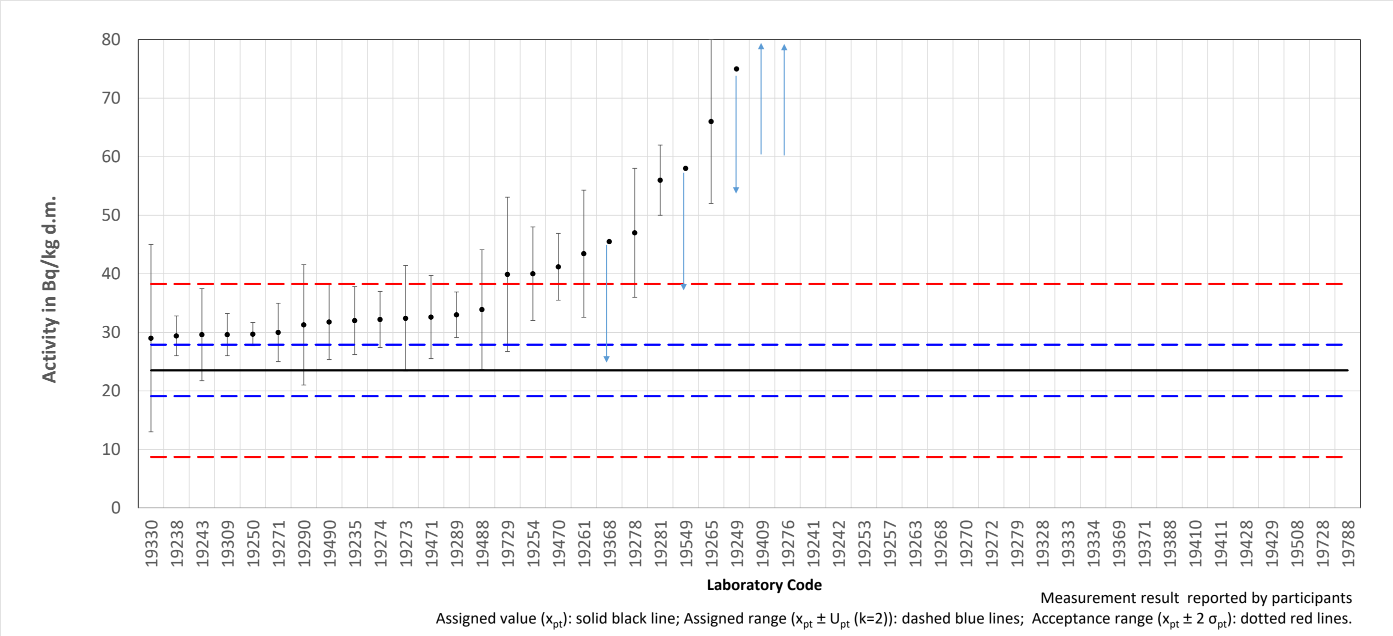
Lab.Code	x_i	±	*k*	Technique	*D%*	*z score*	ζ score
19388							
19389	24.1	3.7	1	Gamma-spec. with chem. sep.	2.6%	0.08	0.14
19391	20.1	2.1	1	Direct gamma-spec.	-14.5%	-0.46	-1.12
19408	21.0	2.0	1	Direct gamma-spec.	-10.6%	-0.34	-0.84
19409	132.32	12.38	2	Direct gamma-spec.	463.1%	14.73	16.56
19410							
19411							
19428							
19429							
19431	20.0	2.0	1	Direct gamma-spec.	-14.9%	-0.47	-1.18
19432	19.18	8.13	2	Direct gamma-spec.	-18.4%	-0.58	-0.93
19468	< 17.0			Direct gamma-spec.			
19470	41.2	5.7	1	Direct gamma-spec.	75.3%	2.40	2.90
19471	32.6	7.1	1	Direct gamma-spec.	38.7%	1.23	1.22
19488	33.9	10.2	2	Direct gamma-spec.	44.3%	1.41	1.87
19490	31.77	6.41	2	Direct gamma-spec.	35.2%	1.12	2.13
19508							
19549	< 58.0			Direct gamma-spec.			
19728							
19729	39.9	13.2	1	Direct gamma-spec.	69.8%	2.22	1.23
19788							

Pb-210 in JRC-NORM-01

x_{pt} = 23.5	$u(x_{pt})$ = 2.2 *(k=1)*	σ_{pt} = 7.4		(in Bq/kg d.m.)
		σ'_{pt} = SDPA	**z prime**	



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\,\sigma_{pt}$): dotted red lines.



Activity in Bq/kg d.m.
0
10
20
30
40
50
60
70
80
19330 19238 19243 19309 19250 19271 19290 19490 19235 19274 19273 19471 19289 19488 19729 19254 19470 19261 19368 19278 19281 19549 19265 19249 19409 19276 19241 19242 19253 19257 19263 19268 19270 19272 19279 19328 19333 19334 19369 19371 19388 19410 19411 19428 19429 19508 19728 19788
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 8: Ra-226 in JRC-NORM 01

x_{pt} = 85.8 $u(x_{pt})$ = 2.4 σ_{pt} = 17.2 (in Bq/kg dm)

Lab.Code	x_i	±	*k*	Technique	*D%*	*z score*	ζ score
19228	81.0	2.5	1	Direct gamma-spec.	-5.6%	-0.28	-1.39
19229	78.144	0.938	2	Direct gamma-spec.	-8.9%	-0.45	-3.13
19230	105.6	6.5	1	Direct gamma-spec.	23.1%	1.15	2.86
19231	80.38	1.0	1	Direct gamma-spec.	-6.3%	-0.32	-2.09
19232	79.2	8.4	2	Direct gamma-spec.	-7.7%	-0.38	-1.36
19233	74.1	6.6	1	Direct gamma-spec.	-13.6%	-0.68	-1.67
19234	89.3	1.7	1	Direct gamma-spec.	4.1%	0.20	1.19
19235	90.1	7.3	1	Gamma-spectrometry, equilibrium conditions, derived from Pb-214	5.0%	0.25	0.56
19236	81.6	8.1	1	Direct gamma-spec.	-4.9%	-0.24	-0.50
19237	77.0	12.0	2	Direct gamma-spec.	-10.3%	-0.51	-1.36
19238	86.0	3.0	2	Direct gamma-spec.	0.2%	0.01	0.07
19239	72.7	1.0	2	Secular equilibrium - Gamma-spec.	-15.3%	-0.76	-5.35
19240	93.6	3.7	2	Direct gamma-spec.	9.1%	0.45	2.57
19241	83.0	5.0	1	Direct gamma-spec.	-3.3%	-0.16	-0.50
19242	86.9	3.6	2	Direct gamma-spec.	1.3%	0.06	0.37
19243	83.06	9.297	2	Direct gamma-spec.	-3.2%	-0.16	-0.52
19244	86.6	6.5	2	Direct gamma-spec.	0.9%	0.05	0.20
19245	80.9	4.3	1	Direct gamma-spec.	-5.7%	-0.29	-1.00
19246	100.3	8.6	2	Direct gamma-spec.	16.9%	0.84	2.94
19247	101.5	5.1	1	Direct gamma-spec.	18.3%	0.91	2.79
19249	77.3	9.4	2	Direct gamma-spec.	-9.9%	-0.50	-1.61
19250	84.4	2.9	1	gamma-spectrometry Pb-214, Bi-214	-1.6%	-0.08	-0.37
19251	86.0	9.7	2	Direct gamma-spec.	0.2%	0.01	0.04
19252	76.92	2.46	1	Direct gamma-spec.	-10.3%	-0.52	-2.58
19253	82.2	3.3	2	Direct gamma-spec.	-4.2%	-0.21	-1.24
19254	84.0	6.0	1	Gamma spectrometry	-2.1%	-0.10	-0.28
19255	84.26	2.54	2	Direct gamma-spec.	-1.8%	-0.09	-0.57
19256	79.0	7.0	2	Direct gamma-spec.	-7.9%	-0.40	-1.60
19257	86.0	6.0	1	Direct gamma-spec.	0.2%	0.01	0.03
19258	75.8	6.5	2	Direct gamma-spec.	-11.7%	-0.58	-2.48
19259	81.01	13.0	2	Direct gamma-spec.	-5.6%	-0.28	-0.69
19260	77.1	5.2	1	Direct gamma-spec.	-10.1%	-0.51	-1.52
19261	15.04	4.23	2	Liquid-scint. counting	-82.5%	-4.12	-22.13
19263							
19264	90.0	5.5	1	Direct gamma-spec.	4.9%	0.24	0.70

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19265	92.0	5.0	1	Direct gamma-spec.	7.2%	0.36	1.12
19266							
19267	88.6	7.2	1	Direct gamma-spec.	3.3%	0.16	0.37
19268							
19269	72.0	5.0	1	Direct gamma-spec.	-16.1%	-0.80	-2.49
19270	85.1	6.0	2	Direct gamma-spec.	-0.8%	-0.04	-0.18
19271	83.0	2.0	1	Direct gamma-spec.	-3.3%	-0.16	-0.90
19272	115.9	2.4	2	Direct gamma-spec.	35.1%	1.75	11.22
19273	75.9	2.7	2	Direct gamma-spec.	-11.5%	-0.58	-3.60
19274	84.6	4.5	1	Direct gamma-spec.	-1.4%	-0.07	-0.24
19276	95.5	7.6	2	Direct gamma-spec.	11.3%	0.57	2.16
19277	92.5	3.9	2	Direct gamma-spec.	7.8%	0.39	2.17
19278	87.6	6.4	2	Direct gamma-spec.	2.1%	0.10	0.45
19279	83.6	12.0	2	Direct gamma-spec.	-2.6%	-0.13	-0.34
19281	100.0	8.0	2	Direct gamma-spec.	16.6%	0.83	3.04
19288	89.0	20.0	2	Direct gamma-spec.	3.7%	0.19	0.31
19289	80.0	5.0	1	Direct gamma-spec.	-6.8%	-0.34	-1.05
19290	80.41	7.11	2	Direct gamma-spec.	-6.3%	-0.31	-1.26
19291	83.5	8.4	2	Direct gamma-spec.	-2.7%	-0.13	-0.48
19308	85.6	8.0	1	Direct gamma-spec.	-0.2%	-0.01	-0.02
19309	68.2	7.9	2	Precipitation. Solid scint. (ZnS(Ag))	-20.5%	-1.03	-3.81
19310	172.1	26.4	2	Direct gamma-spec.	100.6%	5.03	6.43
19311	89.0	6.0	1	Direct gamma-spec.	3.7%	0.19	0.50
19313	81.344	6.575	1	Direct gamma-spec.	-5.2%	-0.26	-0.64
19314	83.04	8.4	2	Direct gamma-spec.	-3.2%	-0.16	-0.57
19316	73.3	8.06	1	Direct gamma-spec.	-14.6%	-0.73	-1.49
19318	83.4	1.5	1	Direct gamma-spec.	-2.8%	-0.14	-0.85
19328	82.0	6.0	2	Direct gamma-spec.	-4.4%	-0.22	-0.99
19329	91.15	0.47	2	Direct gamma-spec.	6.2%	0.31	2.22
19330	87.0	15.0	2	Gamma-spec. with chem. sep.	1.4%	0.07	0.15
19332	79.0	4.1	1	Direct gamma-spec.	-7.9%	-0.40	-1.43
19333							
19334	72.9	6.0	1	Direct gamma-spec.	-15.0%	-0.75	-2.00
19336	91.0	5.5	1	Direct gamma-spec.	6.1%	0.30	0.87
19368	83.4	1.6	2	Direct gamma-spec.	-2.8%	-0.14	-0.95
19369	73.6	1.7	2	Direct gamma-spec.	-14.2%	-0.71	-4.79
19370	84.0	4.0	1	Direct gamma-spec.	-2.1%	-0.10	-0.39
19371	81.0	4.0	1	Direct gamma-spec.	-5.6%	-0.28	-1.03
19372	83.0	10.0	2	Direct gamma-spec.	-3.3%	-0.16	-0.50

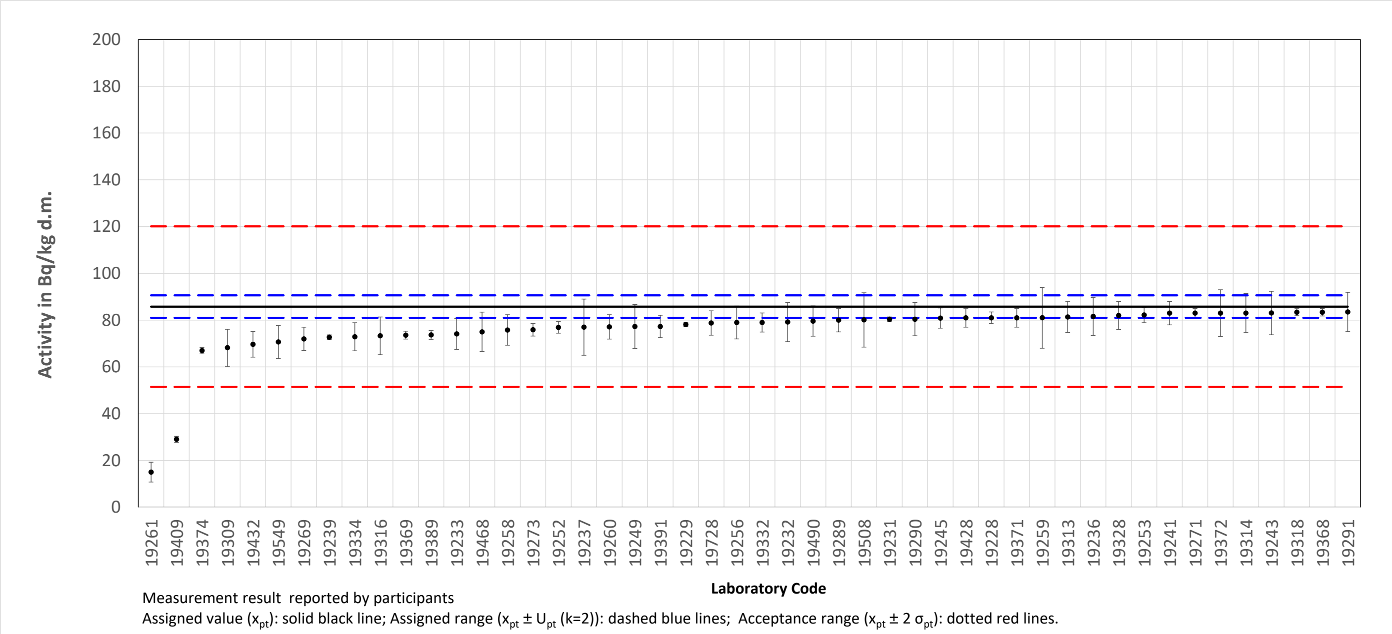
Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19374	67.0	1.4	1.73	Direct gamma-spec.	-21.9%	-1.10	-7.43
19388	113.19	2.94	1.645	Direct gamma-spec.	31.9%	1.60	9.16
19389	73.7	1.9	1	Gamma-spec. with chem. sep.	-14.1%	-0.71	-3.95
19391	77.3	4.8	1	Direct gamma-spec.	-9.9%	-0.50	-1.58
19408	87.0	6.0	1	Direct gamma-spec.	1.4%	0.07	0.19
19409	29.05	1.24	2	Direct gamma-spec.	-66.1%	-3.31	-22.91
19410	93.85	9.46	0.891	Direct gamma-spec.	9.4%	0.47	0.74
19411	87.5	6.1	2	Direct gamma-spec.	2.0%	0.10	0.44
19428	80.96	3.92	2	Direct gamma-spec.	-5.6%	-0.28	-1.56
19429	84.162	9.512	1	Direct gamma-spec.	-1.9%	-0.10	-0.17
19431	88.0	6.0	1	Direct gamma-spec.	2.6%	0.13	0.34
19432	69.67	5.47	2	Direct gamma-spec.	-18.8%	-0.94	-4.43
19468	75.0	8.46	2	Direct gamma-spec.	-12.6%	-0.63	-2.22
19470	84.0	2.1	1	Direct gamma-spec.	-2.1%	-0.10	-0.56
19471	85.8	7.2	1	Direct gamma-spec.	0.0%	0.00	0.00
19488	126.0	11.0	2	Direct gamma-spec.	46.9%	2.34	6.70
19490	79.59	6.46	2	Direct gamma-spec.	-7.2%	-0.36	-1.54
19508	80.1	11.6	2	Direct gamma-spec.	-6.6%	-0.33	-0.91
19549	70.66	7.11	2	Direct gamma-spec.	-17.6%	-0.88	-3.53
19728	78.8	5.2	1.96	Direct gamma-spec.	-8.2%	-0.41	-1.96
19729	85.4	3.9	1	Direct gamma-spec.	-0.5%	-0.02	-0.09
19788							

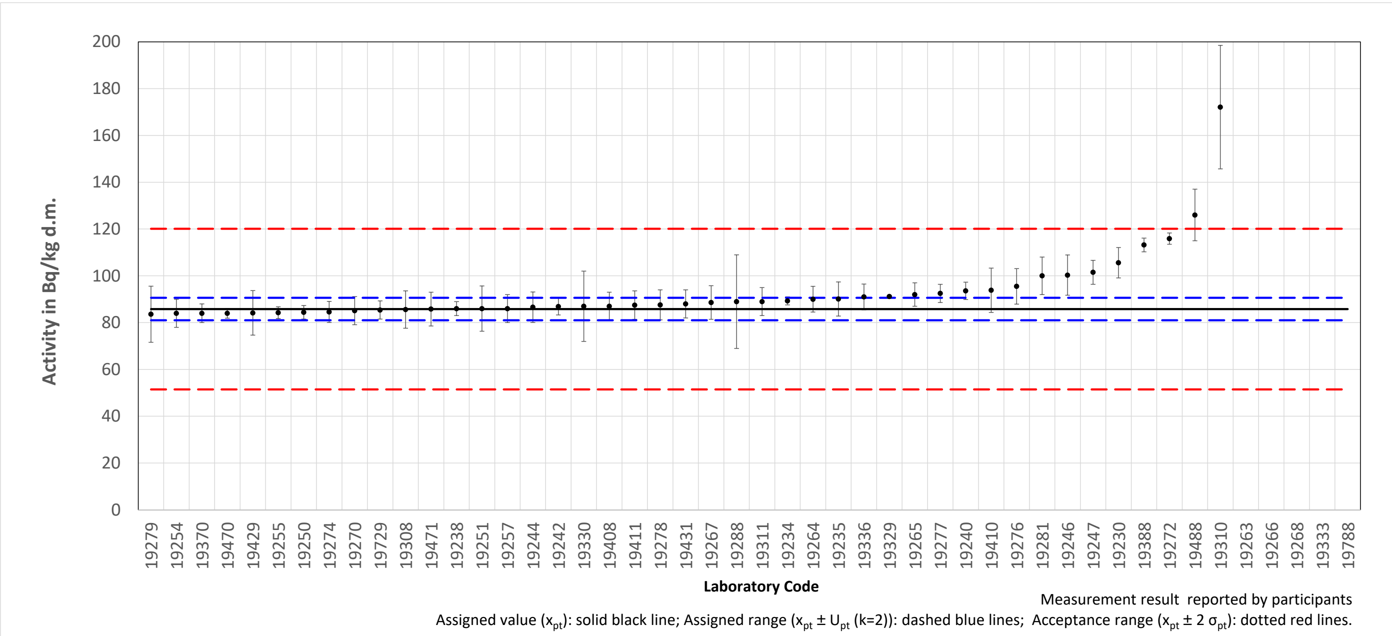
Ra-226 in JRC-NORM-01

x_{pt} = 85.8 **$u(x_{pt})$ =** 2.4 **σ_{pt} =** 17.2 (in Bq/kg d.m.)

(k=1)

z score





Annex 9: Ra-228 in JRC-NORM 01

x_{pt} = 50.0 $u(x_{pt})$ = 1.0 σ_{pt} = 10.0 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	47.2	1.8	1	Direct gamma-spec.	-5.6%	-0.28	-1.35
19229	46.441	0.954	2	Direct gamma-spec.	-7.1%	-0.36	-3.16
19230	37.6	2.6	1	gamma-spectrometry Ac-228	-24.8%	-1.24	-4.44
19231	52.58	1.2	1	Direct gamma-spec.	5.2%	0.26	1.64
19232	49.8	5.1	2	Direct gamma-spec.	-0.4%	-0.02	-0.07
19233	46.0	3.4	1	Direct gamma-spec.	-8.0%	-0.40	-1.13
19234	50.7	1.6	1	Direct gamma-spec.	1.4%	0.07	0.37
19235	53.0	4.2	1	gamma-spectrometry Ac-228	6.0%	0.30	0.69
19236	49.7	6.1	1	Direct gamma-spec.	-0.6%	-0.03	-0.05
19237	48.4	5.9	2	Direct gamma-spec.	-3.2%	-0.16	-0.51
19238	55.0	5.0	2	Direct gamma-spec.	10.0%	0.50	1.85
19239							
19240							
19241	52.0	5.0	1	Direct gamma-spec.	4.0%	0.20	0.39
19242	51.9	3.4	2	Direct gamma-spec.	3.8%	0.19	0.96
19243	49.4	6.489	2	Direct gamma-spec.	-1.2%	-0.06	-0.18
19244	54.4	5.7	2	Direct gamma-spec.	8.8%	0.44	1.45
19245	50.8	2.4	1	Direct gamma-spec.	1.6%	0.08	0.31
19246	49.5	6.4	2	Direct gamma-spec.	-1.0%	-0.05	-0.15
19247	51.0	1.5	1	Direct gamma-spec.	2.0%	0.10	0.55
19249	44.8	5.9	2	Direct gamma-spec.	-10.4%	-0.52	-1.67
19250	52.5	2.1	1	gamma-spectrometry Ac-228	5.0%	0.25	1.07
19251	57.4	7.4	2	Direct gamma-spec.	14.8%	0.74	1.93
19252	46.1	2.21	1	Direct gamma-spec.	-7.8%	-0.39	-1.60
19253	51.7	3.8	2	Direct gamma-spec.	3.4%	0.17	0.79
19254	51.0	4.0	1	Gamma spectrometry	2.0%	0.10	0.24
19255	49.01	1.63	2	Direct gamma-spec.	-2.0%	-0.10	-0.76
19256	48.0	5.0	2	Direct gamma-spec.	-4.0%	-0.20	-0.74
19257							
19258							
19259	52.4	3.52	2	Direct gamma-spec.	4.8%	0.24	1.18
19260	50.3	3.2	1	Direct gamma-spec.	0.6%	0.03	0.09
19261	49.9	0.92	2	Direct gamma-spec.	-0.2%	-0.01	-0.09

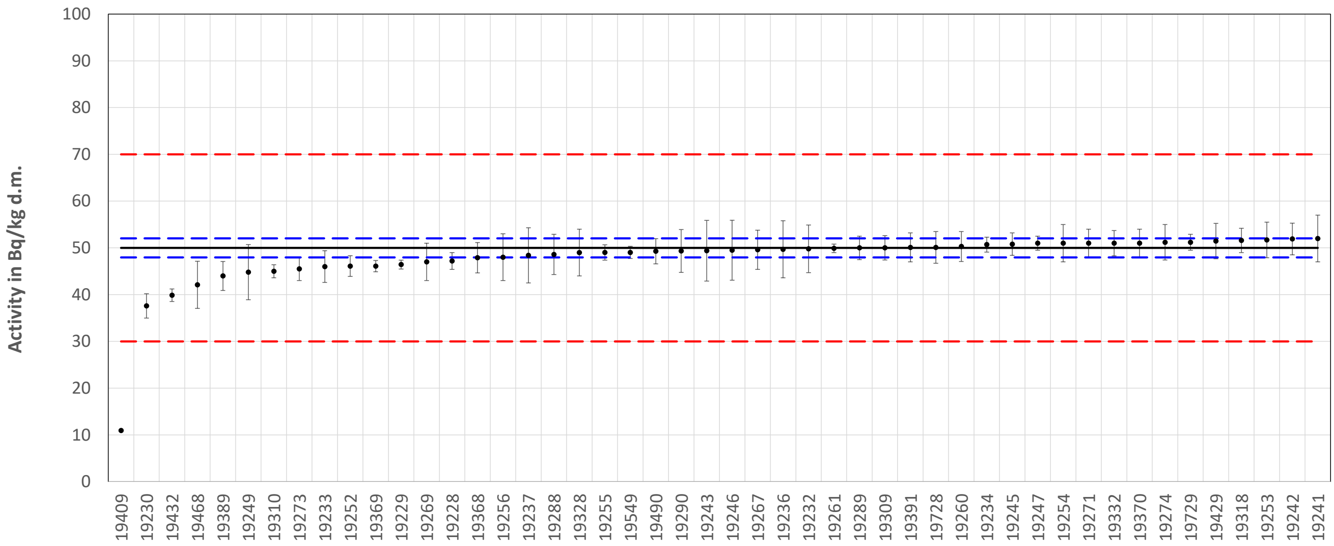
19263							
19264	52.6	3.6	1	Direct gamma-spec.	5.2%	0.26	0.69
19265	56.0	3.0	1	Direct gamma-spec.	12.0%	0.60	1.89
19266							
19267	49.6	4.2	1	Direct gamma-spec.	-0.8%	-0.04	-0.09
19268							
19269	47.0	4.0	1	Direct gamma-spec.	-6.0%	-0.30	-0.73
19270	54.2	4.2	2	Direct gamma-spec.	8.4%	0.42	1.80
19271	51.0	3.0	1	Direct gamma-spec.	2.0%	0.10	0.32
19272	77.0	1.9	2	Direct gamma-spec.	54.0%	2.70	19.36
19273	45.5	2.5	2	Direct gamma-spec.	-9.0%	-0.45	-2.79
19274	51.2	3.8	1	Direct gamma-spec.	2.4%	0.12	0.30
19276	68.9	5.5	2	Direct gamma-spec.	37.8%	1.89	6.44
19277	54.7	1.8	2	Direct gamma-spec.	9.4%	0.47	3.45
19278	52.8	4.5	2	Direct gamma-spec.	5.6%	0.28	1.13
19279							
19281	60.5	4.8	2	Direct gamma-spec.	21.0%	1.05	4.03
19288	48.6	4.3	2	Direct gamma-spec.	-2.8%	-0.14	-0.59
19289	50.0	2.5	1	Direct gamma-spec.	0.0%	0.00	0.00
19290	49.34	4.58	2	Direct gamma-spec.	-1.3%	-0.07	-0.26
Lab.Code	x_i	±	k	**Technique**	*D%*	*z score*	ζ score
19291	52.0	2.2	2	Direct gamma-spec.	4.0%	0.20	1.33
19308	64.0	12.0	1	Direct gamma-spec.	28.0%	1.40	1.16
19309	50.0	2.6	2	Direct gamma-spec.	0.0%	0.00	0.00
19310	45.0	1.4	2	gamma-spectrometry Ac-228	-10.0%	-0.50	-4.04
19311	56.0	5.0	1	Direct gamma-spec.	12.0%	0.60	1.18
19313							
19314	54.04	7.2	2	Direct gamma-spec.	8.1%	0.40	1.08
19316							
19318	51.6	2.6	1	Direct gamma-spec.	3.2%	0.16	0.57
19328	49.0	5.0	2	Direct gamma-spec.	-2.0%	-0.10	-0.37
19329	58.91	0.54	2	Direct gamma-spec.	17.8%	0.89	8.44
19330	54.0	7.0	2	Gamma-spec. with chem. sep.	8.0%	0.40	1.10
19332	51.0	2.7	1	Direct gamma-spec.	2.0%	0.10	0.35
19333							
19334	56.6	1.4	1	Direct gamma-spec.	13.2%	0.66	3.81
19336	53.0	3.5	1	Direct gamma-spec.	6.0%	0.30	0.82

19368	47.9	3.24	2	Direct gamma-spec.	-4.2%	-0.21	-1.10
19369	46.1	1.2	2	Direct gamma-spec.	-7.8%	-0.39	-3.29
19370	51.0	3.0	1	Direct gamma-spec.	2.0%	0.10	0.32
19371	52.0	2.0	1	Direct gamma-spec.	4.0%	0.20	0.89
19372							
19374							
19388							
19389	44.0	3.1	1	Gamma-spec. with chem. sep.	-12.0%	-0.60	-1.84
19391	50.1	3.1	1	Direct gamma-spec.	0.2%	0.01	0.03
19408	54.0	3.0	1	Direct gamma-spec.	8.0%	0.40	1.26
19409	10.94	0.16	2	Direct gamma-spec.	-78.1%	-3.91	-38.14
19410							
19411							
19428	72.4	4.0	2	Direct gamma-spec.	44.8%	2.24	9.98
19429	51.457	3.768	1	Direct gamma-spec.	2.9%	0.15	0.37
19431	54.0	5.0	1	Direct gamma-spec.	8.0%	0.40	0.78
19432	39.88	1.34	2	Direct gamma-spec.	-20.2%	-1.01	-8.29
19468	42.1	5.04	2	Direct gamma-spec.	-15.8%	-0.79	-2.91
19470	54.1	2.0	1	Direct gamma-spec.	8.2%	0.41	1.83
19471							
19488							
19490	49.28	2.7	2	Direct gamma-spec.	-1.4%	-0.07	-0.43
19508							
19549	49.03	1.3	2	Direct gamma-spec.	-1.9%	-0.10	-0.80
19728	50.1	3.4	1.96	Direct gamma-spec.	0.2%	0.01	0.05
19729	51.2	1.7	1	Direct gamma-spec.	2.4%	0.12	0.61
19788							

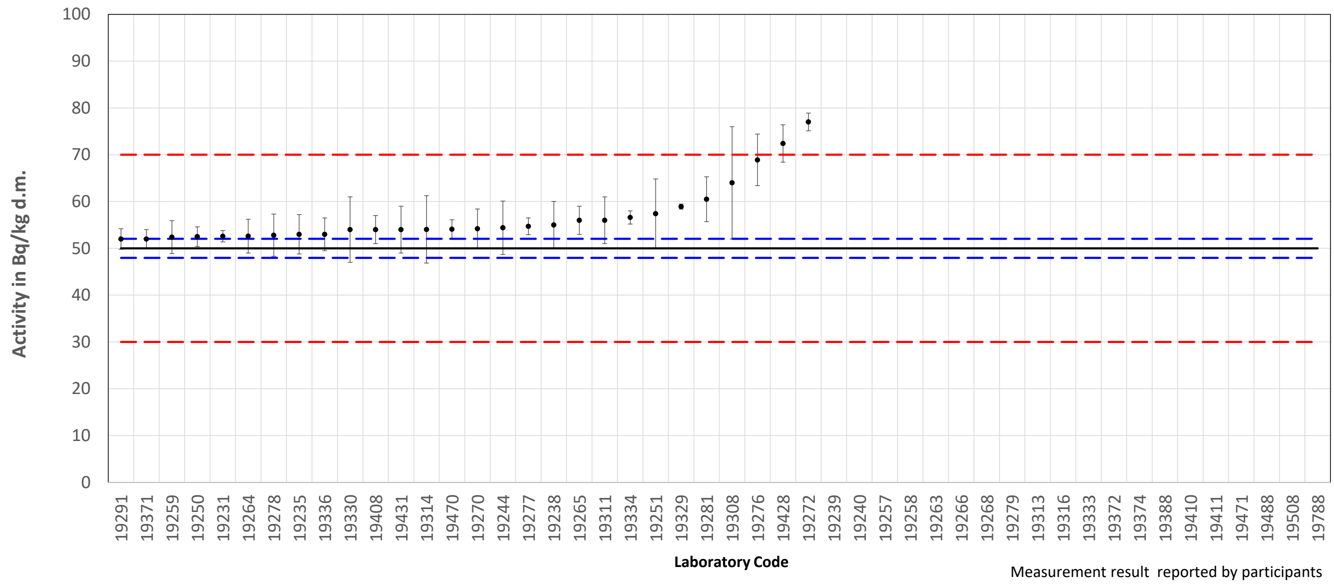
Ra-228 in JRC-NORM-01

x_{pt} = 50.0 $u(x_{pt})$ = 1.0 *(k=1)* σ_{pt} = 10.0 (in Bq/kg d.m.)

z score



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 10: Th-228 in JRC-NORM 01

x_{pt} = 51.0 $u(x_{pt})$ = 0.8 σ_{pt} = 10.2 (in Bq/kg dm)

Lab.Code	x_i	±	*k*	Technique	*D%*	*z* score	ζ score
19228	48.3	1.8	1	Direct gamma-spec.	-5.3%	-0.26	-1.38
19229	46.441	0.954	2	Direct gamma-spec.	-8.9%	-0.45	-5.04
19230							
19231	50.74	1.1	1	Direct gamma-spec.	-0.5%	-0.03	-0.19
19232	50.1	5.8	2	Direct gamma-spec.	-1.8%	-0.09	-0.30
19233	53.6	4.7	1	Direct gamma-spec.	5.1%	0.25	0.55
19234	46.8	2.0	1	Direct gamma-spec.	-8.2%	-0.41	-1.96
19235	53.6	3.4	1	Gamma-spectrometry, equilibrium conditions, derived from Pb-212	5.1%	0.25	0.75
19236	52.1	4.9	1	Direct gamma-spec.	2.2%	0.11	0.22
19237							
19238	56.0	4.0	2	Direct gamma-spec.	9.8%	0.49	2.33
19239							
19240							
19241	52.0	5.0	1	Direct gamma-spec.	2.0%	0.10	0.20
19242	50.2	3.1	2	Direct gamma-spec.	-1.6%	-0.08	-0.46
19243	51.83	6.891	2	Alpha spectrometry	1.6%	0.08	0.24
19244	51.8	3.9	2	Direct gamma-spec.	1.6%	0.08	0.38
19245	52.7	3.2	1	Direct gamma-spec.	3.3%	0.17	0.52
19246	49.5	6.4	2	Direct gamma-spec.	-2.9%	-0.15	-0.46
19247	52.2	1.6	1	Direct gamma-spec.	2.4%	0.12	0.68
19249	53.1	6.7	2	Direct gamma-spec.	4.1%	0.21	0.61
19250	50.7	1.8	1	gamma-spec. Pb-212, Bi-212, Tl-208	-0.6%	-0.03	-0.15
19251	46.3	7.5	2	Direct gamma-spec.	-9.2%	-0.46	-1.23
19252							
19253	51.3	2.1	2	Direct gamma-spec.	0.6%	0.03	0.23
19254	56.0	4.0	1	Gamma spectrometry	9.8%	0.49	1.23
19255							
19256	51.0	4.0	2	Alpha spectrometry	0.0%	0.00	0.00
19257	54.0	4.0	1	Direct gamma-spec.	5.9%	0.29	0.74
19258							
19259	50.91	4.11	2	Direct gamma-spec.	-0.2%	-0.01	-0.04
19260	51.6	4.6	1	Direct gamma-spec.	1.2%	0.06	0.13

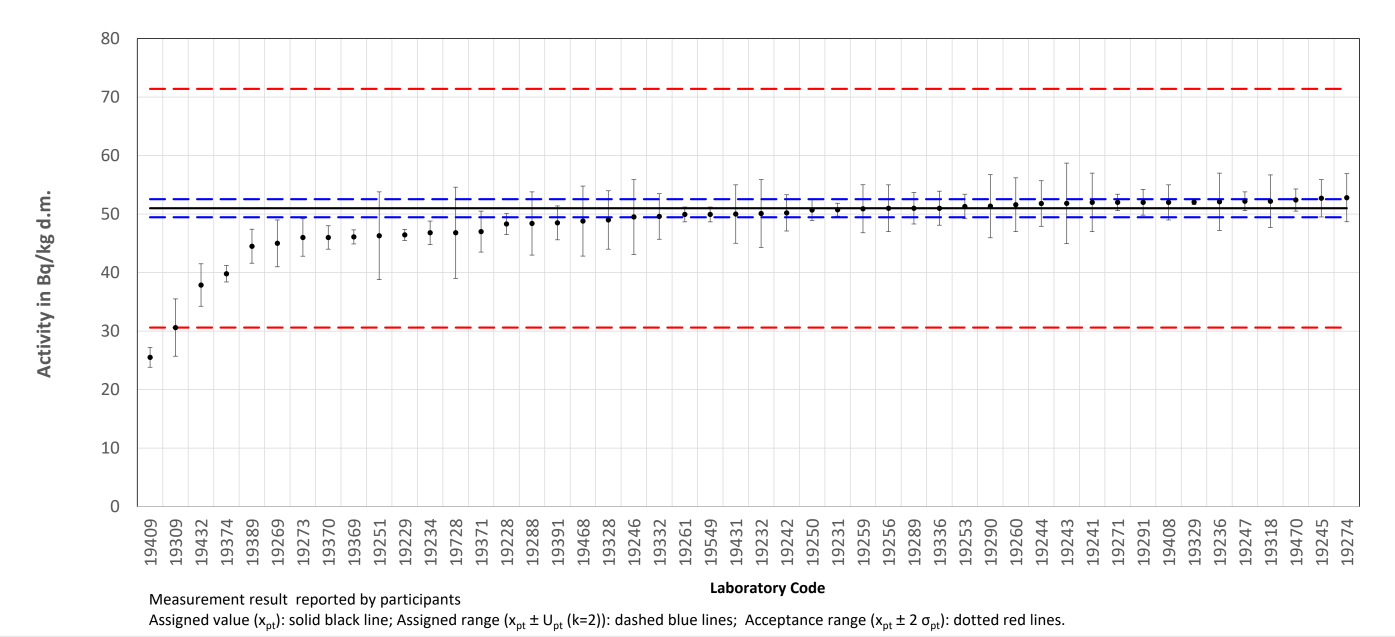
Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19261	49.94	1.27	2	Alpha spectrometry	-2.1%	-0.10	-1.06
19263							
19264	53.1	3.4	1	Direct gamma-spec.	4.1%	0.21	0.60
19265	56.0	3.0	1	Direct gamma-spec.	9.8%	0.49	1.61
19266							
19267	53.2	3.5	1	Direct gamma-spec.	4.3%	0.22	0.61
19268							
19269	45.0	4.0	1	Direct gamma-spec.	-11.8%	-0.59	-1.47
19270	53.8	4.8	2	Direct gamma-spec.	5.5%	0.27	1.11
19271	52.0	1.4	1	Direct gamma-spec.	2.0%	0.10	0.63
19272	75.1	2.3	2	Direct gamma-spec.	47.3%	2.36	17.43
19273	46.0	3.2	2	Direct gamma-spec.	-9.8%	-0.49	-2.82
19274	52.8	4.1	1	Direct gamma-spec.	3.5%	0.18	0.43
19276	199.4	33.5	2	Direct gamma-spec.	291.0%	14.55	8.85
19277	61.6	5.1	2	Direct gamma-spec.	20.8%	1.04	3.98
19278	52.8	4.5	2	Direct gamma-spec.	3.5%	0.18	0.76
19279							
19281	59.7	4.2	2	Direct gamma-spec.	17.1%	0.85	3.89
19288	48.4	5.4	2	Direct gamma-spec.	-5.1%	-0.25	-0.93
19289	51.0	2.7	1	Direct gamma-spec.	0.0%	0.00	0.00
19290	51.35	5.39	2	Direct gamma-spec.	0.7%	0.03	0.12
19291	52.0	2.2	2	Direct gamma-spec.	2.0%	0.10	0.75
19308	53.75	1.26	1	Direct gamma-spec.	5.4%	0.27	1.86
19309	30.6	4.9	2	Alpha spectrometry	-40.0%	-2.00	-7.95
19310							
19311	56.0	5.0	1	Direct gamma-spec.	9.8%	0.49	0.99
19313							
19314	52.94	4.9	2	Direct gamma-spec. Pb 212 at To	3.8%	0.19	0.76
19316							
19318	52.2	4.5	2	Alpha spectrometry	2.4%	0.12	0.50
19328	49.0	5.0	2	Direct gamma-spec.	-3.9%	-0.20	-0.76
19329	52.05	0.43	2	Direct gamma-spec.	2.1%	0.10	1.32
19330	53.0	6.0	2	Gamma-spec. with chem. sep.	3.9%	0.20	0.65
19332	49.6	3.9	1	Direct gamma-spec.	-2.7%	-0.14	-0.35
19333							
19334	56.3	1.1	1	Direct gamma-spec.	10.4%	0.52	3.95

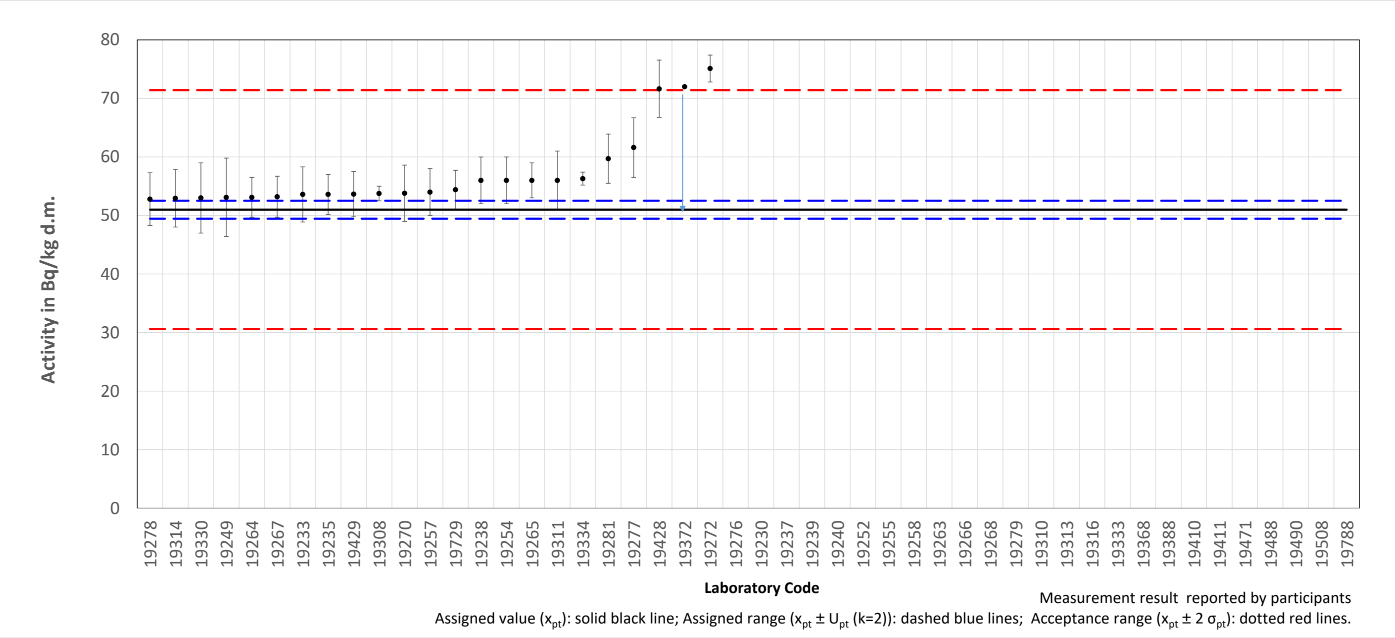
Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19336	51.0	2.9	1	Direct gamma-spec.	0.0%	0.00	0.00
19368							
19369	46.1	1.2	2	Direct gamma-spec.	-9.6%	-0.48	-5.03
19370	46.0	2.0	1	Direct gamma-spec.	-9.8%	-0.49	-2.33
19371	47.0	3.5	1	Direct gamma-spec.	-7.8%	-0.39	-1.12
19372	< 72.0			Direct gamma-spec.			
19374	39.8	1.4	1.73	Direct gamma-spec.	-22.0%	-1.10	-10.04
19388							
19389	44.5	2.9	1	Gamma-spec. with chem. sep.	-12.7%	-0.64	-2.17
19391	48.5	2.9	1	Direct gamma-spec.	-4.9%	-0.25	-0.83
19408	52.0	3.0	1	Direct gamma-spec.	2.0%	0.10	0.32
19409	25.51	1.69	2	Direct gamma-spec.	-50.0%	-2.50	-22.33
19410							
19411							
19428	71.63	4.9	2	Direct gamma-spec.	40.5%	2.02	8.04
19429	53.644	3.879	1	Direct gamma-spec.	5.2%	0.26	0.67
19431	50.0	5.0	1	Direct gamma-spec.	-2.0%	-0.10	-0.20
19432	37.87	3.64	2	Direct gamma-spec.	-25.7%	-1.29	-6.65
19468	48.8	5.99	2	Direct gamma-spec.	-4.3%	-0.22	-0.71
19470	52.4	1.9	1	Direct gamma-spec.	2.7%	0.14	0.68
19471							
19488							
19490							
19508							
19549	49.94	1.27	2	Direct gamma-spec.	-2.1%	-0.10	-1.06
19728	46.8	7.8	1.96	Direct gamma-spec.	-8.2%	-0.41	-1.04
19729	54.4	3.3	1	Direct gamma-spec.	6.7%	0.33	1.00
19788							

Th-228 in JRC-NORM-01

x_{pt} = 51.0 $u(x_{pt})$ = 0.8 *(k=1)* σ_{pt} = 10.2 (in Bq/kg d.m.)

z score


Activity in Bq/kg d.m.
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.


Activity in Bq/kg d.m.
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 11: Th-232 in JRC-NORM 01

x_{pt} = 50.3 $u(x_{pt})$ = 1.0 σ_{pt} = 10.1 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	47.2	1.8	1	Direct gamma-spec.	-6.2%	-0.31	-1.50
19229	46.441	0.954	2	Direct gamma-spec.	-7.7%	-0.38	-3.41
19230	49.0	3.5	1	ICP-MS	-2.6%	-0.13	-0.36
19231	50.97	1.2	1	Direct gamma-spec.	1.3%	0.07	0.42
19232	49.8	5.1	2	Direct gamma-spec.	-1.0%	-0.05	-0.18
19233	46.0	3.4	1	Direct gamma-spec.	-8.5%	-0.43	-1.21
19234	51.0	2.2	1	Direct gamma-spec.	1.4%	0.07	0.29
19235	53.0	4.2	1	Gamma-spec. equilibrium; Ac-228	5.4%	0.27	0.62
19236							
19237							
19238	58.0	8.0	2	Alpha spectrometry	15.3%	0.77	1.86
19239							
19240							
19241	52.0	5.0	1	Direct gamma-spec.	3.4%	0.17	0.33
19242							
19243	49.38	6.599	2	Alpha spectrometry	-1.8%	-0.09	-0.27
19244	52.7	3.2	2	Direct gamma-spec.	4.8%	0.24	1.26
19245							
19246	49.5	6.4	2	Direct gamma-spec.	-1.6%	-0.08	-0.24
19247	51.6	1.6	1	Direct gamma-spec.	2.6%	0.13	0.68
19249							
19250	52.5	2.1	1	estimated activity Th-228, Ra-228	4.4%	0.22	0.94
19251	57.4	7.4	2	Direct gamma-spec.	14.1%	0.71	1.85
19252							
19253							
19254	49.0	2.0	1	Alpha spectrometry	-2.6%	-0.13	-0.58
19255	50.43	1.72	2	Direct gamma-spec.	0.3%	0.01	0.10
19256	51.0	4.0	2	Alpha spectrometry	1.4%	0.07	0.31
19257	52.0	2.0	1	Direct gamma-spec.	3.4%	0.17	0.76
19258	46.0	8.0	2	Direct gamma-spec.	-8.5%	-0.43	-1.04
19259	51.09	3.52	2	Direct gamma-spec.	1.6%	0.08	0.39
19260	50.3	3.2	1	Direct gamma-spec.	0.0%	0.00	0.00
19261	55.57	18.63	2	Alpha spectrometry	10.5%	0.52	0.56

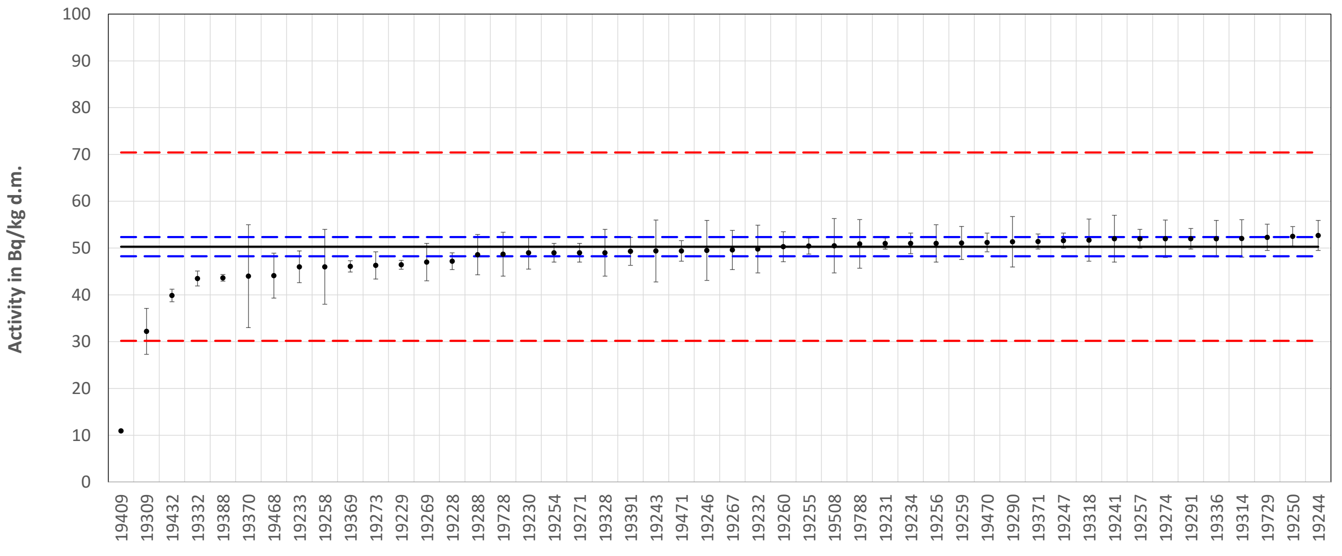
19263	96.3	27.9	2	ICP-MS	91.5%	4.57	3.29
19264							
19265	56.0	3.0	1	Direct gamma-spec.	11.3%	0.57	1.80
19266							
19267	49.6	4.2	1	Direct gamma-spec.	-1.4%	-0.07	-0.16
19268				ICP-OES			
19269	47.0	4.0	1	Direct gamma-spec.	-6.6%	-0.33	-0.80
19270	54.2	4.2	2	Direct gamma-spec.	7.8%	0.39	1.67
19271	49.0	2.0	1	Alpha spectrometry	-2.6%	-0.13	-0.58
19272							
19273	46.3	2.9	2	Direct gamma-spec.	-8.0%	-0.40	-2.25
19274	52.0	4.0	1	Direct gamma-spec.	3.4%	0.17	0.41
19276	2764.7	356.5	2	Direct gamma-spec.	5396.4%	269.82	15.23
19277	116.0	7.0	2		130.6%	6.53	18.01
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	52.8	4.5	2	Direct gamma-spec.	5.0%	0.25	1.01
19279	53.8	8.2	2	Direct gamma-spec.	7.0%	0.35	0.83
19281							
19288	48.6	4.3	2	Direct gamma-spec.	-3.4%	-0.17	-0.71
19289							
19290	51.35	5.39	2	Direct gamma-spec.	2.1%	0.10	0.36
19291	52.0	2.2	2	Direct gamma-spec.	3.4%	0.17	1.13
19308	53.29	1.7	1	Direct gamma-spec.	5.9%	0.30	1.51
19309	32.2	4.9	2	Alpha spectrometry	-36.0%	-1.80	-6.81
19310							
19311	56.0	5.0	1	Direct gamma-spec.	11.3%	0.57	1.12
19313							
19314	52.06	4.0	2	Direct gamma-spec. of Ac 228 at To	3.5%	0.17	0.78
19316							
19318	51.7	4.5	2	Alpha spectrometry	2.8%	0.14	0.57
19328	49.0	5.0	2	Direct gamma-spec.	-2.6%	-0.13	-0.48
19329	53.18	0.33	2	Direct gamma-spec.	5.7%	0.29	2.77
19330							
19332	43.5	1.6	1	Alpha spectrometry	-13.5%	-0.68	-3.58
19333	63.5	10.0	2	Direct gamma-spec.	26.2%	1.31	2.59
19334	56.6	1.4	1	Direct gamma-spec.	12.5%	0.63	3.63
19336	52.0	3.9	1	Direct gamma-spec.	3.4%	0.17	0.42

19368							
19369	46.1	1.2	2	Direct gamma-spec.	-8.3%	-0.42	-3.53
19370	44.0	11.0	1	Alpha spectrometry	-12.5%	-0.63	-0.57
19371	51.4	1.6	1	Direct gamma-spec.	2.2%	0.11	0.58
19372	< 466.0			Direct gamma-spec.			
19374							
19388	43.64	0.71	1.645	Direct gamma-spec.	-13.2%	-0.66	-5.98
19389							
19391	49.3	3.0	1	Direct gamma-spec.	-2.0%	-0.10	-0.32
19408	53.0	5.0	1	Direct gamma-spec.	5.4%	0.27	0.53
19409	10.94	0.16	2	Direct gamma-spec.	-78.3%	-3.91	-38.25
19410	56.41	5.26	0.891	Direct gamma-spec.	12.1%	0.61	1.02
19411	54.0	3.8	2	Direct gamma-spec.	7.4%	0.37	1.71
19428	72.09	3.1	2	Direct gamma-spec.	43.3%	2.17	11.72
19429							
19431	53.0	5.0	1	Direct gamma-spec.	5.4%	0.27	0.53
19432	39.88	1.34	2	Direct gamma-spec.	-20.7%	-1.04	-8.50
19468	44.1	4.8	2	Direct gamma-spec.	-12.3%	-0.62	-2.38
19470	51.2	2.0	1	Alpha spectrometry	1.8%	0.09	0.40
19471	49.4	2.2	1	Direct gamma-spec.	-1.8%	-0.09	-0.37
19488	55.9	4.5	2	Direct gamma-spec.	11.1%	0.56	2.26
19490							
19508	50.5	5.8	2	Direct gamma-spec.	0.4%	0.02	0.07
19549	< 55.0			Direct gamma-spec.			
19728	48.7	4.7	1.96	Direct gamma-spec.	-3.2%	-0.16	-0.61
19729	52.3	2.8	1	Direct gamma-spec. Th-232 decay products in equilibrium.	4.0%	0.20	0.67
19788	50.9	5.2	2	Alpha spectrometry	1.2%	0.06	0.21

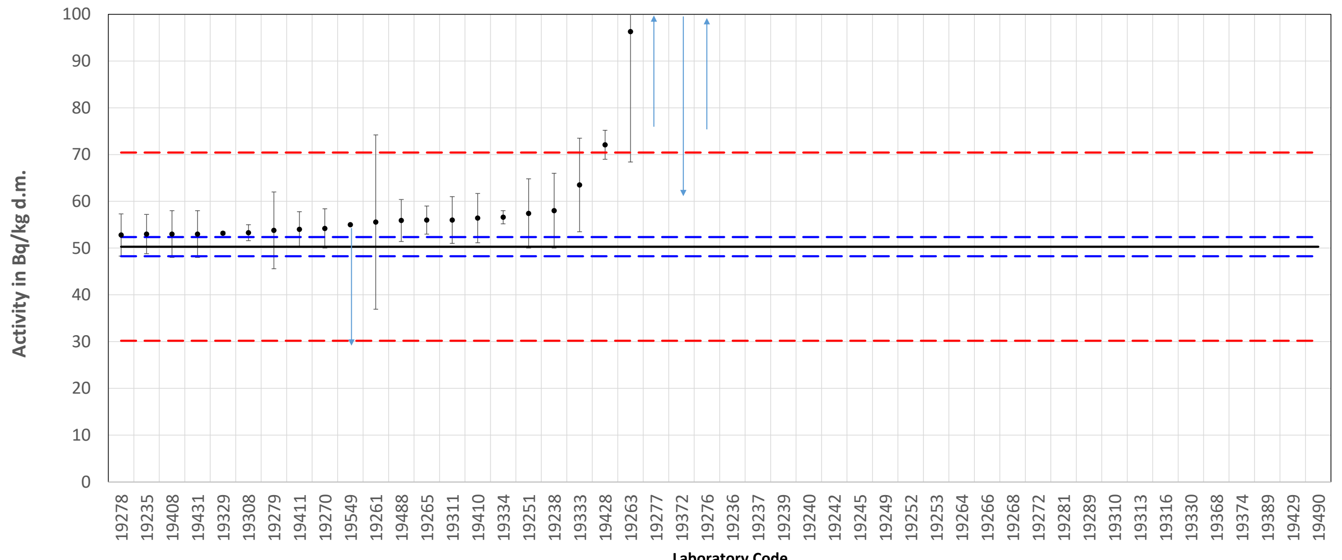
Th-232 in JRC-NORM-01

x_{pt} = 50.3 **$u(x_{pt})$ =** 1.0 *(k=1)* σ_{pt} = 10.1 (in Bq/kg d.m.)

z score



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 12: U-238 in JRC-NORM 01

x_{pt} = 82.3 $u(x_{pt})$ = 3.7 σ_{pt} = 24.7 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	85.0	7.0	1	Direct gamma-spec.	3.3%	0.11	0.34
19229	71.842	2.056	2	Direct gamma-spec.	-12.7%	-0.42	-2.73
19230	84.0	7.0	1	ICP-MS	2.1%	0.07	0.21
19231	93.92	6.8	1	Direct gamma-spec.	14.1%	0.47	1.50
19232	81.5	13.9	2	Direct gamma-spec.	-1.0%	-0.03	-0.10
19233	64.0	6.5	1	Direct gamma-spec.	-22.2%	-0.74	-2.45
19234	82.7	12.0	1	Direct gamma-spec.	0.5%	0.02	0.03
19235	96.5	9.0	1	Gamma-spec. U235/Ra226 deconvol. Factor 21,73 U238/U235	17.3%	0.58	1.46
19236	71.6	7.0	1	Direct gamma-spec.	-13.0%	-0.43	-1.35
19237							
19238	85.0	7.0	2	Direct gamma-spec. Th234	3.3%	0.11	0.53
19239							
19240							
19241	82.0	8.0	1	Direct gamma-spec.	-0.4%	-0.01	-0.03
19242							
19243	85.41	7.588	2	Alpha spectrometry	3.8%	0.13	0.59
19244	74.8	9.5	2	Direct gamma-spec.	-9.1%	-0.30	-1.25
19245	81.0	14.0	1	Direct gamma-spec.	-1.6%	-0.05	-0.09
19246	101.9	30.4	2	Direct gamma-spec.	23.8%	0.79	1.25
19247	65.4	5.9	1	Direct gamma-spec.	-20.5%	-0.68	-2.43
19249							
19250	90.5	6.9	1	calculated from the peak 186 keV	10.0%	0.33	1.05
19251	73.1	14.2	2	Direct gamma-spec.	-11.2%	-0.37	-1.15
19252							
19253							
19254	88.0	3.0	1	Alpha spectrometry	6.9%	0.23	1.20
19255							
19256	83.0	8.0	2	Alpha spectrometry	0.9%	0.03	0.13
19257	83.0	5.0	1	Direct gamma-spec.	0.9%	0.03	0.11
19258	50.8	9.8	2	Direct gamma-spec.	-38.3%	-1.28	-5.13
19259	94.48	24.0	2	Direct gamma-spec.	14.8%	0.49	0.97
19260	64.3	7.8	1	Direct gamma-spec.	-21.9%	-0.73	-2.09
19261	92.51	6.43	2	Alpha spectrometry	12.4%	0.41	2.08

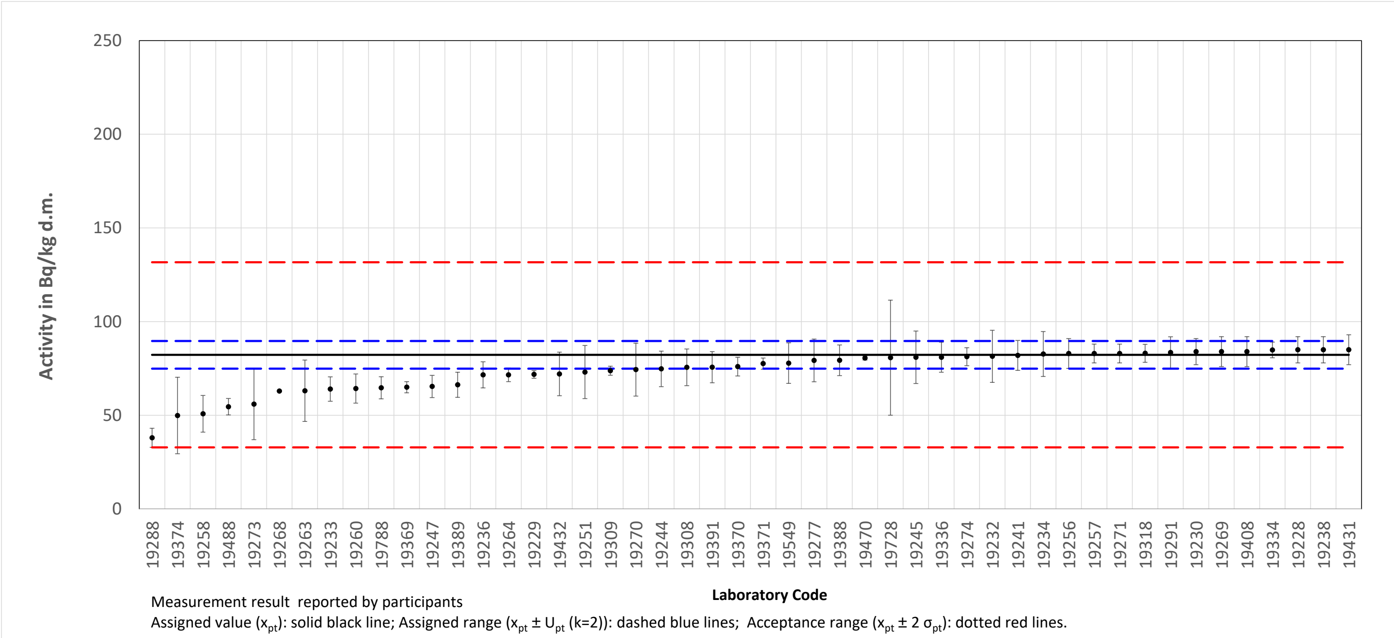
19263	63.1	16.4	2	ICP-MS	-23.3%	-0.78	-2.13
19264	71.6	3.6	1	Direct gamma-spec.	-13.0%	-0.43	-2.07
19265	100.0	9.0	1	Direct gamma-spec.	21.5%	0.72	1.82
19266							
19267	91.0	16.0	1	Direct gamma-spec.	10.6%	0.35	0.53
19268	62.94	0.118	1.05	ICP-OES	-23.5%	-0.78	-5.24
19269	84.0	8.0	1	Direct gamma-spec.	2.1%	0.07	0.19
19270	74.4	14.1	2	Direct gamma-spec.	-9.6%	-0.32	-0.99
19271	83.0	5.0	1	Alpha spectrometry	0.9%	0.03	0.11
19272	187.6	10.5	2	Direct gamma-spec.	127.9%	4.26	16.40
19273	56.0	19.0	2	Direct gamma-spec.	-32.0%	-1.07	-2.58
19274	81.3	4.8	1	Direct gamma-spec.	-1.2%	-0.04	-0.17
19276	208.2	36.7	2	Direct gamma-spec.	153.0%	5.10	6.73
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19277	79.3	11.4	2	Direct gamma-spec.	-3.6%	-0.12	-0.44
19278							
19279	89.0	26.0	2	Direct gamma-spec.	8.1%	0.27	0.50
19281	102.0	9.0	2	Direct gamma-spec.	23.9%	0.80	3.38
19288	38.0	5.1	2	Direct gamma-spec.	-53.8%	-1.79	-9.87
19289	96.0	4.5	1	Direct gamma-spec.	16.6%	0.55	2.35
19290	87.09	17.08	2	Direct gamma-spec.	5.8%	0.19	0.51
19291	83.5	8.4	2	Direct gamma-spec.	1.5%	0.05	0.21
19308	75.62	9.8	1	Direct gamma-spec.	-8.1%	-0.27	-0.64
19309	73.8	2.4	2	Alpha spectrometry	-10.3%	-0.34	-2.19
19310							
19311	92.0	23.0	1	Direct gamma-spec.	11.8%	0.39	0.42
19313							
19314	93.97	20.0	2	Direct gamma-spec. Th 234(63 keV)	14.2%	0.47	1.09
19316							
19318	83.1	4.8	1	Direct gamma-spec.	1.0%	0.03	0.13
19328	122.0	38.0	2	Direct gamma-spec.	48.2%	1.61	2.05
19329	93.59	1.02	2	Direct gamma-spec.	13.7%	0.46	3.03
19330	90.0	40.0	2	Gamma-spec. with chem. sep.	9.4%	0.31	0.38
19332	87.7	5.8	1	Alpha spectrometry	6.6%	0.22	0.79
19333	127.7	10.0	2	Direct gamma-spec.	55.2%	1.84	7.30
19334	84.9	4.2	1	Direct gamma-spec.	3.2%	0.11	0.46
19336	81.0	8.0	1	Direct gamma-spec.	-1.6%	-0.05	-0.15
19368							

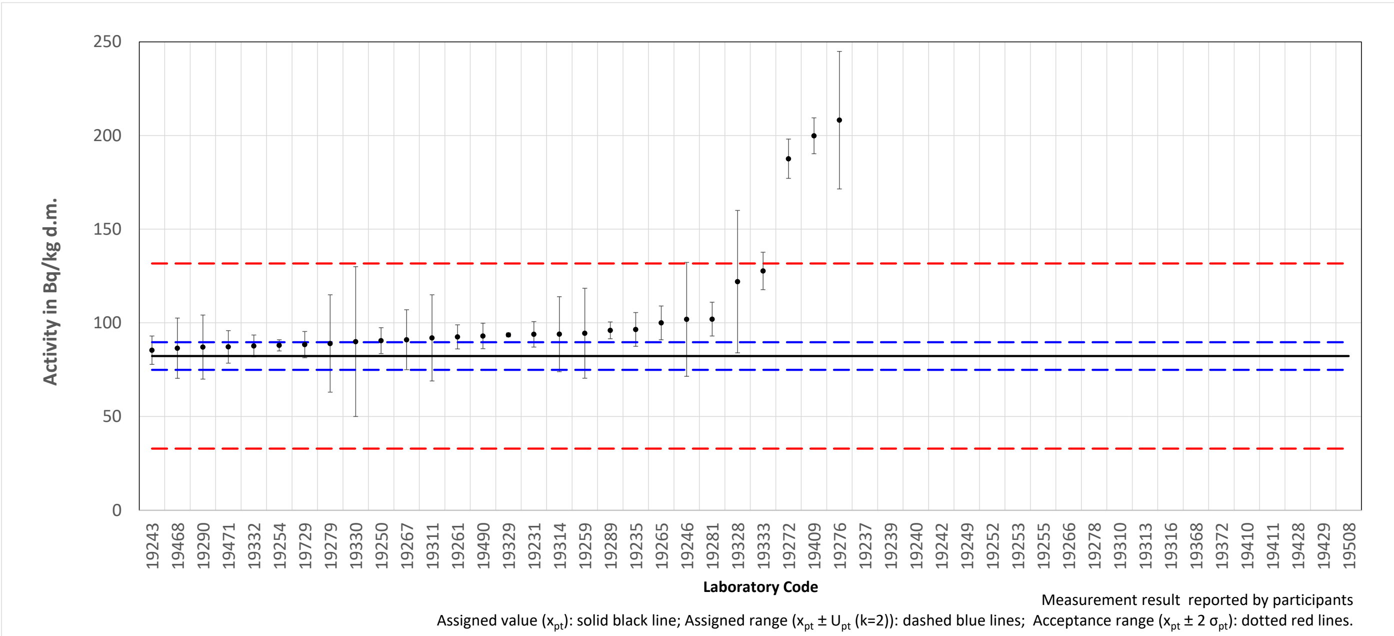
19369	65.0	3.0	2	Direct gamma-spec.	-21.0%	-0.70	-4.34
19370	76.0	5.0	1	Alpha spectrometry	-7.7%	-0.26	-1.01
19371	77.6	3.0	1	Direct gamma-spec.	-5.7%	-0.19	-0.99
19372							
19374	49.9	20.4	1.73	Direct gamma-spec.	-39.4%	-1.31	-2.62
19388	79.37	8.18	1.645	Direct gamma-spec.	-3.6%	-0.12	-0.47
19389	66.3	6.7	1	Gamma-spec. with chem. sep.	-19.4%	-0.65	-2.09
19391	75.7	8.3	1	Direct gamma-spec.	-8.0%	-0.27	-0.73
19408	84.0	8.0	1	Direct gamma-spec.	2.1%	0.07	0.19
19409	199.82	9.59	2	Direct gamma-spec.	142.8%	4.76	19.42
19410							
19411							
19428							
19429							
19431	85.0	8.0	1	Direct gamma-spec.	3.3%	0.11	0.31
19432	72.08	11.63	2	Direct gamma-spec.	-12.4%	-0.41	-1.48
19468	86.5	16.1	2	Direct gamma-spec.	5.1%	0.17	0.47
19470	80.6	1.1	1	Alpha spectrometry	-2.1%	-0.07	-0.44
19471	87.2	8.7	1	Direct gamma-spec.	6.0%	0.20	0.52
19488	54.6	4.4	2	Direct gamma-spec.	-33.7%	-1.12	-6.44
19490	93.02	6.83	2	Alpha spectrometry	13.0%	0.43	2.13
19508							
19549	77.86	10.81	2	Direct gamma-spec.	-5.4%	-0.18	-0.68
19728	80.8	30.7	1.96	Direct gamma-spec.	-1.8%	-0.06	-0.09
19729	88.4	7.0	1	Direct gamma-spec. Equilibrium U238, Pa234m & Th-234.	7.4%	0.25	0.77
19788	64.7	5.9	2	Alpha spectrometry	-21.4%	-0.71	-3.72

U-238 in JRC-NORM-01

x_{pt} = 82.3 $u(x_{pt})$ = 3.7 *(k=1)* σ_{pt} = 24.7 (in Bq/kg d.m.)

z score


250
200
150
100
50
0
Activity in Bq/kg d.m.
19288 19374 19258 19488 19273 19268 19263 19233 19260 19788 19369 19247 19389 19236 19264 19229 19432 19251 19309 19270 19244 19308 19391 19370 19371 19549 19277 19388 19470 19728 19245 19336 19274 19232 19241 19234 19256 19257 19271 19318 19291 19230 19269 19408 19334 19228 19238 19431
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.


250
200
150
100
50
0
Activity in Bq/kg d.m.
19243 19468 19290 19471 19332 19254 19729 19279 19330 19250 19267 19311 19261 19490 19329 19231 19314 19259 19289 19235 19265 19246 19281 19328 19333 19272 19409 19276 19237 19239 19240 19242 19249 19252 19253 19255 19266 19278 19310 19313 19316 19368 19372 19410 19411 19428 19429 19508
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 13: K-40 in JRC-NORM 02

x_{pt} = 314.6 $u(x_{pt})$ = 10.4 σ_{pt} = 62.9 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	330.0	16.0	1	Direct gamma-spec.	4.9%	0.24	0.81
19229							
19230							
19231	361.5	8.4	1	Direct gamma-spec.	14.9%	0.75	3.50
19232	308.0	24.0	2	Direct gamma-spec.	-2.1%	-0.10	-0.42
19233	298.0	24.0	1		-5.3%	-0.26	-0.63
19234	454.7	22.6	1	Direct gamma-spec.	44.5%	2.23	5.63
19235	304.9	18.7	1	Direct gamma-spec.	-3.1%	-0.15	-0.45
19236	324.0	15.0	1	Direct gamma-spec.	3.0%	0.15	0.51
19237	371.0	43.0	2	Direct gamma-spec.	17.9%	0.90	2.36
19238							
19239							
19240	335.0	10.0	2	Direct gamma-spec.	6.5%	0.32	1.76
19241	317.0	20.0	1	Direct gamma-spec.	0.8%	0.04	0.11
19242							
19243	307.7	35.25	2	Direct gamma-spec.	-2.2%	-0.11	-0.34
19244							
19245	312.0	17.0	1	Direct gamma-spec.	-0.8%	-0.04	-0.13
19246	349.3	31.2	2	Direct gamma-spec.	11.0%	0.55	1.85
19247	306.4	9.2	1	Direct gamma-spec.	-2.6%	-0.13	-0.59
19249	241.0	34.0	2	Direct gamma-spec.	-23.4%	-1.17	-3.69
19250	324.0	12.0	1	Direct gamma-spec.	3.0%	0.15	0.59
19251	345.0	37.0	2	Direct gamma-spec.	9.7%	0.48	1.43
19252							
19253	327.0	22.0	2	Direct gamma-spec.	3.9%	0.20	0.82
19254	304.0	11.0	1	Gamma spectrometry	-3.4%	-0.17	-0.70
19256	391.0	33.0	2	Direct gamma-spec.	24.3%	1.21	3.91
19257	308.0	7.0	1	Direct gamma-spec.	-2.1%	-0.10	-0.53
19258	125.0	12.0	2	Direct gamma-spec.	-60.3%	-3.01	-15.76
19259	372.96	17.18	2	Direct gamma-spec.	18.6%	0.93	4.32
19260	324.0	16.9	1	Direct gamma-spec.	3.0%	0.15	0.47
19261	328.9	9.97	2	Direct gamma-spec.	4.5%	0.23	1.24
19263							

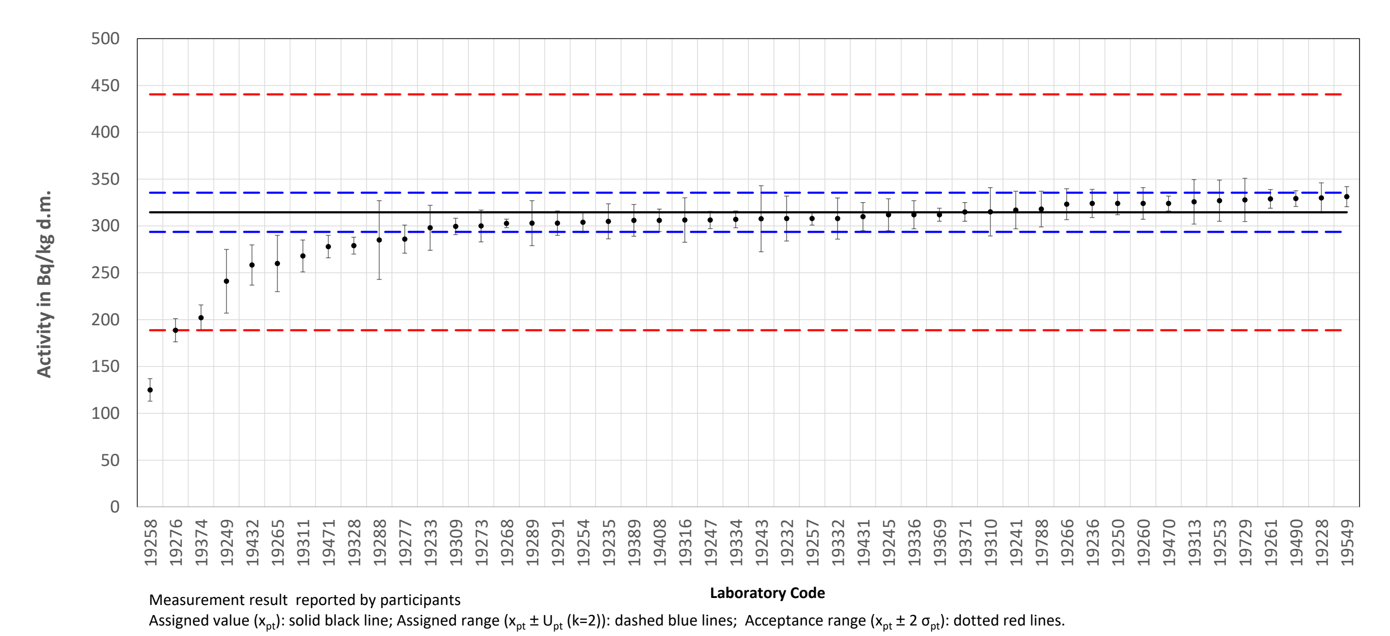
Lab.Code	x_i	±	*k*	Technique	*D%*	*z* score	ζ score
19264	359.0	31.0	1	Direct gamma-spec.	14.1%	0.71	1.36
19265	260.0	30.0	1	Direct gamma-spec.	-17.4%	-0.87	-1.72
19266	323.27	16.48	1	Direct gamma-spec.	2.8%	0.14	0.44
19267	349.0	22.0	1	Direct gamma-spec.	10.9%	0.55	1.41
19268	302.703	4.541	1.05	ICP-OES	-3.8%	-0.19	-1.05
19269							
19270	382.0	17.0	2	Direct gamma-spec.	21.4%	1.07	5.01
19271	359.0	14.0	1	Direct gamma-spec.	14.1%	0.71	2.54
19272							
19273	300.0	17.0	2	Direct gamma-spec.	-4.6%	-0.23	-1.09
19274	362.3	18.0	1	Direct gamma-spec.	15.2%	0.76	2.29
19276	188.7	12.4	2	Direct gamma-spec.	-40.0%	-2.00	-10.38
19277	286.0	15.0	2	Direct gamma-spec.	-9.1%	-0.45	-2.23
19278							
19279							
19281	350.0	25.0	2	Direct gamma-spec.	11.3%	0.56	2.17
19288	285.0	42.0	2	Direct gamma-spec.	-9.4%	-0.47	-1.26
19289	303.0	24.0	1	Direct gamma-spec.	-3.7%	-0.18	-0.44
19290	336.37	47.14	2	Direct gamma-spec.	6.9%	0.35	0.84
19291	303.0	13.0	2	Direct gamma-spec.	-3.7%	-0.18	-0.94
19308	340.0	7.0	1	Direct gamma-spec.	8.1%	0.40	2.02
19309	299.5	8.7	2	Direct gamma-spec.	-4.8%	-0.24	-1.34
19310	315.1	25.8	2	Direct gamma-spec.	0.2%	0.01	0.03
19311	268.0	17.0	1	Direct gamma-spec.	-14.8%	-0.74	-2.34
19313	325.813	23.76	1	Direct gamma-spec.	3.6%	0.18	0.43
19314	376.04	22.6	2	Direct gamma-spec.	19.5%	0.98	4.00
19316	306.32	23.74	1	Direct gamma-spec.	-2.6%	-0.13	-0.32
19318	361.0	16.0	1	Direct gamma-spec.	14.7%	0.74	2.43
19328	279.0	9.0	2	Direct gamma-spec.	-11.3%	-0.57	-3.13
19329	367.61	5.63	2	Direct gamma-spec.	16.8%	0.84	4.91
19330	340.0	30.0	2	Gamma-spec. with chem. sep.	8.1%	0.40	1.39
19332	308.0	22.0	1	Direct gamma-spec.	-2.1%	-0.10	-0.27
19333							
19334	307.0	9.0	1	Direct gamma-spec.	-2.4%	-0.12	-0.55
19336	312.0	15.0	1	Direct gamma-spec.	-0.8%	-0.04	-0.14
19368							

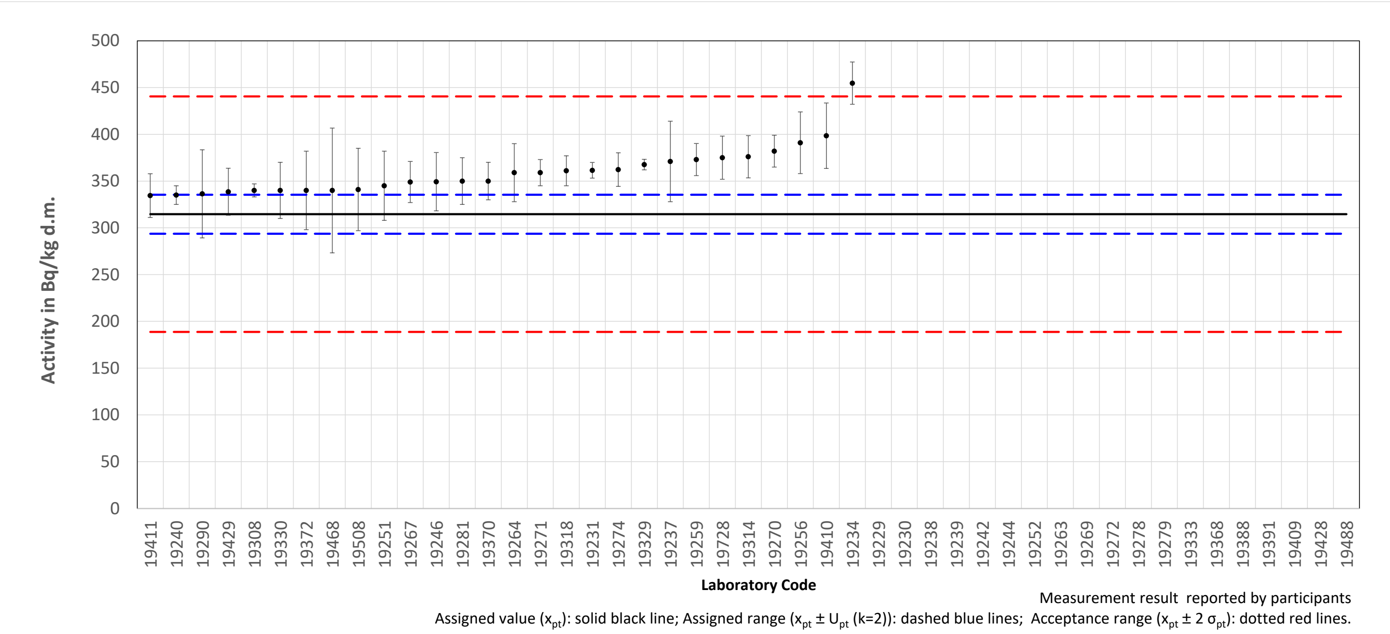
Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19369	312.0	7.0	2	Direct gamma-spec.	-0.8%	-0.04	-0.24
19370	350.0	20.0	1	Direct gamma-spec.	11.3%	0.56	1.57
19371	315.0	10.0	1	Direct gamma-spec.	0.1%	0.01	0.03
19372	340.0	42.0	2	Direct gamma-spec.	8.1%	0.40	1.08
19374	202.0	13.7	1.73	Direct gamma-spec.	-35.8%	-1.79	-8.60
19388							
19389	306.0	17.0	1	Gamma-spec. with chem. sep.	-2.7%	-0.14	-0.43
19391							
19408	306.0	12.0	1	Direct gamma-spec.	-2.7%	-0.14	-0.54
19409							
19410	398.47	34.98	0.896	Direct gamma-spec.	26.7%	1.33	2.08
19411	334.5	23.4	2	Direct gamma-spec.	6.3%	0.32	1.27
19428							
19429	338.565	25.126	1	Direct gamma-spec.	7.6%	0.38	0.88
19431	310.0	15.0	1	Direct gamma-spec.	-1.5%	-0.07	-0.25
19432	258.4	21.45	2	Direct gamma-spec.	-17.9%	-0.89	-3.76
19468	340.0	66.7	2	Direct gamma-spec.	8.1%	0.40	0.73
19470	324.0	8.0	1	Direct gamma-spec.	3.0%	0.15	0.72
19471	278.0	12.0	1	Direct gamma-spec.	-11.6%	-0.58	-2.30
19488							
19490	329.22	8.39	2	Direct gamma-spec.	4.6%	0.23	1.30
19508	341.0	44.0	2	Direct gamma-spec.	8.4%	0.42	1.08
19549	331.35	10.73	2	Direct gamma-spec.	5.3%	0.27	1.43
19728	375.0	23.0	1.96	Direct gamma-spec.	19.2%	0.96	3.85
19729	327.8	23.1	1	Direct gamma-spec.	4.2%	0.21	0.52
19788	318.0	19.0	2	Direct gamma-spec.	1.1%	0.05	0.24

K-40 in JRC-NORM-02

x_{pt} = 314.6 | $u(x_{pt})$ = 10.4 *(k=1)* | σ_{pt} = 62.9 (in Bq/kg d.m.)

z score





Annex 14: Pb-210 in JRC-NORM 02

x_{pt} = 33.5 $u(x_{pt})$ = 1.6 σ_{pt} = 10.1 (in Bq/kg dm)

Lab.Code	x_i	±	*k*	Technique	*D%*	*z* score	ζ score
19228	42.0	5.0	1	Direct gamma-spec.	25.4%	0.85	1.62
19229							
19230							
19231	33.12	2.7	1	Direct gamma-spec.	-1.1%	-0.04	-0.12
19232	28.0	6.8	2	Direct gamma-spec.	-16.4%	-0.55	-1.47
19233	20.9	3.4	1		-37.6%	-1.25	-3.36
19234	39.3	6.1	1	Direct gamma-spec.	17.3%	0.58	0.92
19235	31.8	3.9	1	Direct gamma-spec.	-5.1%	-0.17	-0.40
19236	37.7	5.7	1	Direct gamma-spec.	12.5%	0.42	0.71
19237	30.1	5.4	2	Direct gamma-spec.	-10.1%	-0.34	-1.08
19238							
19239							
19240	30.5	1.5	2	Direct gamma-spec.	-9.0%	-0.30	-1.71
19241							
19242							
19243	35.08	6.024	2	Direct gamma-spec.	4.7%	0.16	0.46
19244							
19245	32.6	2.4	1	Direct gamma-spec.	-2.7%	-0.09	-0.31
19246	27.9	8.4	2	Direct gamma-spec.	-16.7%	-0.56	-1.25
19247	26.6	3.4	1	Direct gamma-spec.	-20.6%	-0.69	-1.84
19249	< 48.0		2	Direct gamma-spec.			
19250	28.8	1.9	1	Direct gamma-spec.	-14.0%	-0.47	-1.90
19251	28.5	8.2	2	Direct gamma-spec.	-14.9%	-0.50	-1.14
19252							
19253							
19254	32.0	6.0	1	Gamma spectrometry	-4.5%	-0.15	-0.24
19256	34.0	7.0	2	Direct gamma-spec.	1.5%	0.05	0.13
19257							
19258	8.8	2.4	2	Direct gamma-spec.	-73.7%	-2.46	-12.39
19259	33.35	5.94	2	Direct gamma-spec.	-0.4%	-0.01	-0.04
19260	38.8	8.0	1	Direct gamma-spec.	15.8%	0.53	0.65
19261	6.42	1.61	2	Liquid-scint. counting	-80.8%	-2.69	-15.18
19263							

19264	34.1	2.0	1	Direct gamma-spec.	1.8%	0.06	0.23
19265	29.0	6.0	1	Direct gamma-spec.	-13.4%	-0.45	-0.72
19266	29.43	4.3	1	Direct gamma-spec.	-12.1%	-0.40	-0.89
19267	26.8	3.3	1	Direct gamma-spec.	-20.0%	-0.67	-1.83
19268							
19269							
19270							
19271	43.0	6.0	1	Direct gamma-spec.	28.4%	0.95	1.53
19272							
19273	46.6	5.0	2	Direct gamma-spec.	39.1%	1.30	4.42
19274	43.8	10.0	1	Direct gamma-spec.	30.7%	1.02	1.02
19276	184.7	87.9	2	Direct gamma-spec.	451.3%	15.04	3.44
19277	33.2	5.9	2	Direct gamma-spec.	-0.9%	-0.03	-0.09
19278							
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19279							
19281	34.0	3.0	2	Direct gamma-spec.	1.5%	0.05	0.23
19288	12.4	6.3	2	Direct gamma-spec.	-63.0%	-2.10	-5.98
19289	39.7	5.0	1	Direct gamma-spec.	18.5%	0.62	1.18
19290	32.46	10.77	2	Direct gamma-spec.	-3.1%	-0.10	-0.19
19291	32.2	5.5	2	Direct gamma-spec.	-3.9%	-0.13	-0.41
19308	26.01	4.8	1	Direct gamma-spec.	-22.4%	-0.75	-1.48
19309	34.7	3.0	2	Direct gamma-spec.	3.6%	0.12	0.55
19310	28.9	6.6	2	Direct gamma-spec.	-13.7%	-0.46	-1.26
19311	31.0	4.6	1	Direct gamma-spec.	-7.5%	-0.25	-0.51
19313	27.336	2.121	1	Direct gamma-spec.	-18.4%	-0.61	-2.32
19314	33.7	7.1	2	Direct gamma-spec.	0.6%	0.02	0.05
19316	26.46	3.46	1	Direct gamma-spec.	-21.0%	-0.70	-1.85
19318	39.1	5.9	1	Direct gamma-spec.	16.7%	0.56	0.92
19328	18.8	6.4	2	Direct gamma-spec.	-43.9%	-1.46	-4.11
19329	34.63	4.67	2	Direct gamma-spec.	3.4%	0.11	0.40
19330	36.0	6.0	2	Gamma-spec. with chem. sep.	7.5%	0.25	0.74
19332	29.0	2.6	1	Direct gamma-spec.	-13.4%	-0.45	-1.48
19333							
19334							
19336	28.6	2.5	1	Direct gamma-spec.	-14.6%	-0.49	-1.65
19368							

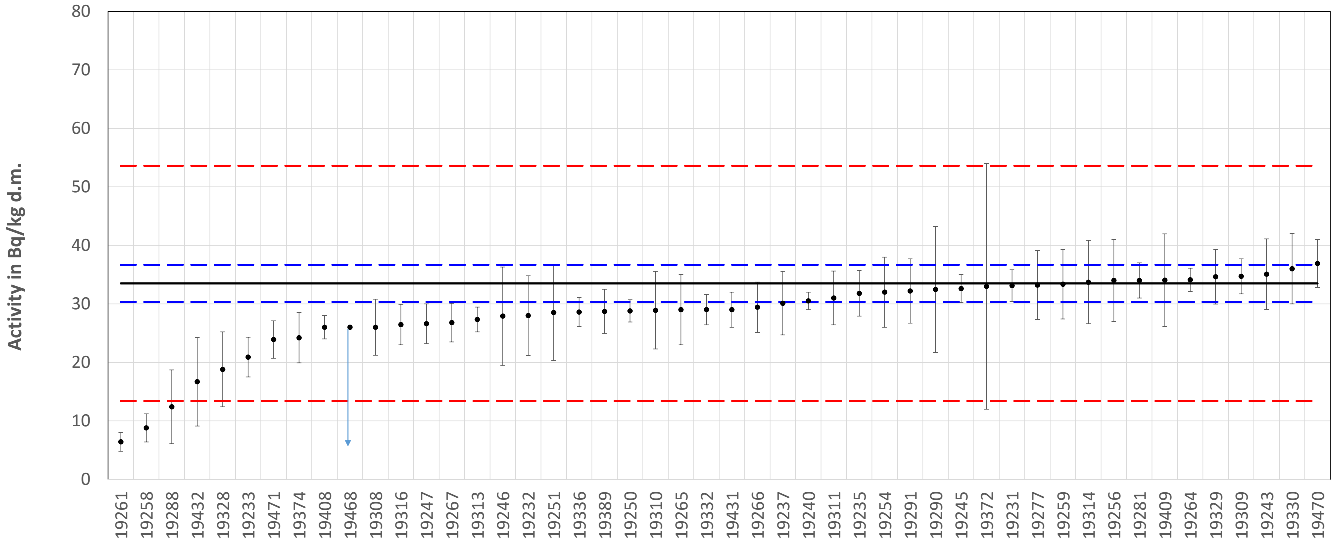
19369								
19370	38.0	6.0	1	Direct gamma-spec.	13.4%	0.45	0.72
19371								
19372	33.0	21.0	2	Direct gamma-spec.	-1.5%	-0.05	-0.05
19374	24.2	4.3	1.76	Direct gamma-spec.	-27.8%	-0.93	-3.19
19388								
19389	28.7	3.8	1	Gamma-spec. with chem. sep.	-14.3%	-0.48	-1.17
19391								
19408	26.0	2.0	1	Direct gamma-spec.	-22.4%	-0.75	-2.93
19409	34.04	7.91	2	Direct gamma-spec.	1.6%	0.05	0.13
19410								
19411								
19428								
19429								
19431	29.0	3.0	1	Direct gamma-spec.	-13.4%	-0.45	-1.33
19432	16.69	7.56	2	Direct gamma-spec.	-50.2%	-1.67	-4.10
19468	< 26.0			Direct gamma-spec.			
19470	36.9	4.1	1	Direct gamma-spec.	10.1%	0.34	0.77
19471	23.9	3.2	1	Direct gamma-spec.	-28.7%	-0.96	-2.69
19488								
19490	41.73	7.31	2	Direct gamma-spec.	24.6%	0.82	2.06
19508								
19549	< 60.0			Direct gamma-spec.			
19728								
19729	37.1	11.4	1	Direct gamma-spec.	10.7%	0.36	0.31
19788								

Pb-210 in JRC-NORM-02

x_{pt} = 33.5 $u(x_{pt})$ = 1.6 σ_{pt} = 10.1 (in Bq/kg d.m.)

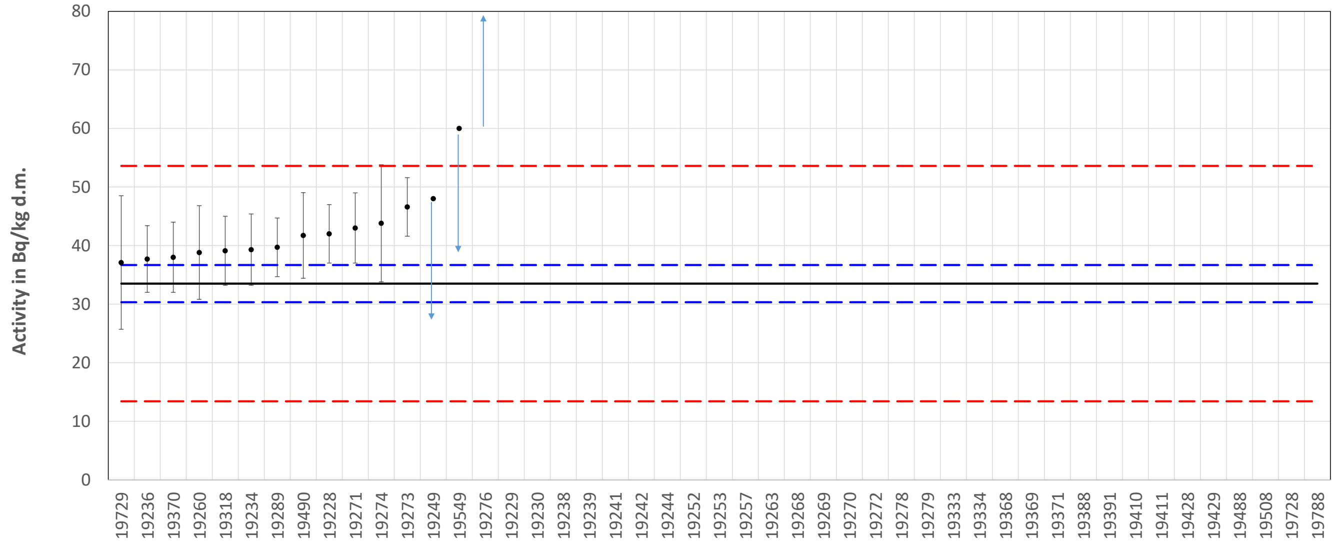
(k=1)

z score



Measurement result reported by participants

Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants

Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 15: Ra-226 in JRC-NORM 02

x_{pt} = 32.4 $u(x_{pt})$ = 1.0 σ_{pt} = 6.5 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	33.6	1.15	1	Direct gamma-spec.	3.7%	0.19	0.80
19229							
19230							
19231	32.6	0.7	1	Direct gamma-spec.	0.6%	0.03	0.17
19232	32.8	4.0	2	Direct gamma-spec.	1.2%	0.06	0.18
19233	45.2	9.8	1		39.5%	1.98	1.30
19234	41.7	1.0	1	Direct gamma-spec.	28.7%	1.44	6.73
19235	34.5	2.8	1	Gamma-spectrometry, equilibrium conditions, derived from Pb-214	6.5%	0.32	0.71
19236	31.9	4.9	1	Direct gamma-spec.	-1.5%	-0.08	-0.10
19237	31.2	5.2	2	Direct gamma-spec.	-3.7%	-0.19	-0.43
19238							
19239							
19240	35.2	1.5	2	Direct gamma-spec.	8.6%	0.43	2.31
19241	30.0	3.0	1	Direct gamma-spec.	-7.4%	-0.37	-0.76
19242							
19243	34.93	4.058	2	Direct gamma-spec.	7.8%	0.39	1.13
19244							
19245	32.6	1.7	1	Direct gamma-spec.	0.6%	0.03	0.10
19246	46.8	8.6	2	Direct gamma-spec.	44.4%	2.22	3.27
19247	34.9	2.8	1	Direct gamma-spec.	7.7%	0.39	0.85
19249	22.0	2.9	2	Direct gamma-spec.	-32.1%	-1.60	-5.99
19250	31.6	1.2	1	gamma-spectrometry Pb-214, Bi-214	-2.5%	-0.12	-0.52
19251	34.7	4.2	2	Direct gamma-spec.	7.1%	0.35	1.00
19252							
19253	28.8	1.6	2	Direct gamma-spec.	-11.1%	-0.56	-2.89
19254	31.0	1.0	1	Gamma spectrometry	-4.3%	-0.22	-1.01
19256	32.0	4.0	2	Direct gamma-spec.	-1.2%	-0.06	-0.18
19257	33.0	2.0	1	Direct gamma-spec.	1.9%	0.09	0.27
19258	10.8	0.9	2	Direct gamma-spec.	-66.7%	-3.33	-20.47
19259	32.87	7.3	2	Direct gamma-spec.	1.5%	0.07	0.12
19260	29.9	1.7	1	Direct gamma-spec.	-7.7%	-0.39	-1.28
19261	12.06	3.45	2	Liquid-scint. counting	-62.8%	-3.14	-10.32

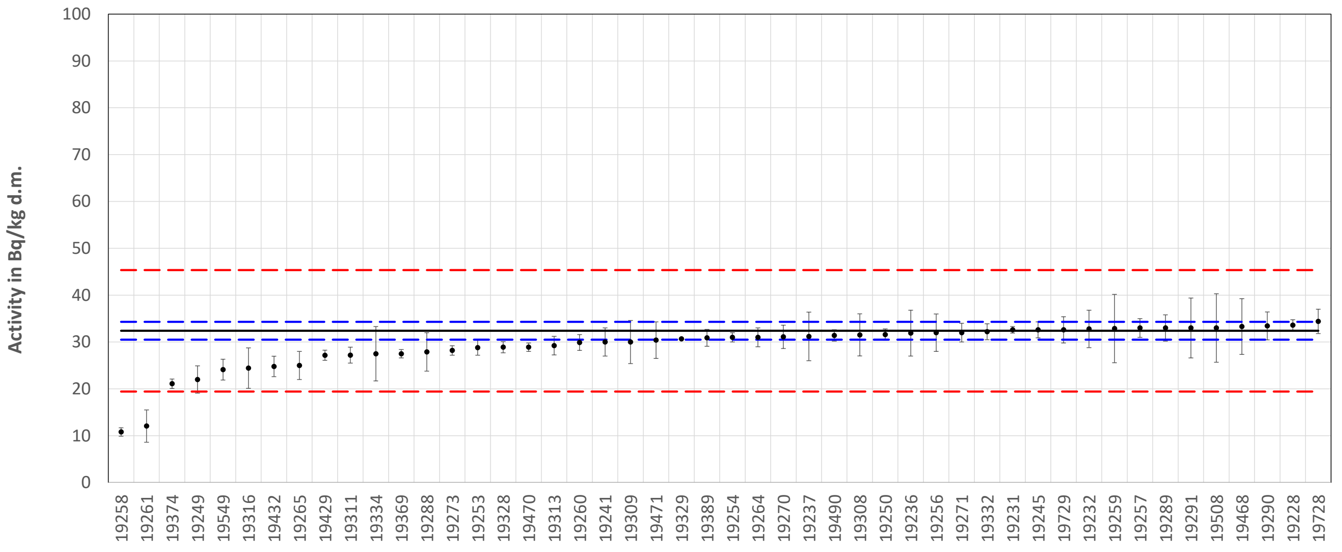
19263							
19264	31.0	2.0	1	Direct gamma-spec.	-4.3%	-0.22	-0.63
19265	25.0	3.0	1	Direct gamma-spec.	-22.8%	-1.14	-2.35
19266							
19267	36.6	3.1	1	Direct gamma-spec.	13.0%	0.65	1.29
19268							
19269							
19270	31.1	2.5	2	Direct gamma-spec.	-4.0%	-0.20	-0.83
19271	32.0	2.0	1	Direct gamma-spec.	-1.2%	-0.06	-0.18
19272							
19273	28.2	1.0	2	Direct gamma-spec.	-13.0%	-0.65	-3.90
19274	43.2	3.8	1	Direct gamma-spec.	33.3%	1.67	2.76
19276	85.6	6.9	2	Direct gamma-spec.	164.2%	8.21	14.86
19277	36.4	1.8	2	Direct gamma-spec.	12.3%	0.62	3.05
Lab.Code	x_i	±	k	**Technique**	*D%*	*z* **score**	ζ **score**
19278							
19279							
19281	37.6	3.0	2	Direct gamma-spec.	16.0%	0.80	2.92
19288	27.9	4.1	2	Direct gamma-spec.	-13.9%	-0.69	-1.99
19289	33.0	2.8	1	Direct gamma-spec.	1.9%	0.09	0.20
19290	33.44	2.98	2	Direct gamma-spec.	3.2%	0.16	0.59
19291	33.0	6.4	2	Direct gamma-spec.	1.9%	0.09	0.18
19308	31.52	4.5	1	Direct gamma-spec.	-2.7%	-0.14	-0.19
19309	30.0	4.6	2	Precipitation. Solid scint. (ZnS(Ag))	-7.4%	-0.37	-0.96
19310	65.6	11.6	2	Direct gamma-spec.	102.5%	5.12	5.65
19311	27.2	1.7	1	Direct gamma-spec.	-16.0%	-0.80	-2.67
19313	29.226	1.977	1	Direct gamma-spec.	-9.8%	-0.49	-1.45
19314	35.34	9.1	2	Direct gamma-spec.	9.1%	0.45	0.63
19316	24.43	4.31	1	Direct gamma-spec.	-24.6%	-1.23	-1.81
19318	37.2	1.6	1	Direct gamma-spec.	14.8%	0.74	2.58
19328	28.9	1.2	2	Direct gamma-spec.	-10.8%	-0.54	-3.10
19329	30.69	0.17	2	Direct gamma-spec.	-5.3%	-0.26	-1.78
19330	35.0	5.0	2	Gamma-spec. with chem. sep.	8.0%	0.40	0.97
19332	32.2	1.7	1	Direct gamma-spec.	-0.6%	-0.03	-0.10
19333							
19334	27.5	5.8	1	Direct gamma-spec.	-15.1%	-0.76	-0.83
19336	34.9	2.1	1	Direct gamma-spec.	7.7%	0.39	1.08

19368							
19369	27.5	0.9	2	Direct gamma-spec.	-15.1%	-0.76	-4.64
19370	35.0	2.0	1	Direct gamma-spec.	8.0%	0.40	1.17
19371	47.4	5.0	1	Direct gamma-spec.	46.3%	2.31	2.95
19372	45.0	6.0	2	Direct gamma-spec.	38.9%	1.94	4.00
19374	21.1	1.0	1.73	Direct gamma-spec.	-34.9%	-1.74	-10.13
19388							
19389	30.9	1.8	1	Gamma-spec. with chem. sep.	-4.6%	-0.23	-0.74
19391							
19408	35.0	4.0	1	Direct gamma-spec.	8.0%	0.40	0.63
19409	61.58	5.42	2	Direct gamma-spec.	90.1%	4.50	10.16
19410	40.36	5.83	0.896	Direct gamma-spec.	24.6%	1.23	1.21
19411	35.0	2.5	2	Direct gamma-spec.	8.0%	0.40	1.65
19428							
19429	27.171	1.088	1	Direct gamma-spec.	-16.1%	-0.81	-3.61
19431	36.0	4.0	1	Direct gamma-spec.	11.1%	0.56	0.88
19432	24.79	2.19	2	Direct gamma-spec.	-23.5%	-1.17	-5.24
19468	33.3	5.96	2	Direct gamma-spec.	2.8%	0.14	0.29
19470	28.9	0.9	1	Direct gamma-spec.	-10.8%	-0.54	-2.67
19471	30.4	3.9	1	Direct gamma-spec.	-6.2%	-0.31	-0.50
19488							
19490	31.41	1.21	2	Direct gamma-spec.	-3.1%	-0.15	-0.88
19508	33.0	7.3	2	Direct gamma-spec.	1.9%	0.09	0.16
19549	24.1	2.23	2	Direct gamma-spec.	-25.6%	-1.28	-5.65
19728	34.4	2.6	1.96	Direct gamma-spec.	6.2%	0.31	1.22
19729	32.6	2.8	1	Direct gamma-spec.	0.6%	0.03	0.07
19788							

Ra-226 in JRC-NORM-02

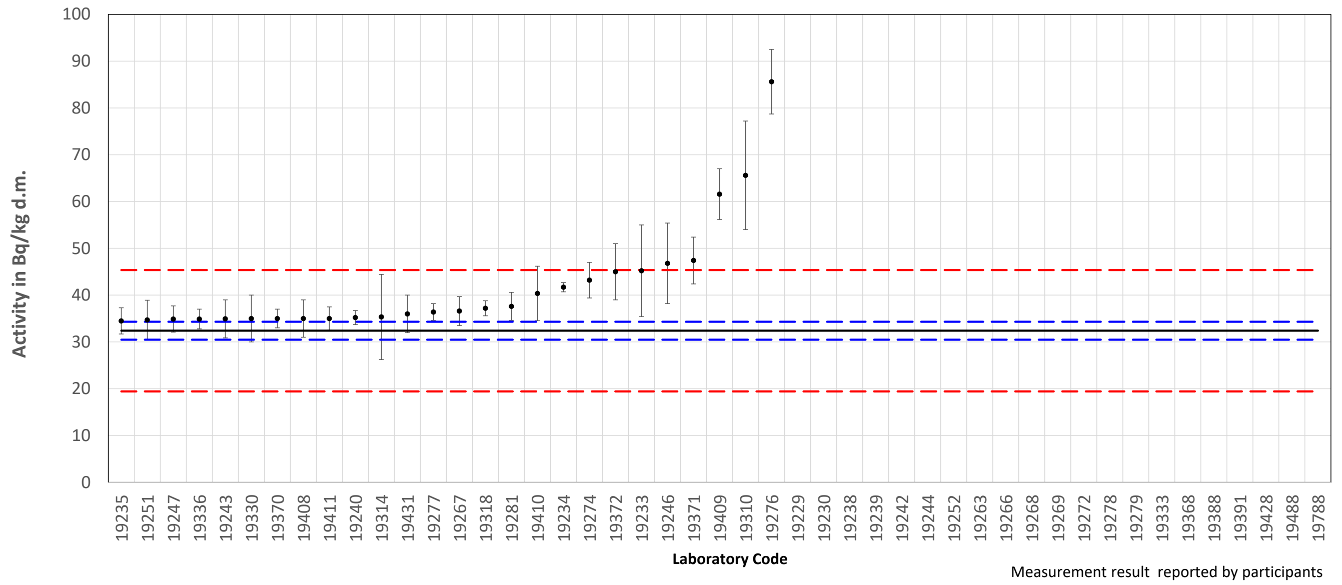
x_{pt} = 32.4 $u(x_{pt})$ = 1.0 *(k=1)* σ_{pt} = 6.5 (in Bq/kg d.m.)

z score



Measurement result reported by participants

Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants

Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 16: Ra-228 in JRC-NORM 02

x_{pt} = 22.9 $u(x_{pt})$ = 0.6 σ_{pt} = 4.6 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	22.9	0.9	1	Direct gamma-spec.	0.0%	0.00	0.00
19229							
19230							
19231	28.75	0.9	1	Direct gamma-spec.	25.5%	1.28	5.32
19232	23.9	2.5	2	Direct gamma-spec.	4.4%	0.22	0.71
19233	25.9	2.2	1		13.1%	0.66	1.31
19234	31.1	1.3	1	Direct gamma-spec.	35.8%	1.79	5.67
19235	22.5	1.9	1	Gamma-spec. Ac-228	-1.7%	-0.09	-0.20
19236	24.5	2.0	1	Direct gamma-spec.	7.0%	0.35	0.76
19237	24.7	3.0	2	Direct gamma-spec.	7.9%	0.39	1.11
19238							
19239							
19240							
19241	23.0	2.0	1	Direct gamma-spec.	0.4%	0.02	0.05
19242							
19243	23.72	3.385	2	Direct gamma-spec.	3.6%	0.18	0.45
19244							
19245	23.9	1.0	1	Direct gamma-spec.	4.4%	0.22	0.85
19246	23.2	4.4	2	Direct gamma-spec.	1.3%	0.07	0.13
19247	22.8	0.7	1	Direct gamma-spec.	-0.4%	-0.02	-0.11
19249	17.2	2.4	2	Direct gamma-spec.	-24.9%	-1.24	-4.20
19250	23.9	1.2	1	gamma-spec. Ac-228	4.4%	0.22	0.74
19251	25.5	3.9	2	Direct gamma-spec.	11.4%	0.57	1.27
19252							
19253	23.1	2.8	2	Direct gamma-spec.	0.9%	0.04	0.13
19254	23.0	2.0	1	Gamma spectrometry	0.4%	0.02	0.05
19256	25.0	3.0	2	Direct gamma-spec.	9.2%	0.46	1.29
19257							
19258							
19259	28.86	3.16	2	Direct gamma-spec.	26.0%	1.30	3.50
19260	25.8	1.8	1	Direct gamma-spec.	12.7%	0.63	1.52
19261	20.82	0.66	2	Direct gamma-spec.	-9.1%	-0.45	-2.92
19263							

19264	26.3	1.8	1	Direct gamma-spec.	14.8%	0.74	1.78
19265	20.0	2.0	1	Direct gamma-spec.	-12.7%	-0.63	-1.38
19266							
19267	24.3	2.2	1	Direct gamma-spec.	6.1%	0.31	0.61
19268							
19269							
19270	25.9	2.7	2	Direct gamma-spec.	13.1%	0.66	2.01
19271	26.0	3.0	1	Direct gamma-spec.	13.5%	0.68	1.01
19272							
19273	20.7	1.0	2	Direct gamma-spec.	-9.6%	-0.48	-2.73
19274	28.2	2.8	1	Direct gamma-spec.	23.1%	1.16	1.85
19276	61.8	5.0	2	Direct gamma-spec.	169.9%	8.49	15.09
19277	24.2	1.3	2	Direct gamma-spec.	5.7%	0.28	1.43
19278							
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19279							
19281	29.7	2.5	2	Direct gamma-spec.	29.7%	1.48	4.85
19288	20.9	3.0	2	Direct gamma-spec.	-8.7%	-0.44	-1.23
19289	23.0	1.9	1	Direct gamma-spec.	0.4%	0.02	0.05
19290	24.72	2.28	2	Direct gamma-spec.	7.9%	0.40	1.40
19291	23.7	1.0	2	Direct gamma-spec.	3.5%	0.17	0.99
19308	26.8	6.9	1	Direct gamma-spec.	17.0%	0.85	0.56
19309	23.1	1.4	2	Direct gamma-spec.	0.9%	0.04	0.21
19310	21.4	1.0	2	Direct gamma-spec. Ac-228	-6.6%	-0.33	-1.86
19311	21.0	1.7	1	Direct gamma-spec.	-8.3%	-0.41	-1.05
19313							
19314	28.62	3.5	2	Direct gamma-spec. Ac-228 at To	25.0%	1.25	3.07
19316							
19318	26.7	1.4	1	Direct gamma-spec.	16.6%	0.83	2.47
19328	21.3	1.3	2	Direct gamma-spec.	-7.0%	-0.35	-1.76
19329	24.05	0.26	2	Direct gamma-spec.	5.0%	0.25	1.78
19330	23.0	3.0	2	Gamma-spec. with chem. sep.	0.4%	0.02	0.06
19332	25.9	1.5	1	Direct gamma-spec.	13.1%	0.66	1.84
19333							
19334	23.1	0.9	1	Direct gamma-spec.	0.9%	0.04	0.18
19336	24.7	1.6	1	Direct gamma-spec.	7.9%	0.39	1.05
19368							

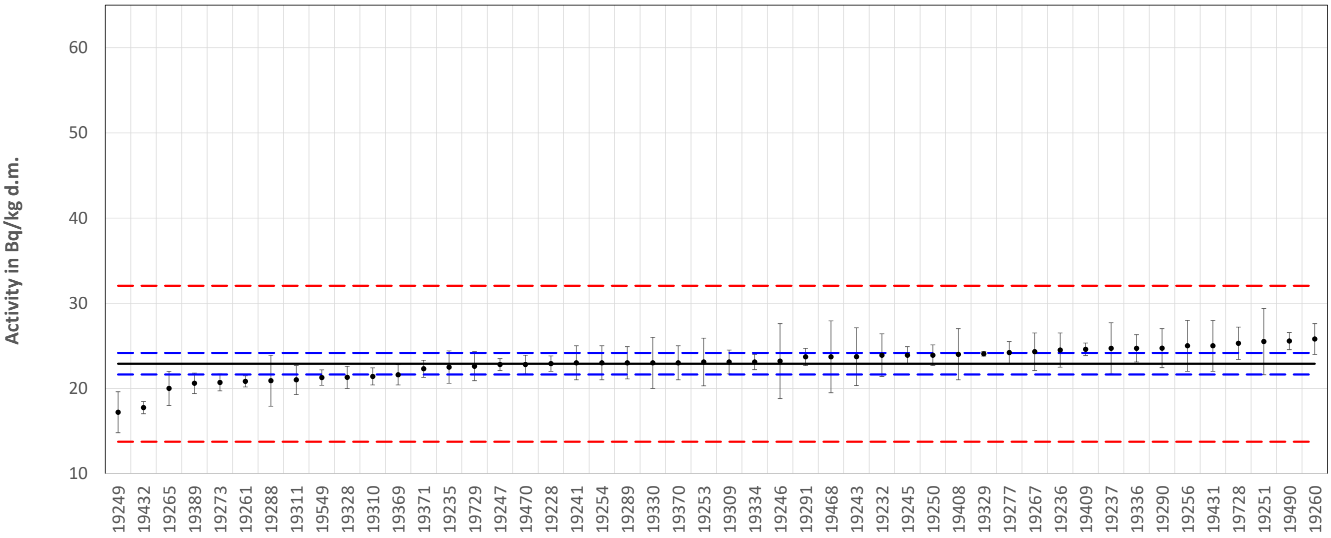
19369	21.6	1.2	2	Direct gamma-spec.	-5.7%	-0.28	-1.49
19370	23.0	2.0	1	Direct gamma-spec.	0.4%	0.02	0.05
19371	22.3	1.0	1	Direct gamma-spec.	-2.6%	-0.13	-0.51
19372							
19374							
19388							
19389	20.6	1.2	1	Gamma-spec. with chem. sep.	-10.0%	-0.50	-1.70
19391							
19408	24.0	3.0	1	Direct gamma-spec.	4.8%	0.24	0.36
19409	24.59	0.74	2	Direct gamma-spec.	7.4%	0.37	2.31
19410							
19411							
19428							
19429	29.642	2.248	1	Direct gamma-spec.	29.4%	1.47	2.89
19431	25.0	3.0	1	Direct gamma-spec.	9.2%	0.46	0.68
19432	17.74	0.72	2	Direct gamma-spec.	-22.5%	-1.13	-7.09
19468	23.7	4.22	2	Direct gamma-spec.	3.5%	0.17	0.36
19470	22.8	1.1	1	Direct gamma-spec.	-0.4%	-0.02	-0.08
19471							
19488							
19490	25.56	1.01	2	Direct gamma-spec.	11.6%	0.58	3.29
19508							
19549	21.27	0.9	2	Direct gamma-spec.	-7.1%	-0.36	-2.10
19728	25.3	1.9	1.96	Direct gamma-spec.	10.5%	0.52	2.07
19729	22.6	1.7	1	Direct gamma-spec.	-1.3%	-0.07	-0.17
19788							

Ra-228 in JRC-NORM-02

x_{pt} = 22.9 $u(x_{pt})$ = 0.6 σ_{pt} = 4.6 (in Bq/kg d.m.)

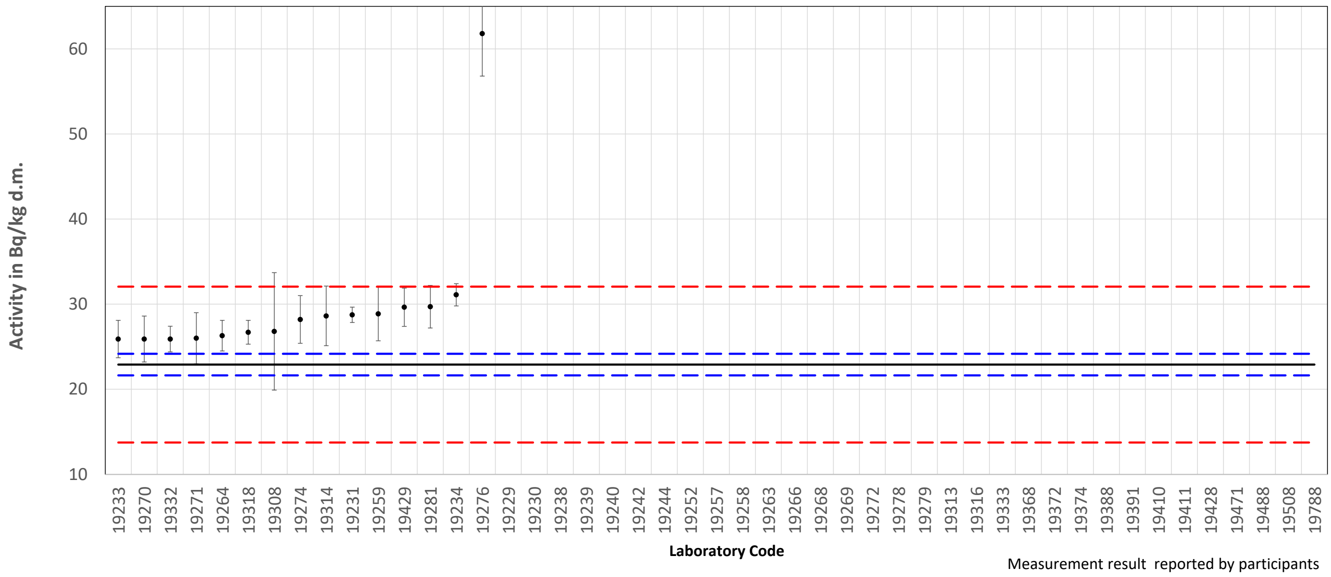
(k=1)

z score



Measurement result reported by participants

Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants

Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 17: Th-228 in JRC-NORM 02

x_{pt} = 23.6 $u(x_{pt})$ = 0.7 σ_{pt} = 4.7   (in Bq/kg dm)

Lab.Code	x_i	±	*k*	Technique	*D%*	*z* score	ζ score
19228	23.9	1.0	1	Direct gamma-spec.	1.3%	0.06	0.25
19229							
19230							
19231	26.3	0.9	1	Direct gamma-spec.	11.4%	0.57	2.42
19232	23.3	3.0	2	Direct gamma-spec.	-1.3%	-0.06	-0.18
19233	28.4	1.9	1		20.3%	1.02	2.39
19234	27.6	1.5	1	Direct gamma-spec.	16.9%	0.85	2.44
19235	23.7	1.5	1	Gamma-spectrometry, equilibrium conditions, derived from Pb-212	0.4%	0.02	0.06
19236	24.4	2.2	1	Direct gamma-spec.	3.4%	0.17	0.35
19237							
19238							
19239							
19240							
19241	23.0	2.0	1	Direct gamma-spec.	-2.5%	-0.13	-0.29
19242							
19243	25.64	6.583	2	Direct gamma-spec.	8.6%	0.43	0.61
19244							
19245	23.5	1.3	1	Direct gamma-spec.	-0.4%	-0.02	-0.07
19246	23.2	4.4	2	Direct gamma-spec.	-1.7%	-0.08	-0.17
19247	23.0	0.7	1	Direct gamma-spec.	-2.5%	-0.13	-0.63
19249	20.3	4.3	2	Direct gamma-spec.	-14.0%	-0.70	-1.47
19250	23.0	0.9	1	gamma-spec. Pb-212, Bi-212, Tl-208	-2.5%	-0.13	-0.54
19251	23.2	3.8	2	Direct gamma-spec.	-1.7%	-0.08	-0.20
19252							
19253	23.1	1.9	2	Direct gamma-spec.	-2.1%	-0.11	-0.43
19254	23.0	1.0	1	Gamma spectrometry	-2.5%	-0.13	-0.50
19256	22.0	3.0	2	Alpha spectrometry	-6.8%	-0.34	-0.98
19257	25.0	1.0	1	Direct gamma-spec.	5.9%	0.30	1.17
19258							
19259	26.84	3.19	2	Direct gamma-spec.	13.7%	0.69	1.88
19260	25.7	2.2	1	Direct gamma-spec.	8.9%	0.44	0.91
19261	41.62	12.95	2	Alpha spectrometry	76.4%	3.82	2.77

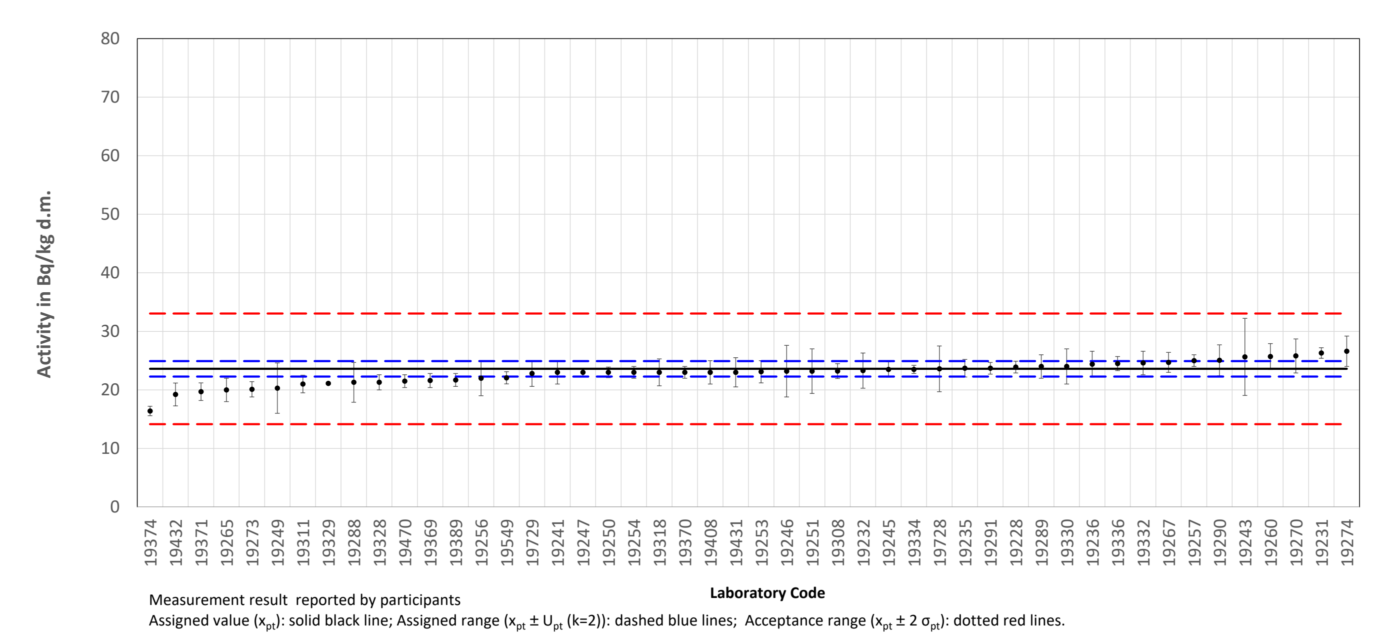
19263							
19264	27.2	1.8	1	Direct gamma-spec.	15.3%	0.76	1.88
19265	20.0	2.0	1	Direct gamma-spec.	-15.3%	-0.76	-1.71
19266							
19267	24.7	1.7	1	Direct gamma-spec.	4.7%	0.23	0.60
19268							
19269							
19270	25.8	2.9	2	Direct gamma-spec.	9.3%	0.47	1.38
19271	27.6	1.1	1	Direct gamma-spec.	16.9%	0.85	3.12
19272							
19273	20.1	1.3	2	Direct gamma-spec.	-14.8%	-0.74	-3.79
19274	26.6	2.6	1	Direct gamma-spec.	12.7%	0.64	1.12
19276	178.9	30.1	2	Direct gamma-spec.	658.1%	32.90	10.31
19277	28.3	1.8	2	Direct gamma-spec.	19.9%	1.00	4.22
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278							
19279							
19281	29.3	2.3	2	Direct gamma-spec.	24.2%	1.21	4.31
19288	21.3	3.4	2	Direct gamma-spec.	-9.7%	-0.49	-1.26
19289	24.0	2.0	1	Direct gamma-spec.	1.7%	0.08	0.19
19290	25.05	2.65	2	Direct gamma-spec.	6.1%	0.31	0.98
19291	23.7	1.0	2	Direct gamma-spec.	0.4%	0.02	0.12
19308	23.21	1.27	1	Direct gamma-spec.	-1.7%	-0.08	-0.27
19309	28.8	5.9	2	Alpha spectrometry	22.0%	1.10	1.72
19310							
19311	21.0	1.5	1	Direct gamma-spec.	-11.0%	-0.55	-1.59
19313							
19314	27.63	3.2	2	Direct gamma-spec Pb 212 at To	17.1%	0.85	2.33
19316							
19318	23.0	2.3	2	Alpha spectrometry	-2.5%	-0.13	-0.45
19328	21.3	1.3	2	Direct gamma-spec.	-9.7%	-0.49	-2.49
19329	21.12	0.19	2	Direct gamma-spec.	-10.5%	-0.53	-3.74
19330	24.0	3.0	2	Gamma-spec. with chem. sep.	1.7%	0.08	0.24
19332	24.6	2.0	1	Direct gamma-spec.	4.2%	0.21	0.48
19333							
19334	23.5	0.7	1	Direct gamma-spec.	-0.4%	-0.02	-0.10
19336	24.5	1.2	1	Direct gamma-spec.	3.8%	0.19	0.66

19368							
19369	21.6	1.2	2	Direct gamma-spec.	-8.5%	-0.42	-2.25
19370	23.0	1.0	1	Direct gamma-spec.	-2.5%	-0.13	-0.50
19371	19.7	1.5	1	Direct gamma-spec.	-16.5%	-0.83	-2.38
19372	75.0	14.0	2	Direct gamma-spec.	217.8%	10.89	7.31
19374	16.4	0.8	1.73	Direct gamma-spec.	-30.5%	-1.53	-8.97
19388							
19389	21.7	1.1	1	Gamma-spec. with chem. sep.	-8.1%	-0.40	-1.48
19391							
19408	23.0	2.0	1	Direct gamma-spec.	-2.5%	-0.13	-0.29
19409	71.31	9.47	2	Direct gamma-spec.	202.2%	10.11	9.98
19410							
19411							
19428							
19429	29.818	2.19	1	Direct gamma-spec.	26.3%	1.32	2.72
19431	23.0	2.5	1	Direct gamma-spec.	-2.5%	-0.13	-0.23
19432	19.23	1.95	2	Direct gamma-spec.	-18.5%	-0.93	-3.72
19468	32.4	7.4	2	Direct gamma-spec.	37.3%	1.86	2.34
19470	21.5	1.1	1	Direct gamma-spec.	-8.9%	-0.44	-1.64
19471							
19488							
19490							
19508							
19549	22.06	1.04	2	Direct gamma-spec.	-6.5%	-0.33	-1.84
19728	23.6	3.9	1.96	Direct gamma-spec.	0.0%	0.00	0.00
19729	22.8	2.2	1	Direct gamma-spec.	-3.4%	-0.17	-0.35
19788							

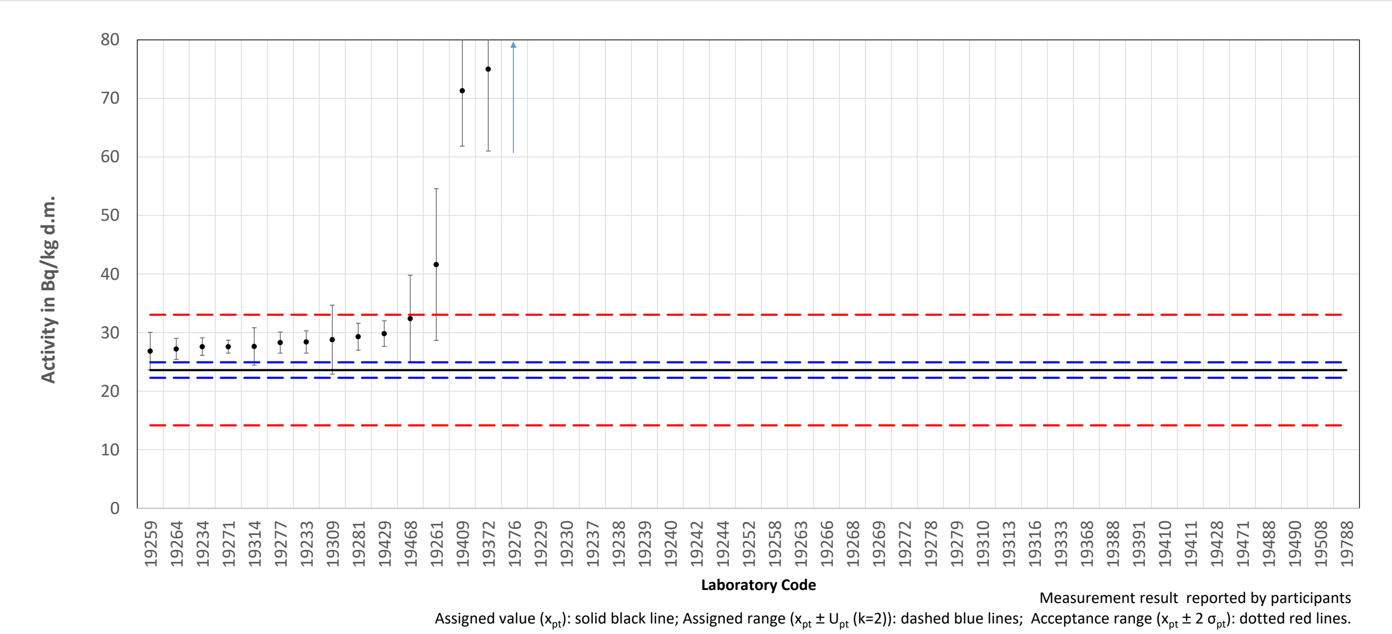
Th-228 in JRC-NORM-02

x_{pt} = 23.6 **$u(x_{pt})$ =** 0.7 *(k=1)* σ_{pt} = 4.7 (in Bq/kg d.m.)

z score



80
70
60
50
40
30
20
10
0
Activity in Bq/kg d.m.
19374 19432 19371 19265 19273 19249 19311 19329 19288 19328 19470 19369 19389 19256 19549 19729 19241 19247 19250 19254 19318 19370 19408 19431 19253 19246 19251 19308 19232 19245 19334 19728 19235 19291 19228 19289 19330 19236 19336 19332 19267 19257 19290 19243 19260 19270 19231 19274
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



80
70
60
50
40
30
20
10
0
Activity in Bq/kg d.m.
19259 19264 19234 19271 19314 19277 19233 19309 19281 19429 19468 19261 19409 19372 19276 19229 19230 19237 19238 19239 19240 19242 19244 19252 19258 19263 19266 19268 19269 19272 19278 19279 19310 19313 19316 19333 19368 19388 19391 19410 19411 19428 19471 19488 19490 19508 19788
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 18: Th-232 in JRC-NORM 02

x_{pt} =	23.1	$u(x_{pt})$ =	0.6	σ_{pt} =	4.6	(in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	22.9	0.9	1	Direct gamma-spec.	-0.9%	-0.04	-0.18
19229							
19230							
19231	27.69	0.9	1	Direct gamma-spec.	19.9%	0.99	4.14
19232	23.9	2.5	2	Direct gamma-spec.	3.5%	0.17	0.57
19233	25.9	2.2	1		12.1%	0.61	1.22
19234	30.8	1.7	1	Direct gamma-spec.	33.3%	1.67	4.23
19235	22.5	1.9	1	Gamma-spec. equilibrium conditions, derived from Ra-228	-2.6%	-0.13	-0.30
19236							
19237							
19238							
19239							
19240							
19241	23.0	2.0	1	Direct gamma-spec.	-0.4%	-0.02	-0.05
19242							
19243							
19244							
19245							
19246	23.2	4.4	2	Direct gamma-spec.	0.4%	0.02	0.04
19247	22.9	0.7	1	Direct gamma-spec.	-0.9%	-0.04	-0.21
19249							
19250	23.9	1.2	1	max activity Th-228, Ra-228	3.5%	0.17	0.59
19251	25.5	3.9	2	Direct gamma-spec.	10.4%	0.52	1.17
19252							
19253							
19254	24.0	1.0	1	Alpha spectrometry	3.9%	0.19	0.76
19256	18.0	3.0	2	Alpha spectrometry	-22.1%	-1.10	-3.12
19257	23.0	1.0	1	Direct gamma-spec.	-0.4%	-0.02	-0.08
19258	9.6	1.7	2	Direct gamma-spec.	-58.4%	-2.92	-12.63
19259	28.06	3.16	2	Direct gamma-spec.	21.5%	1.07	2.90
19260	25.8	1.8	1	Direct gamma-spec.	11.7%	0.58	1.41
19261	21.57	7.68	2	Alpha spectrometry	-6.6%	-0.33	-0.39

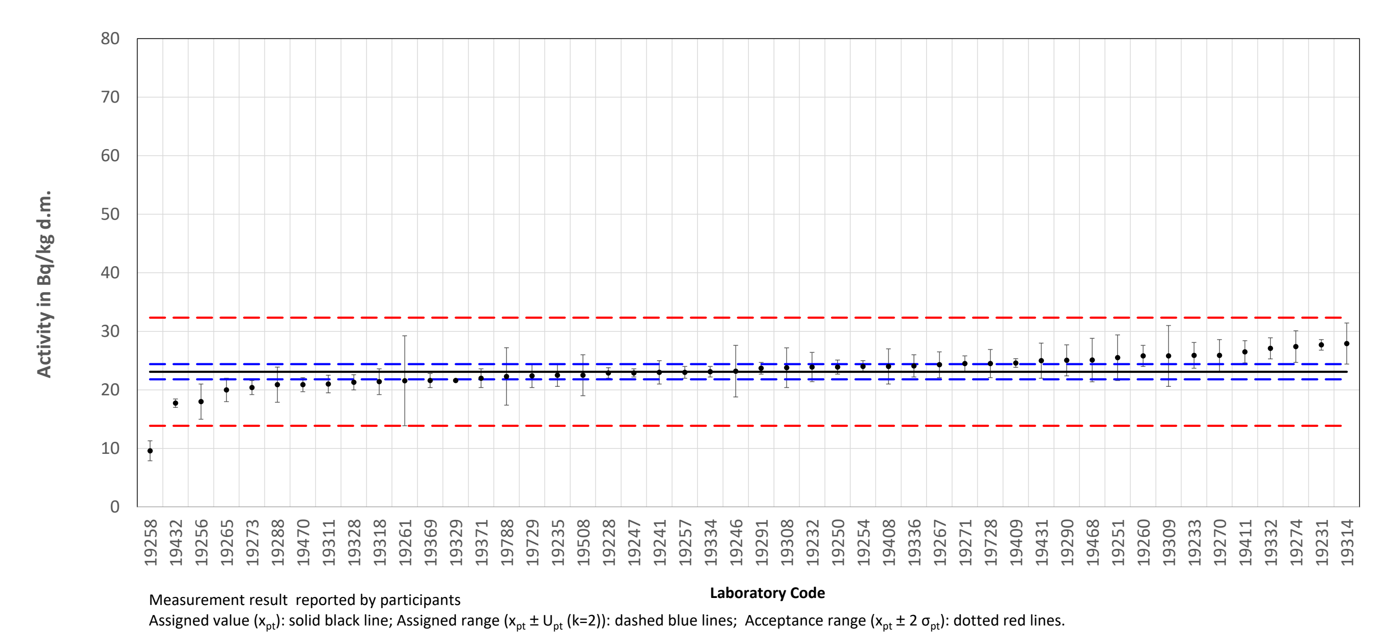
19263	43.9	12.7	2	ICP-MS	90.0%	4.50	3.26
19264							
19265	20.0	2.0	1	Direct gamma-spec.	-13.4%	-0.67	-1.47
19266							
19267	24.3	2.2	1	Direct gamma-spec.	5.2%	0.26	0.52
19268	330.599	0.351	1.05	ICP-OES	1331.2%	66.56	421.60
19269							
19270	25.9	2.7	2	Direct gamma-spec.	12.1%	0.61	1.87
19271	24.5	1.3	1	Alpha spectrometry	6.1%	0.30	0.96
19272							
19273	20.4	1.2	2	Direct gamma-spec.	-11.7%	-0.58	-3.06
19274	27.4	2.7	1	Direct gamma-spec.	18.6%	0.93	1.55
19276	2479.8	319.8	2	Direct gamma-spec.	10635.1%	531.75	15.36
19277	52.5	3.1	2		127.3%	6.36	17.50
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	**ζ score**
19278							
19279							
19281							
19288	20.9	3.0	2	Direct gamma-spec.	-9.5%	-0.48	-1.35
19289							
19290	25.05	2.65	2	Direct gamma-spec.	8.4%	0.42	1.32
19291	23.7	1.0	2	Direct gamma-spec.	2.6%	0.13	0.73
19308	23.79	3.39	1	Direct gamma-spec.	3.0%	0.15	0.20
19309	25.8	5.2	2	Alpha spectrometry	11.7%	0.58	1.01
19310							
19311	21.0	1.5	1	Direct gamma-spec.	-9.1%	-0.45	-1.29
19313							
19314	27.92	3.5	2	Direct gamma-spec. Ac 228	20.9%	1.04	2.58
19316							
19318	21.4	2.2	2	Alpha spectrometry	-7.4%	-0.37	-1.33
19328	21.3	1.3	2	Direct gamma-spec.	-7.8%	-0.39	-1.96
19329	21.61	0.15	2	Direct gamma-spec.	-6.5%	-0.32	-2.28
19330							
19332	27.1	1.8	1	Alpha spectrometry	17.3%	0.87	2.09
19333							
19334	23.1	0.9	1	Direct gamma-spec.	0.0%	0.00	0.00
19336	24.1	1.9	1	Direct gamma-spec.	4.3%	0.22	0.50

19368							
19369	21.6	1.2	2	Direct gamma-spec.	-6.5%	-0.32	-1.70
19370	33.0	9.0	1	Alpha spectrometry	42.9%	2.14	1.10
19371	22.0	1.6	1	Direct gamma-spec.	-4.8%	-0.24	-0.64
19372	< 360.0			Direct gamma-spec.			
19374							
19388							
19389							
19391							
19408	24.0	3.0	1	Direct gamma-spec.	3.9%	0.19	0.29
19409	24.59	0.74	2	Direct gamma-spec.	6.5%	0.32	2.00
19410	28.9	3.51	0.896	Direct gamma-spec.	25.1%	1.26	1.46
19411	26.5	1.9	2	Direct gamma-spec.	14.7%	0.74	2.96
19428							
19429							
19431	25.0	3.0	1	Direct gamma-spec.	8.2%	0.41	0.62
19432	17.74	0.72	2	Direct gamma-spec.	-23.2%	-1.16	-7.23
19468	25.1	3.72	2	Direct gamma-spec.	8.7%	0.43	1.02
19470	20.9	1.2	1	Alpha spectrometry	-9.5%	-0.48	-1.61
19471							
19488							
19490							
19508	22.5	3.5	2	Direct gamma-spec.	-2.6%	-0.13	-0.32
19549	< 30.0			Direct gamma-spec.			
19728	24.5	2.4	1.96	Direct gamma-spec.	6.1%	0.30	1.01
19729	22.4	2.0	1	Direct gamma-Spec. Th-232 decay products are in equilibrium.	-3.0%	-0.15	-0.33
19788	22.3	4.9	2	Alpha spectrometry	-3.5%	-0.17	-0.32

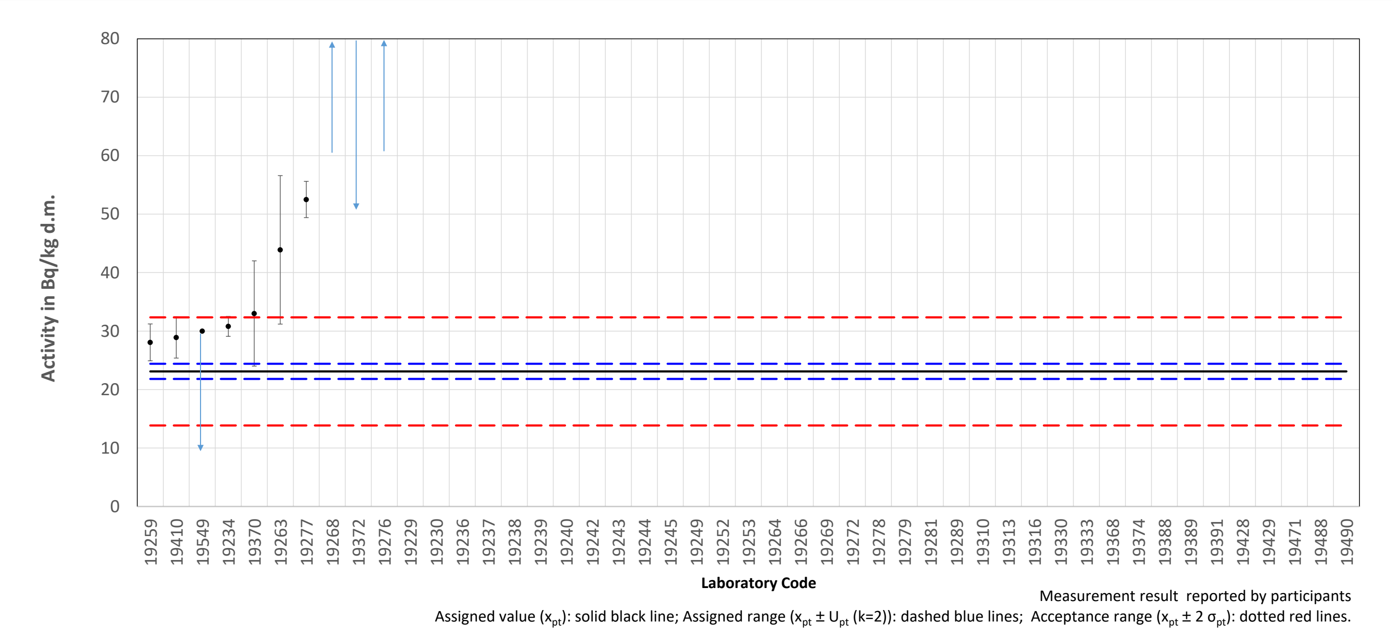
Th-232 in JRC-NORM-02

x_{pt} = 23.1 $u(x_{pt})$ = 0.6 *(k=1)* σ_{pt} = 4.6 (in Bq/kg d.m.)

z score



Activity in Bq/kg d.m.
80
70
60
50
40
30
20
10
0
19258 19432 19256 19265 19273 19288 19470 19311 19328 19318 19261 19369 19329 19371 19788 19729 19235 19508 19228 19247 19241 19257 19334 19246 19291 19308 19232 19250 19254 19408 19336 19267 19271 19728 19409 19431 19290 19468 19251 19260 19309 19233 19270 19411 19332 19274 19231 19314
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range (x_{pt} ± U_{pt} (k=2)): dashed blue lines; Acceptance range (x_{pt} ± 2 σ_{pt}): dotted red lines.



Activity in Bq/kg d.m.
80
70
60
50
40
30
20
10
0
19259 19410 19549 19234 19370 19263 19277 19268 19372 19276 19229 19230 19236 19237 19238 19239 19240 19242 19243 19244 19245 19249 19252 19253 19264 19266 19269 19272 19278 19279 19281 19289 19310 19313 19316 19330 19333 19368 19374 19388 19389 19391 19428 19429 19471 19488 19490
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range (x_{pt} ± U_{pt} (k=2)): dashed blue lines; Acceptance range (x_{pt} ± 2 σ_{pt}): dotted red lines.

Annex 19: U-238 in JRC-NORM 02

x_{pt} = 33.6 $u(x_{pt})$ = 1.3 σ_{pt} = 10.1 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	36.0	3.0	1	Direct gamma-spec.	7.1%	0.24	0.74
19229							
19230							
19231	38.08	3.2	1	Direct gamma-spec.	13.3%	0.44	1.30
19232	33.9	10.1	2	Direct gamma-spec.	0.9%	0.03	0.06
19233	28.9	3.4	1		-14.0%	-0.47	-1.30
19234	40.6	7.5	1	Direct gamma-spec.	20.8%	0.69	0.92
19235	32.3	3.3	1	Gamma-spec, deconv. U-235/Ra-226 Faktor 21,73 U-238/U-235	-3.9%	-0.13	-0.37
19236	30.6	3.2	1	Direct gamma-spec.	-8.9%	-0.30	-0.87
19237							
19238							
19239							
19240							
19241	30.0	3.0	1	Direct gamma-spec.	-10.7%	-0.36	-1.11
19242							
19243	32.29	4.871	2	Direct gamma-spec.	-3.9%	-0.13	-0.48
19244							
19245	29.0	14.0	1	Direct gamma-spec.	-13.7%	-0.46	-0.33
19246	43.6	22.2	2	Direct gamma-spec.	29.8%	0.99	0.90
19247	29.1	1.9	1	Direct gamma-spec.	-13.4%	-0.45	-1.98
19249							
19250	41.3	3.1	1	calculated from the peak 186 keV	22.9%	0.76	2.30
19251	29.5	7.1	2	Direct gamma-spec.	-12.2%	-0.41	-1.09
19252							
19253							
19254	32.0	2.0	1	Alpha spectrometry	-4.8%	-0.16	-0.68
19256	35.0	7.0	2	Alpha spectrometry	4.2%	0.14	0.38
19257	36.0	4.0	1	Direct gamma-spec.	7.1%	0.24	0.57
19258	8.1	1.6	2	Direct gamma-spec.	-75.9%	-2.53	-17.12
19259	38.79	8.2	2	Direct gamma-spec.	15.4%	0.51	1.21
19260	34.7	4.3	1	Direct gamma-spec.	3.3%	0.11	0.25
19261	35.37	5.51	2	Alpha spectrometry	5.3%	0.18	0.58

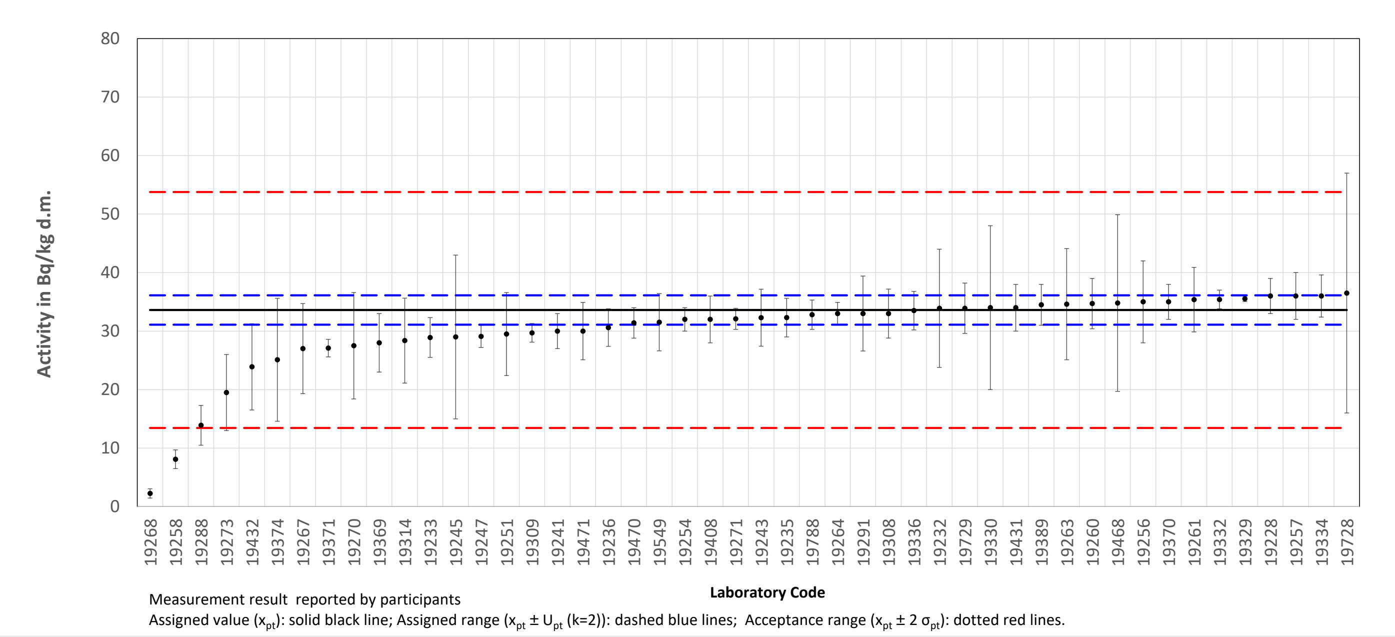
19263	34.6	9.5	2	ICP-MS	3.0%	0.10	0.20
19264	33.0	1.9	1	Direct gamma-spec.	-1.8%	-0.06	-0.26
19265	39.0	5.0	1	Direct gamma-spec.	16.1%	0.54	1.05
19266							
19267	27.0	7.7	1	Direct gamma-spec.	-19.6%	-0.65	-0.85
19268	2.252	0.793	1.05	ICP-OES	-93.3%	-3.11	-21.38
19269							
19270	27.5	9.1	2	Direct gamma-spec.	-18.2%	-0.61	-1.29
19271	32.1	1.8	1	Alpha spectrometry	-4.5%	-0.15	-0.68
19272							
19273	19.5	6.5	2	Direct gamma-spec.	-42.0%	-1.40	-4.05
19274	41.5	3.5	1	Direct gamma-spec.	23.5%	0.78	2.12
19276	186.7	32.9	2	Direct gamma-spec.	455.7%	15.19	9.28
19277	38.3	6.9	2	Direct gamma-spec.	14.0%	0.47	1.28
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278							
19279							
19281	37.4	3.9	2	Direct gamma-spec.	11.3%	0.38	1.64
19288	13.9	3.4	2	Direct gamma-spec.	-58.6%	-1.95	-9.32
19289	43.0	4.4	1	Direct gamma-spec.	28.0%	0.93	2.05
19290	37.84	9.73	2	Direct gamma-spec.	12.6%	0.42	0.84
19291	33.0	6.4	2	Direct gamma-spec.	-1.8%	-0.06	-0.17
19308	33.0	4.18	1	Direct gamma-spec.	-1.8%	-0.06	-0.14
19309	29.7	1.6	2	Alpha spectrometry	-11.6%	-0.39	-2.62
19310							
19311	< 56.0			Direct gamma-spec.			
19313							
19314	28.38	7.26	2	Direct gamma-spec. Th 234(63keV)	-15.5%	-0.52	-1.36
19316							
19318	37.3	3.9	1	Direct gamma-spec.	11.0%	0.37	0.90
19328	43.0	11.0	2	Direct gamma-spec.	28.0%	0.93	1.67
19329	35.53	0.48	2	Direct gamma-spec.	5.7%	0.19	1.51
19330	34.0	14.0	2	Gamma-spec. with chem. sep.	1.2%	0.04	0.06
19332	35.4	1.6	1	Alpha spectrometry	5.4%	0.18	0.88
19333							
19334	36.0	3.6	1	Direct gamma-spec.	7.1%	0.24	0.63
19336	33.5	3.3	1	Direct gamma-spec.	-0.3%	-0.01	-0.03

19368							
19369	28.0	5.0	2	Direct gamma-spec.	-16.7%	-0.56	-2.00
19370	35.0	3.0	1	Alpha spectrometry	4.2%	0.14	0.43
19371	27.1	1.5	1	Direct gamma-spec.	-19.3%	-0.64	-3.32
19372							
19374	25.1	10.5	1.73	Direct gamma-spec.	-25.3%	-0.84	-1.37
19388							
19389	34.5	3.5	1	Gamma-spec. with chem. sep.	2.7%	0.09	0.24
19391							
19408	32.0	4.0	1	Direct gamma-spec.	-4.8%	-0.16	-0.38
19409	417.9	46.89	2	Direct gamma-spec.	1143.8%	38.13	16.37
19410							
19411							
19428							
19429							
19431	34.0	4.0	1	Direct gamma-spec.	1.2%	0.04	0.10
19432	23.89	7.37	2	Direct gamma-spec.	-28.9%	-0.96	-2.49
19468	34.8	15.1	2	Direct gamma-spec.	3.6%	0.12	0.16
19470	31.4	2.6	1	Alpha spectrometry	-6.5%	-0.22	-0.76
19471	30.0	4.9	1	Direct gamma-spec.	-10.7%	-0.36	-0.71
19488							
19490	39.33	5.82	2	Alpha spectrometry	17.1%	0.57	1.81
19508							
19549	31.51	4.89	2	Direct gamma-spec.	-6.2%	-0.21	-0.76
19728	36.5	20.5	1.96	Direct gamma-spec.	8.6%	0.29	0.28
19729	33.9	4.3	1	Direct gamma-spec. U-238 is in equilibrium with Pa234m & Th-234.	0.9%	0.03	0.07
19788	32.8	2.5	2	Alpha spectrometry	-2.4%	-0.08	-0.45

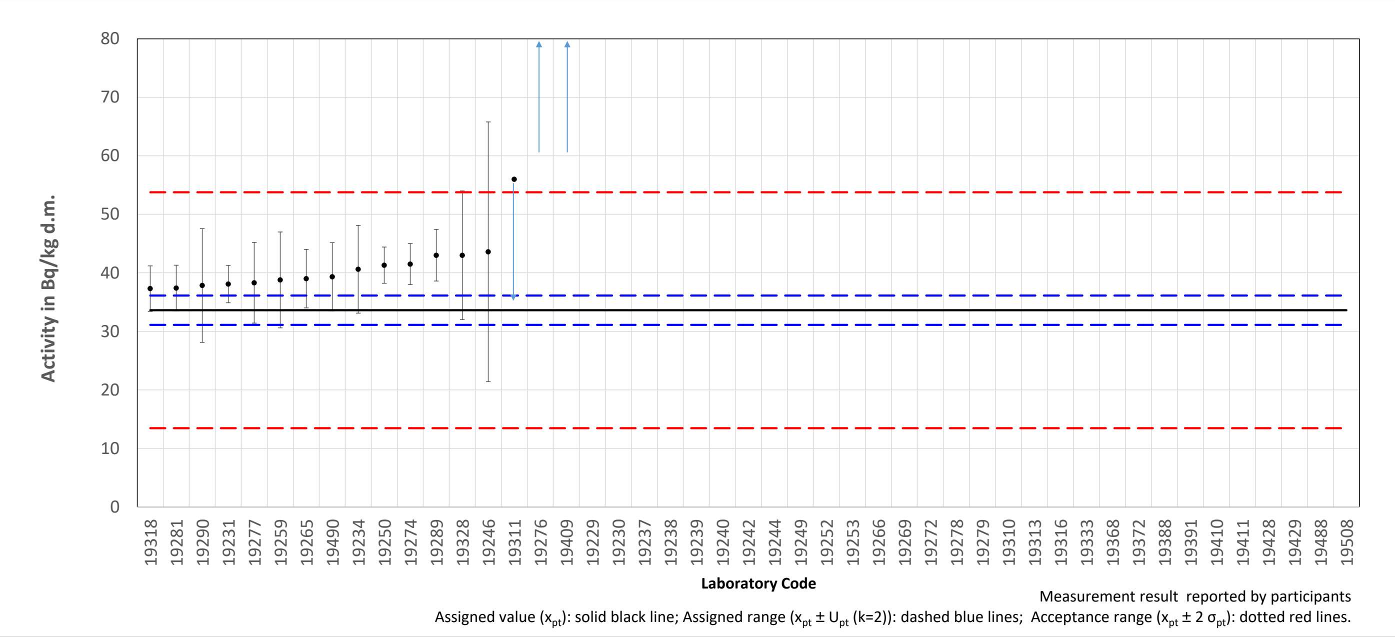
U-238 in JRC-NORM-02

x_{pt} = 33.6 $u(x_{pt})$ = 1.3 *(k=1)* σ_{pt} = 10.1 (in Bq/kg d.m.)

z score



Activity in Bq/kg d.m.
80
70
60
50
40
30
20
10
0
19268 19258 19288 19273 19432 19374 19267 19371 19270 19369 19314 19233 19245 19247 19251 19309 19241 19471 19236 19470 19549 19254 19408 19271 19243 19235 19788 19264 19291 19308 19336 19232 19729 19330 19431 19389 19263 19260 19468 19256 19370 19261 19332 19329 19228 19257 19334 19728
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range (x_{pt} ± U_{pt} (k=2)): dashed blue lines; Acceptance range (x_{pt} ± 2 σ_{pt}): dotted red lines.



Activity in Bq/kg d.m.
80
70
60
50
40
30
20
10
0
19318 19281 19290 19231 19277 19259 19265 19490 19234 19250 19274 19289 19328 19246 19311 19276 19409 19229 19230 19237 19238 19239 19240 19242 19244 19249 19252 19253 19266 19269 19272 19278 19279 19310 19313 19316 19333 19368 19372 19388 19391 19410 19411 19428 19429 19488 19508
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range (x_{pt} ± U_{pt} (k=2)): dashed blue lines; Acceptance range (x_{pt} ± 2 σ_{pt}): dotted red lines.

Annex 20: K-40 in JRC-NORM 03

x_{pt} = 313.3 $u(x_{pt})$ = 4.9 σ_{pt} = 62.7 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	314.0	15.0	1	Direct gamma-spec.	0.2%	0.01	0.04
19229	296.902	3.971	2	Direct gamma-spec.	-5.2%	-0.26	-3.12
19230	264.4	16.7	1	Direct gamma-spec.	-15.6%	-0.78	-2.81
19231	293.92	7.05	1	Direct gamma-spec.	-6.2%	-0.31	-2.26
19232	308.0	25.0	2	Direct gamma-spec.	-1.7%	-0.08	-0.40
19233	296.0	16.0	1		-5.5%	-0.28	-1.03
19234	307.4	16.2	1	Direct gamma-spec.	-1.9%	-0.09	-0.35
19235	302.0	18.5	1	Direct gamma-spec.	-3.6%	-0.18	-0.59
19236	312.0	19.0	1	Direct gamma-spec.	-0.4%	-0.02	-0.07
19237	335.0	39.0	2	Direct gamma-spec.	6.9%	0.35	1.08
19238	312.0	36.0	2	Direct gamma-spec.	-0.4%	-0.02	-0.07
19239	292.3	10.7	2	Direct gamma-spec.	-6.7%	-0.34	-2.90
19240	310.0	9.3	2	Direct gamma-spec.	-1.1%	-0.05	-0.49
19241	312.0	18.0	1	Direct gamma-spec.	-0.4%	-0.02	-0.07
19242	333.0	18.0	2	Direct gamma-spec.	6.3%	0.31	1.92
19243	295.3	33.95	2	Direct gamma-spec.	-5.7%	-0.29	-1.02
19244	329.1	35.0	2	Direct gamma-spec.	5.0%	0.25	0.87
19245	310.0	17.0	1	Direct gamma-spec.	-1.1%	-0.05	-0.19
19246	342.1	30.6	2	Direct gamma-spec.	9.2%	0.46	1.79
19247	331.3	10.5	1	Direct gamma-spec.	5.7%	0.29	1.55
19249	261.0	37.0	2	Direct gamma-spec.	-16.7%	-0.83	-2.73
19250	310.0	12.0	1	Direct gamma-spec.	-1.1%	-0.05	-0.25
19251	322.0	35.0	2	Direct gamma-spec.	2.8%	0.14	0.48
19252	275.7	8.3	1	Direct gamma-spec.	-12.0%	-0.60	-3.91
19253	311.0	13.0	2	Direct gamma-spec.	-0.7%	-0.04	-0.28
19254	305.0	13.0	1	Gamma spectrometry	-2.6%	-0.13	-0.60
19255	356.44	11.66	2	Direct gamma-spec.	13.8%	0.69	5.68
19256	374.0	32.0	2	Direct gamma-spec.	19.4%	0.97	3.63
19257	295.0	2.0	1	Direct gamma-spec.	-5.8%	-0.29	-3.47
19258	278.0	29.0	2	Direct gamma-spec.	-11.3%	-0.56	-2.31
19259	304.42	14.69	2	Direct gamma-spec.	-2.8%	-0.14	-1.01
19260	312.5	15.8	1	Direct gamma-spec.	-0.3%	-0.01	-0.05
19261	333.1	9.18	2	Direct gamma-spec.	6.3%	0.32	2.96

19263							
19264	342.0	30.0	1	Direct gamma-spec.	9.2%	0.46	0.94
19265	330.0	20.0	1	Direct gamma-spec.	5.3%	0.27	0.81
19266	308.58	14.28	1	Direct gamma-spec.	-1.5%	-0.08	-0.31
19267	320.0	20.0	1	Direct gamma-spec.	2.1%	0.11	0.33
19268	321.099	1.284	1.05	ICP-OES	2.5%	0.12	1.55
19269	286.0	23.0	1	Direct gamma-spec.	-8.7%	-0.44	-1.16
19270	348.0	18.0	2	Direct gamma-spec.	11.1%	0.55	3.39
19271	320.0	11.0	1	Direct gamma-spec.	2.1%	0.11	0.56
19272	343.0	16.0	2	Direct gamma-spec.	9.5%	0.47	3.17
19273	360.0	21.0	2	Direct gamma-spec.	14.9%	0.75	4.03
19274	289.0	12.6	1	Direct gamma-spec.	-7.8%	-0.39	-1.80
19276	417.8	24.4	2	Direct gamma-spec.	33.4%	1.67	7.95
19277	267.0	13.0	2	Direct gamma-spec.	-14.8%	-0.74	-5.70
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	303.0	24.0	2	Direct gamma-spec.	-3.3%	-0.16	-0.80
19279	353.0	50.0	2	Direct gamma-spec.	12.7%	0.63	1.56
19281	340.0	25.0	2	Direct gamma-spec.	8.5%	0.43	1.99
19288	295.0	35.0	2	Direct gamma-spec.	-5.8%	-0.29	-1.01
19289	303.0	23.0	1	Direct gamma-spec.	-3.3%	-0.16	-0.44
19290	288.95	40.57	2	Direct gamma-spec.	-7.8%	-0.39	-1.17
19291	299.0	12.0	2	Direct gamma-spec.	-4.6%	-0.23	-1.85
19308	337.0	6.0	1	Direct gamma-spec.	7.6%	0.38	3.07
19309	272.4	6.2	2	Direct gamma-spec.	-13.1%	-0.65	-7.08
19310	314.5	24.2	2	Direct gamma-spec.	0.4%	0.02	0.09
19311	314.0	19.0	1	Direct gamma-spec.	0.2%	0.01	0.04
19313	301.111	20.747	1	Direct gamma-spec.	-3.9%	-0.19	-0.57
19314	316.26	15.8	2	Direct gamma-spec.	0.9%	0.05	0.32
19316	295.52	21.32	1	Direct gamma-spec.	-5.7%	-0.28	-0.81
19318	314.0	14.0	1	Direct gamma-spec.	0.2%	0.01	0.05
19328	341.0	11.0	2	Direct gamma-spec.	8.8%	0.44	3.77
19329	384.9	5.94	2	Direct gamma-spec.	22.9%	1.14	12.54
19330	330.0	30.0	2	Gamma-spec. with chem. sep.	5.3%	0.27	1.06
19332	274.0	20.0	1	Direct gamma-spec.	-12.5%	-0.63	-1.91
19333	398.7	10.0	2	Direct gamma-spec.	27.3%	1.36	12.23
19334	322.0	9.0	1	Direct gamma-spec.	2.8%	0.14	0.85
19336	305.0	14.0	1	Direct gamma-spec.	-2.6%	-0.13	-0.56

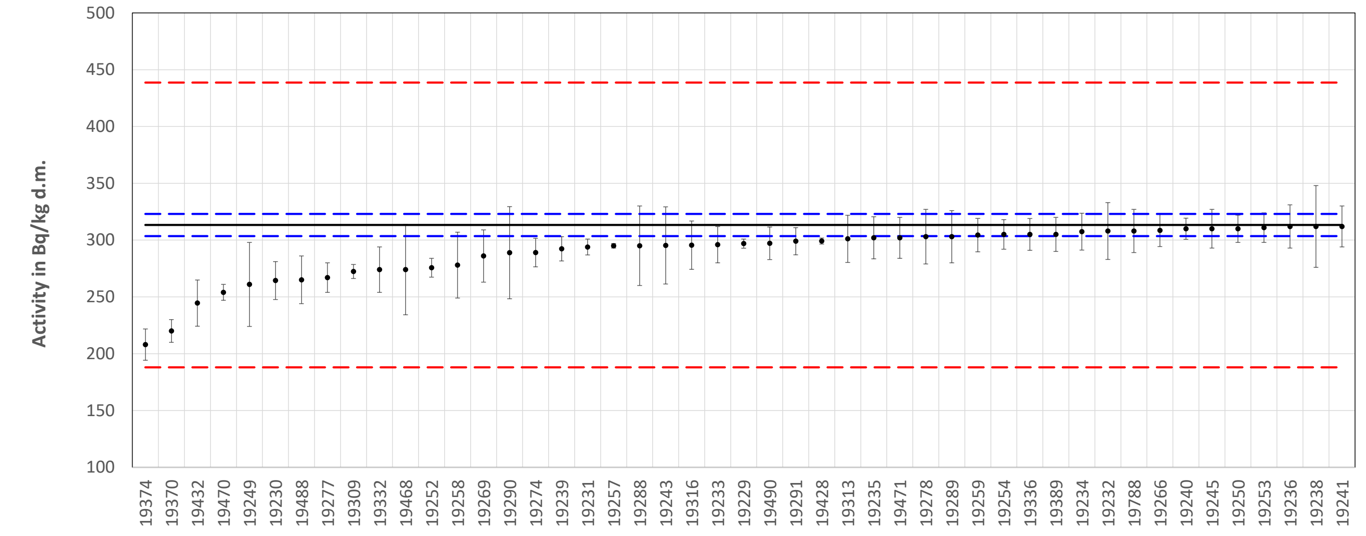
19368	321.0	13.9	2	Direct gamma-spec.	2.5%	0.12	0.91
19369	319.0	6.0	2	Direct gamma-spec.	1.8%	0.09	1.00
19370	220.0	10.0	1	Direct gamma-spec.	-29.8%	-1.49	-8.39
19371	363.0	7.0	1	Direct gamma-spec.	15.9%	0.79	5.83
19372	332.0	40.0	2	Direct gamma-spec.	6.0%	0.30	0.91
19374	208.0	13.8	1.73	Direct gamma-spec.	-33.6%	-1.68	-11.26
19388							
19389	305.0	15.0	1	Gamma-spec. with chem. sep.	-2.6%	-0.13	-0.53
19391	350.0	20.0	1	Direct gamma-spec.	11.7%	0.59	1.78
19408	323.0	15.0	1	Direct gamma-spec.	3.1%	0.15	0.62
19409							
19410	377.37	34.17	0.892	Direct gamma-spec.	20.5%	1.02	1.66
19411	325.0	26.0	2	Direct gamma-spec.	3.7%	0.19	0.84
19428	299.17	2.62	2	Direct gamma-spec.	-4.5%	-0.23	-2.80
19429	338.91	24.152	1	Direct gamma-spec.	8.2%	0.41	1.04
19431	321.0	16.0	1	Direct gamma-spec.	2.5%	0.12	0.46
19432	244.55	20.31	2	Direct gamma-spec.	-21.9%	-1.10	-6.10
19468	274.0	39.8	2	Direct gamma-spec.	-12.5%	-0.63	-1.92
19470	254.0	7.0	1	Direct gamma-spec.	-18.9%	-0.95	-6.95
19471	302.0	18.0	1	Direct gamma-spec.	-3.6%	-0.18	-0.61
19488	265.0	21.0	2	Direct gamma-spec.	-15.4%	-0.77	-4.17
19490	297.16	14.34	2	Direct gamma-spec.	-5.2%	-0.26	-1.86
19508	312.0	42.0	2	Direct gamma-spec.	-0.4%	-0.02	-0.06
19549	337.33	10.31	2	Direct gamma-spec.	7.7%	0.38	3.39
19728	323.0	20.0	1.96	Direct gamma-spec.	3.1%	0.15	0.86
19729	327.2	13.4	1	Direct gamma-spec.	4.4%	0.22	0.97
19788	308.0	19.0	2	Direct gamma-spec.	-1.7%	-0.08	-0.50

K-40 in JRC-NORM-03

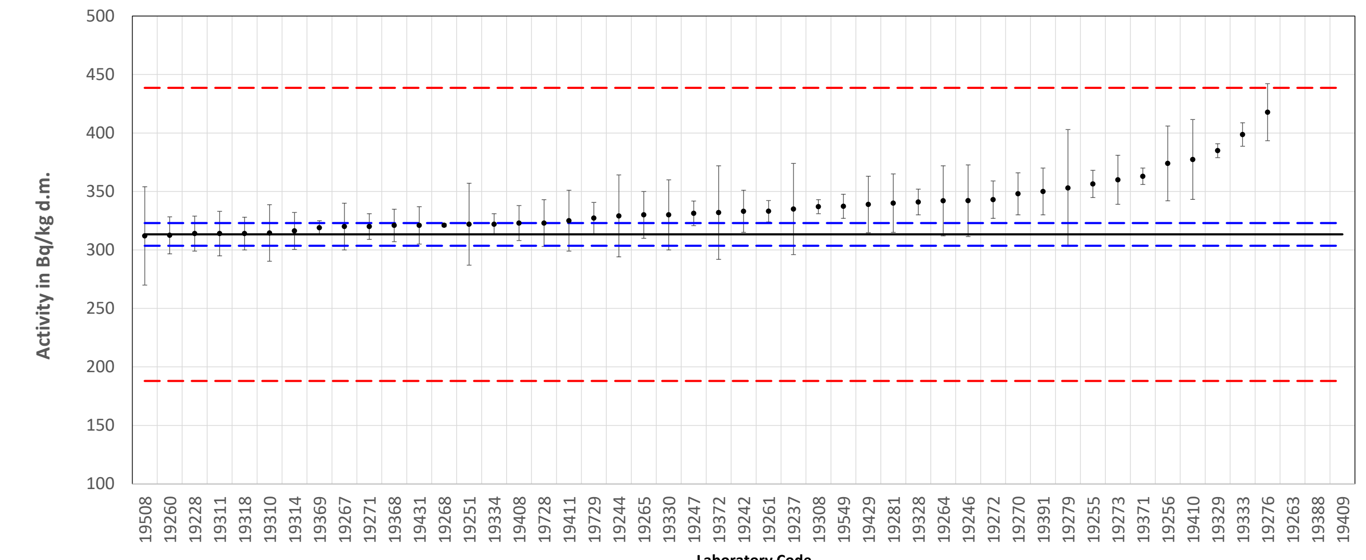
x_{pt} = 313.3 $u(x_{pt})$ = 4.9 σ_{pt} = 62.7 (in Bq/kg d.m.)

(k=1)

z score



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 21: Pb-210 in JRC-NORM 03

x_{pt} = 32.7 $u(x_{pt})$ = 1.7 σ_{pt} = 9.8 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	37.0	4.5	1	Direct gamma-spec.	13.1%	0.44	0.90
19229	28.557	7.311	2	Direct gamma-spec.	-12.7%	-0.42	-1.03
19230	17.3	1.3	1	Direct gamma-spec.	-47.1%	-1.57	-7.24
19231	27.68	2.4	1	Direct gamma-spec.	-15.4%	-0.51	-1.71
19232	27.4	6.0	2	Direct gamma-spec.	-16.2%	-0.54	-1.54
19233	25.1	5.2	1		-23.2%	-0.77	-1.39
19234	29.7	4.7	1	Direct gamma-spec.	-9.2%	-0.31	-0.60
19235	33.8	4.1	1	Direct gamma-spec.	3.4%	0.11	0.25
19236	34.3	3.9	1	Direct gamma-spec.	4.9%	0.16	0.38
19237	31.0	5.9	2	Direct gamma-spec.	-5.2%	-0.17	-0.50
19238	34.0	4.0	2	Direct gamma-spec.	4.0%	0.13	0.50
19239	38.1	5.9	2	Direct gamma-spec.	16.5%	0.55	1.59
19240	22.0	1.1	2	Direct gamma-spec.	-32.7%	-1.09	-6.04
19241							
19242							
19243	32.53	5.836	2	Direct gamma-spec.	-0.5%	-0.02	-0.05
19244	26.1	3.8	2	Direct gamma-spec.	-20.2%	-0.67	-2.60
19245	27.3	2.3	1	Direct gamma-spec.	-16.5%	-0.55	-1.89
19246	26.5	8.6	2	Direct gamma-spec.	-19.0%	-0.63	-1.34
19247	30.8	2.8	1	Direct gamma-spec.	-5.8%	-0.19	-0.58
19249	71.0			Direct gamma-spec.			
19250	27.7	1.9	1	Direct gamma-spec.	-15.3%	-0.51	-1.97
19251	30.6	8.7	2	Direct gamma-spec.	-6.4%	-0.21	-0.45
19252	36.83	3.7	1	Direct gamma-spec.	12.6%	0.42	1.02
19253							
19254	35.0	6.0	1	Gamma spectrometry	7.0%	0.23	0.37
19255	19.28	6.75	2	Direct gamma-spec.	-41.0%	-1.37	-3.56
19256	34.0	6.0	2	Direct gamma-spec.	4.0%	0.13	0.38
19257							
19258	30.4	8.1	2	Direct gamma-spec.	-7.0%	-0.23	-0.52
19259	28.04	5.69	2	Direct gamma-spec.	-14.3%	-0.48	-1.41
19260	36.1	6.0	1	Direct gamma-spec.	10.4%	0.35	0.55
19261	13.75	6.86	2	Liquid-scint. counting	-58.0%	-1.93	-4.96

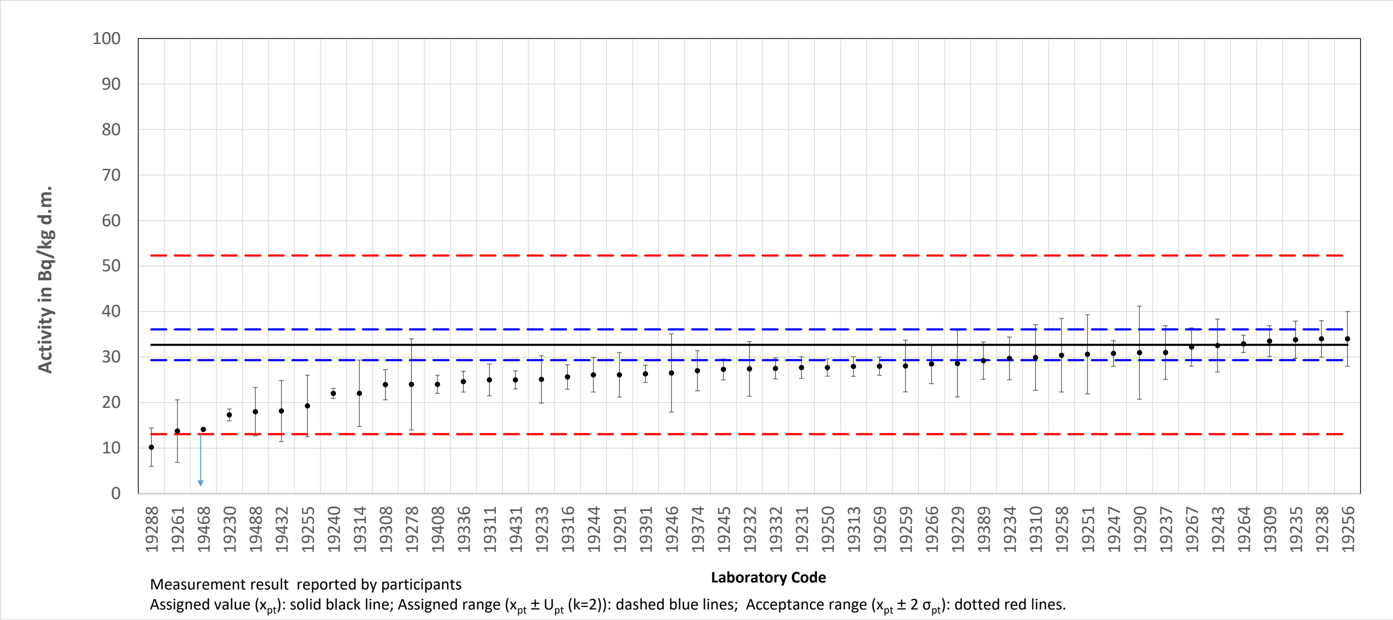
19263							
19264	32.9	1.9	1	Direct gamma-spec.	0.6%	0.02	0.08
19265	84.0	14.0	1	Direct gamma-spec.	156.9%	5.23	3.64
19266	28.48	4.32	1	Direct gamma-spec.	-12.9%	-0.43	-0.91
19267	32.2	4.2	1	Direct gamma-spec.	-1.5%	-0.05	-0.11
19268							
19269	28.0	2.0	1	Direct gamma-spec.	-14.4%	-0.48	-1.80
19270							
19271	38.0	5.0	1	Direct gamma-spec.	16.2%	0.54	1.00
19272	81.0	37.0	2	Direct gamma-spec.	147.7%	4.92	2.60
19273	51.9	10.0	2	Direct gamma-spec.	58.7%	1.96	3.64
19274	< 37.4			Direct gamma-spec.			
19276	164.1	90.1	2	Direct gamma-spec.	401.8%	13.39	2.91
19277	34.5	5.9	2	Direct gamma-spec.	5.5%	0.18	0.53
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	24.0	10.0	2	Direct gamma-spec.	-26.6%	-0.89	-1.65
19279							
19281	34.0	3.0	2	Direct gamma-spec.	4.0%	0.13	0.58
19288	10.2	4.2	2	Direct gamma-spec.	-68.8%	-2.29	-8.36
19289	41.0	5.3	1	Direct gamma-spec.	25.4%	0.85	1.49
19290	30.96	10.22	2	Direct gamma-spec.	-5.3%	-0.18	-0.32
19291	26.1	4.9	2	Direct gamma-spec.	-20.2%	-0.67	-2.22
19308	23.93	3.33	1	Direct gamma-spec.	-26.8%	-0.89	-2.35
19309	33.5	3.4	2	Direct gamma-spec.	2.4%	0.08	0.33
19310	29.9	7.2	2	Direct gamma-spec.	-8.6%	-0.29	-0.70
19311	25.0	3.5	1	Direct gamma-spec.	-23.5%	-0.78	-1.98
19313	27.939	2.152	1	Direct gamma-spec.	-14.6%	-0.49	-1.74
19314	22.05	7.3	2	Direct gamma-spec.	-32.6%	-1.09	-2.65
19316	25.64	2.68	1	Direct gamma-spec.	-21.6%	-0.72	-2.23
19318	34.9	5.3	1	Direct gamma-spec.	6.7%	0.22	0.40
19328							
19329	43.58	5.52	2	Direct gamma-spec.	33.3%	1.11	3.37
19330	37.0	9.0	2	Gamma-spec. with chem. sep.	13.1%	0.44	0.90
19332	27.5	2.3	1	Direct gamma-spec.	-15.9%	-0.53	-1.82
19333							
19334							
19336	24.6	2.3	1		-24.8%	-0.83	-2.84

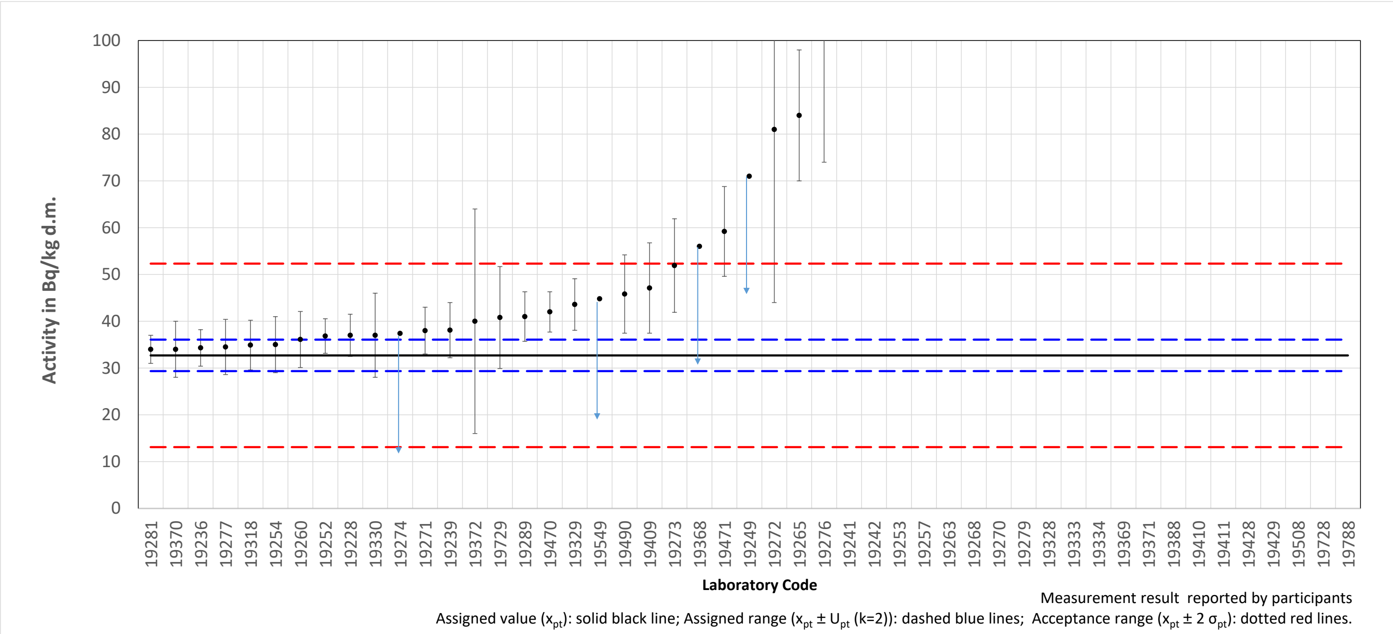
19368	< 56.0			Direct gamma-spec.			
19369							
19370	34.0	6.0	1	Direct gamma-spec.	4.0%	0.13	0.21
19371							
19372	40.0	24.0	2	Direct gamma-spec.	22.3%	0.74	0.60
19374	27.0	4.4	1.76	Direct gamma-spec.	-17.4%	-0.58	-1.89
19388							
19389	29.2	4.1	1	Gamma-spec. with chem. sep.	-10.7%	-0.36	-0.79
19391	26.3	1.9	1	Direct gamma-spec.	-19.6%	-0.65	-2.52
19408	24.0	2.0	1	Direct gamma-spec.	-26.6%	-0.89	-3.33
19409	47.1	9.66	2	Direct gamma-spec.	44.0%	1.47	2.82
19410							
19411							
19428							
19429							
19431	25.0	2.0	1	Direct gamma-spec.	-23.5%	-0.78	-2.95
19432	18.14	6.7	2	Direct gamma-spec.	-44.5%	-1.48	-3.88
19468	< 14.1			Direct gamma-spec.			
19470	42.0	4.3	1	Direct gamma-spec.	28.4%	0.95	2.01
19471	59.2	9.6	1	Direct gamma-spec.	81.0%	2.70	2.72
19488	18.0	5.3	2	Direct gamma-spec.	-45.0%	-1.50	-4.68
19490	45.82	8.37	2	Direct gamma-spec.	40.1%	1.34	2.91
19508							
19549	< 44.8			Direct gamma-spec.			
19728							
19729	< 40.8	10.9	1	Direct gamma-spec.	24.8%	0.83	0.73
19788							

Pb-210 in JRC-NORM-03

x_{pt} = 32.7 $u(x_{pt})$ = 1.7 *(k=1)* σ_{pt} = 9.8 (in Bq/kg d.m.)

z score


Activity in Bq/kg d.m.
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.


Activity in Bq/kg d.m.
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 22: Ra-226 in JRC-NORM 03

x_{pt} = 32.7 $u(x_{pt})$ = 1.1 σ_{pt} = 6.5 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	31.0	0.85	1	Direct gamma-spec.	-5.2%	-0.26	-1.19
19229	30.283	0.432	2	Direct gamma-spec.	-7.4%	-0.37	-2.08
19230	45.2	2.9	1	Direct gamma-spec.	38.2%	1.91	4.01
19231	29.64	0.68	1	Direct gamma-spec.	-9.4%	-0.47	-2.30
19232	31.7	4.0	2	Direct gamma-spec.	-3.1%	-0.15	-0.43
19233	52.7	6.7	1		61.2%	3.06	2.94
19234	32.6	0.7	1	Direct gamma-spec.	-0.3%	-0.02	-0.07
19235	33.0	2.7	1	Gamma-spec. Pb-214	0.9%	0.05	0.10
19236	31.5	2.9	1	Direct gamma-spec.	-3.7%	-0.18	-0.39
19237	29.7	4.9	2	Direct gamma-spec.	-9.2%	-0.46	-1.11
19238	34.0	3.0	2	Direct gamma-spec.	4.0%	0.20	0.69
19239	26.3	5.4	2	Gamma-spectrometry	-19.6%	-0.98	-2.18
19240	33.1	1.3	2	Direct gamma-spec.	1.2%	0.06	0.30
19241	31.0	2.0	1	Direct gamma-spec.	-5.2%	-0.26	-0.74
19242	35.0	1.9	2	Direct gamma-spec.	7.0%	0.35	1.55
19243	33.54	3.861	2	Direct gamma-spec.	2.6%	0.13	0.37
19244	32.8	2.4	2	Direct gamma-spec.	0.3%	0.02	0.06
19245	29.6	1.6	1	Direct gamma-spec.	-9.5%	-0.47	-1.58
19246	42.0	6.8	2	Direct gamma-spec.	28.4%	1.42	2.59
19247	41.1	3.2	1	Direct gamma-spec.	25.7%	1.28	2.47
19249	24.9	4.2	2	Direct gamma-spec.	-23.9%	-1.19	-3.26
19250	32.0	1.2	1	gamma-spectrometry Pb-214, Bi-214	-2.1%	-0.11	-0.42
19251	32.5	3.9	2	Direct gamma-spec.	-0.6%	-0.03	-0.09
19252	29.77	1.13	1	Direct gamma-spec.	-9.0%	-0.45	-1.82
19253	29.0	1.4	2	Direct gamma-spec.	-11.3%	-0.57	-2.76
19254	33.0	1.0	1	Gamma spectrometry	0.9%	0.05	0.20
19255	28.86	1.31	2	Direct gamma-spec.	-11.7%	-0.59	-2.92
19256	32.0	3.0	2	Direct gamma-spec.	-2.1%	-0.11	-0.37
19257	33.0	3.0	1	Direct gamma-spec.	0.9%	0.05	0.09
19258	28.3	2.6	2	Direct gamma-spec.	-13.5%	-0.67	-2.54
19259	29.97	6.85	2	Direct gamma-spec.	-8.3%	-0.42	-0.76
19260	25.9	2.2	1	Direct gamma-spec.	-20.8%	-1.04	-2.74
19261	10.16	2.54	2	Liquid-scint. counting	-68.9%	-3.45	-13.20

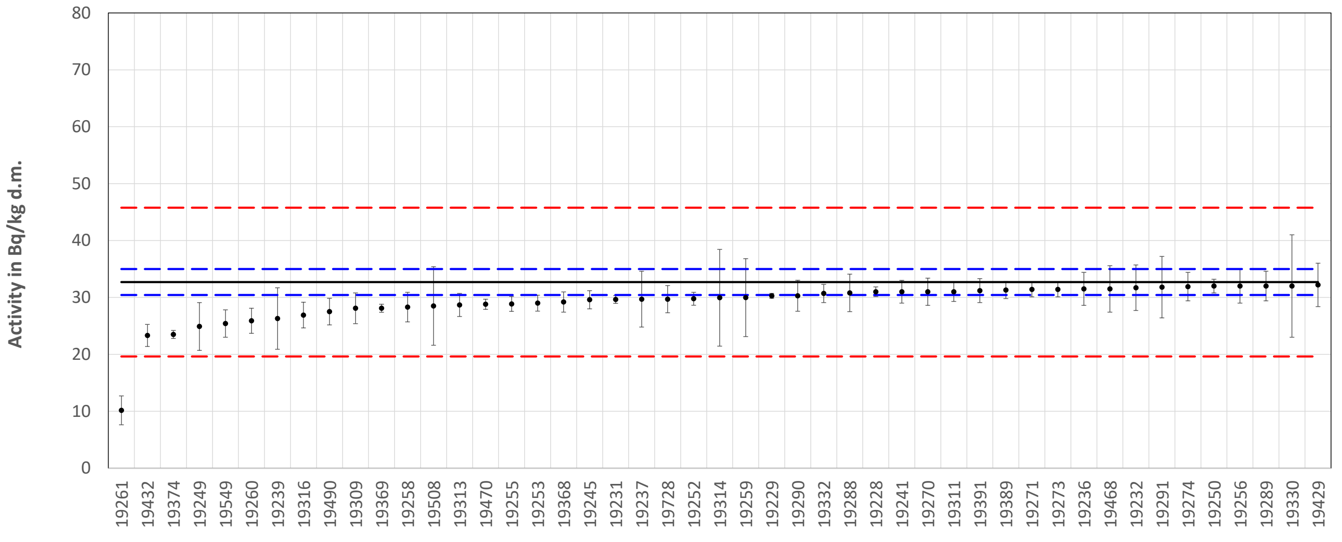
19263							
19264	37.6	2.4	1	Direct gamma-spec.	15.0%	0.75	1.84
19265	34.6	1.9	1	Direct gamma-spec.	5.8%	0.29	0.86
19266							
19267	34.9	2.9	1	Direct gamma-spec.	6.7%	0.34	0.71
19268							
19269	33.0	3.0	1	Direct gamma-spec.	0.9%	0.05	0.09
19270	31.0	2.4	2	Direct gamma-spec.	-5.2%	-0.26	-1.03
19271	31.4	1.3	1	Direct gamma-spec.	-4.0%	-0.20	-0.75
19272	32.5	1.2	2	Direct gamma-spec.	-0.6%	-0.03	-0.16
19273	31.4	1.3	2	Direct gamma-spec.	-4.0%	-0.20	-0.99
19274	31.9	2.5	1	Direct gamma-spec.	-2.4%	-0.12	-0.29
19276	40.2	3.7	2	Direct gamma-spec.	22.9%	1.15	3.45
19277	33.1	1.7	2	Direct gamma-spec.	1.2%	0.06	0.28
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	33.0	2.8	2	Direct gamma-spec.	0.9%	0.05	0.17
19279	42.5	6.2	2	Direct gamma-spec.	30.0%	1.50	2.97
19281	38.7	2.9	2	Direct gamma-spec.	18.3%	0.92	3.25
19288	30.8	3.3	2	Direct gamma-spec.	-5.8%	-0.29	-0.95
19289	32.0	2.6	1	Direct gamma-spec.	-2.1%	-0.11	-0.25
19290	30.29	2.72	2	Direct gamma-spec.	-7.4%	-0.37	-1.36
19291	31.8	5.4	2	Direct gamma-spec.	-2.8%	-0.14	-0.31
19308	35.38	6.88	1	Direct gamma-spec.	8.2%	0.41	0.38
19309	28.1	2.7	2	Precipitation. Solid scint. (ZnS(Ag))	-14.1%	-0.70	-2.60
19310	66.1	10.3	2	Direct gamma-spec.	102.1%	5.11	6.33
19311	31.0	1.7	1	Direct gamma-spec.	-5.2%	-0.26	-0.83
19313	28.678	2.024	1	Direct gamma-spec.	-12.3%	-0.61	-1.73
19314	29.95	8.5	2	Direct gamma-spec.	-8.4%	-0.42	-0.62
19316	26.9	2.25	1	Direct gamma-spec.	-17.7%	-0.89	-2.30
19318	34.8	1.3	1	Direct gamma-spec.	6.4%	0.32	1.21
19328	35.1	2.6	2	Direct gamma-spec.	7.3%	0.37	1.39
19329	32.48	0.19	2	Direct gamma-spec.	-0.7%	-0.03	-0.19
19330	32.0	9.0	2	Gamma-spec. with chem. sep.	-2.1%	-0.11	-0.15
19332	30.7	1.6	1	Direct gamma-spec.	-6.1%	-0.31	-1.02
19333							
19334	35.3	6.1	1	Direct gamma-spec.	8.0%	0.40	0.42
19336	35.0	2.2	1	Direct gamma-spec.	7.0%	0.35	0.93

19368	29.2	1.77	2	Direct gamma-spec.	-10.7%	-0.54	-2.42
19369	28.1	0.7	2	Direct gamma-spec.	-14.1%	-0.70	-3.85
19370	33.0	2.0	1	Direct gamma-spec.	0.9%	0.05	0.13
19371	52.1	4.0	1	Direct gamma-spec.	59.3%	2.97	4.66
19372	47.0	6.0	2	Direct gamma-spec.	43.7%	2.19	4.46
19374	23.5	0.7	1.73	Direct gamma-spec.	-28.1%	-1.41	-7.60
19388							
19389	31.3	1.5	1	Gamma-spec. with chem. sep.	-4.3%	-0.21	-0.74
19391	31.2	2.1	1	Direct gamma-spec.	-4.6%	-0.23	-0.63
19408	35.0	4.0	1	Direct gamma-spec.	7.0%	0.35	0.55
19409	250.45	20.0	2	Direct gamma-spec.	665.9%	33.30	21.63
19410	34.5	5.65	0.892	Direct gamma-spec.	5.5%	0.28	0.28
19411	35.5	2.8	2	Direct gamma-spec.	8.6%	0.43	1.55
19428	35.39	1.84	2	Direct gamma-spec.	8.2%	0.41	1.84
19429	32.209	3.815	1	Direct gamma-spec.	-1.5%	-0.08	-0.12
19431	34.0	4.0	1	Direct gamma-spec.	4.0%	0.20	0.31
19432	23.32	1.94	2	Direct gamma-spec.	-28.7%	-1.43	-6.26
19468	31.5	4.07	2	Direct gamma-spec.	-3.7%	-0.18	-0.51
19470	28.8	0.9	1	Direct gamma-spec.	-11.9%	-0.60	-2.68
19471	33.9	3.8	1	Direct gamma-spec.	3.7%	0.18	0.30
19488	34.8	3.5	2	Direct gamma-spec.	6.4%	0.32	1.01
19490	27.51	2.34	2	Direct gamma-spec.	-15.9%	-0.79	-3.18
19508	28.5	6.9	2	Direct gamma-spec.	-12.8%	-0.64	-1.16
19549	25.41	2.41	2	Direct gamma-spec.	-22.3%	-1.11	-4.39
19728	29.7	2.4	1.96	Direct gamma-spec.	-9.2%	-0.46	-1.79
19729	32.3	1.8	1	Direct gamma-spec.	-1.2%	-0.06	-0.19
19788							

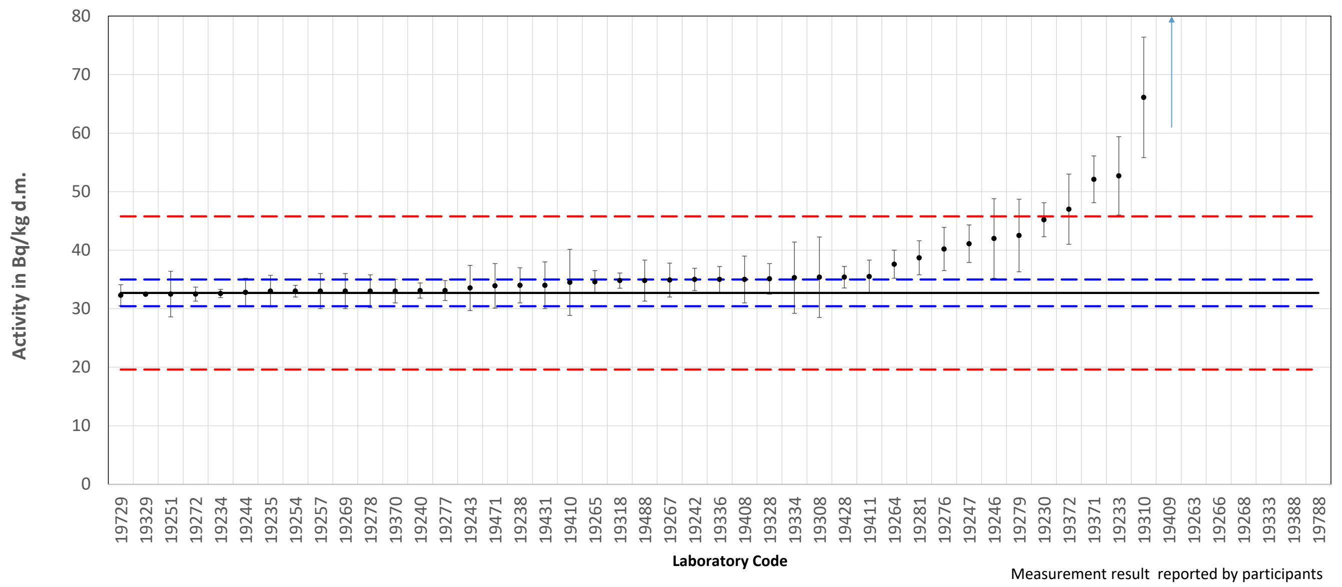
Ra-226 in JRC-NORM-03

x_{pt} = 32.7 $u(x_{pt})$ = 1.1 *(k=1)* σ_{pt} = 6.5 (in Bq/kg d.m.)

z score



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 23: Ra-228 in JRC-NORM 03

x_{pt} = 22.7 $u(x_{pt})$ = 0.6 σ_{pt} = 4.5 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	22.5	0.85	1	Direct gamma-spec.	-0.9%	-0.04	-0.20
19229	20.944	0.74	2	Direct gamma-spec.	-7.7%	-0.39	-2.64
19230	17.7	1.3	1	Gamma-spec. Ac-228	-22.0%	-1.10	-3.54
19231	24.1	0.7	1	Direct gamma-spec.	6.2%	0.31	1.57
19232	22.8	2.5	2	Direct gamma-spec.	0.4%	0.02	0.07
19233	23.5	1.5	1		3.5%	0.18	0.50
19234	22.3	1.6	1	Direct gamma-spec.	-1.8%	-0.09	-0.24
19235	21.9	1.8	1	Gamma-spec. Ac-228	-3.5%	-0.18	-0.42
19236	24.8	1.2	1	Direct gamma-spec.	9.3%	0.46	1.59
19237	24.3	3.0	2	Direct gamma-spec.	7.0%	0.35	1.00
19238	24.0	3.0	2	Direct gamma-spec.	5.7%	0.29	0.81
19239							
19240							
19241	23.0	2.0	1	Direct gamma-spec.	1.3%	0.07	0.14
19242	28.3	3.1	2	Direct gamma-spec.	24.7%	1.23	3.40
19243	22.68	3.212	2	Direct gamma-spec.	-0.1%	0.00	-0.01
19244	23.7	2.6	2	Direct gamma-spec.	4.4%	0.22	0.71
19245	23.3	1.0	1	Direct gamma-spec.	2.6%	0.13	0.52
19246	22.2	4.6	2	Direct gamma-spec.	-2.2%	-0.11	-0.21
19247	24.5	0.8	1	Direct gamma-spec.	7.9%	0.40	1.85
19249	19.4	2.8	2	Direct gamma-spec.	-14.5%	-0.73	-2.19
19250	23.5	1.2	1	Gamma-spec. Ac-228	3.5%	0.18	0.61
19251	24.2	3.8	2	Direct gamma-spec.	6.6%	0.33	0.76
19252	20.3	1.18	1	Gamma-spec. with chem. sep.	-10.6%	-0.53	-1.84
19253	21.6	2.0	2	Direct gamma-spec.	-4.8%	-0.24	-0.96
19254	23.0	2.0	1	Gamma spectrometry	1.3%	0.07	0.14
19255	20.66	1.47	2	Direct gamma-spec.	-9.0%	-0.45	-2.22
19256	23.0	3.0	2	Direct gamma-spec.	1.3%	0.07	0.19
19257							
19258							
19259	24.27	2.42	2	Direct gamma-spec.	6.9%	0.35	1.18
19260	23.8	1.4	1	Direct gamma-spec.	4.8%	0.24	0.73
19261	23.2	1.03	2	Direct gamma-spec.	2.2%	0.11	0.66

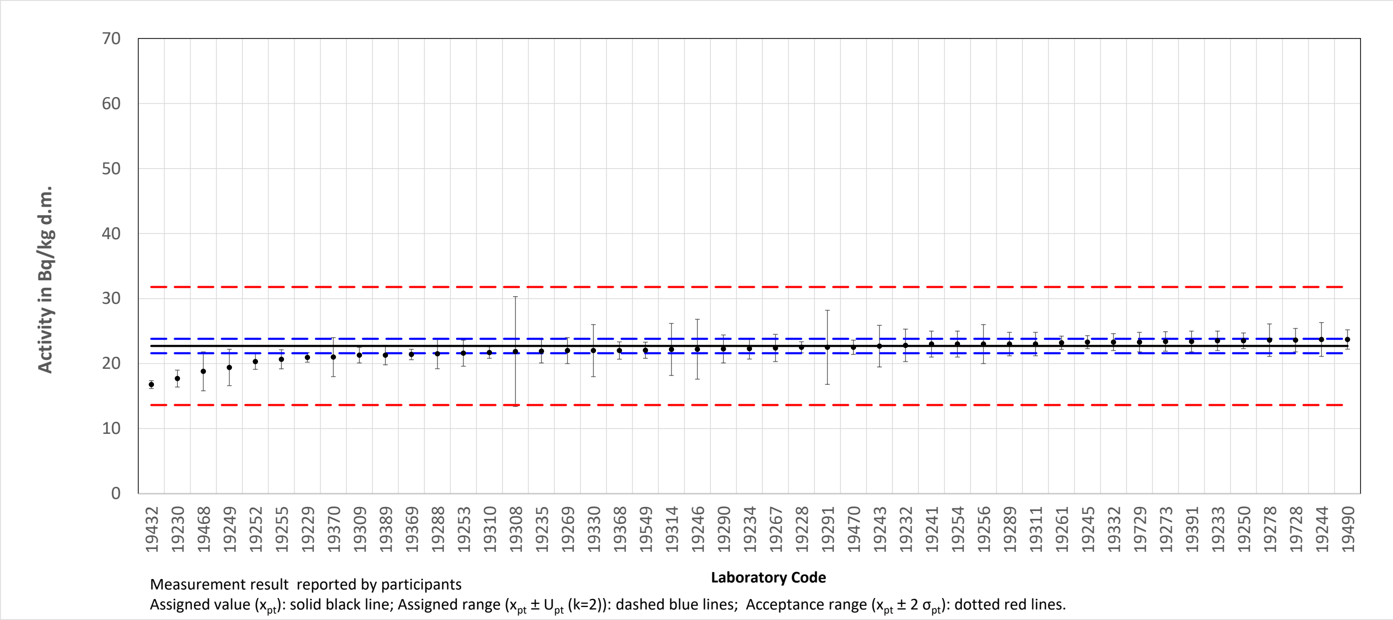
19263							
19264	25.6	1.8	1	Direct gamma-spec.	12.8%	0.64	1.54
19265	25.3	1.4	1	Direct gamma-spec.	11.5%	0.57	1.73
19266							
19267	22.4	2.1	1	Direct gamma-spec.	-1.3%	-0.07	-0.14
19268							
19269	22.0	2.0	1	Direct gamma-spec.	-3.1%	-0.15	-0.34
19270	26.9	3.5	2	Direct gamma-spec.	18.5%	0.93	2.29
19271	24.1	1.9	1	Direct gamma-spec.	6.2%	0.31	0.71
19272	25.4	1.0	2	Direct gamma-spec.	11.9%	0.59	3.62
19273	23.4	1.5	2	Direct gamma-spec.	3.1%	0.15	0.75
19274	24.0	2.2	1	Direct gamma-spec.	5.7%	0.29	0.57
19276	33.4	3.5	2	Direct gamma-spec.	47.1%	2.36	5.83
19277	24.6	1.2	2	Direct gamma-spec.	8.4%	0.42	2.33
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	23.6	2.5	2	Direct gamma-spec.	4.0%	0.20	0.66
19279							
19281	28.3	2.4	2	Direct gamma-spec.	24.7%	1.23	4.24
19288	21.5	2.3	2	Direct gamma-spec.	-5.3%	-0.26	-0.94
19289	23.0	1.8	1	Direct gamma-spec.	1.3%	0.07	0.16
19290	22.25	2.15	2	Direct gamma-spec.	-2.0%	-0.10	-0.37
19291	22.5	5.7	2	Direct gamma-spec.	-0.9%	-0.04	-0.07
19308	21.85	8.45	1	Direct gamma-spec.	-3.7%	-0.19	-0.10
19309	21.3	1.2	2	Direct gamma-spec.	-6.2%	-0.31	-1.72
19310	21.7	0.9	2	Direct gamma-spec. Ac-228	-4.4%	-0.22	-1.40
19311	23.0	1.8	1	Direct gamma-spec.	1.3%	0.07	0.16
19313							
19314	22.17	4.0	2	Direct gamma-spec. Ac-228 at To	-2.3%	-0.12	-0.26
19316							
19318	24.0	1.2	1	Direct gamma-spec.	5.7%	0.29	0.98
19328	24.4	2.7	2	Direct gamma-spec.	7.5%	0.37	1.17
19329	25.08	0.28	2	Direct gamma-spec.	10.5%	0.52	4.17
19330	22.0	4.0	2	Gamma-spec. with chem. sep.	-3.1%	-0.15	-0.34
19332	23.3	1.3	1	Direct gamma-spec.	2.6%	0.13	0.42
19333							
19334	25.6	0.9	1	Direct gamma-spec.	12.8%	0.64	2.74
19336	23.8	1.2	1	Direct gamma-spec.	4.8%	0.24	0.83

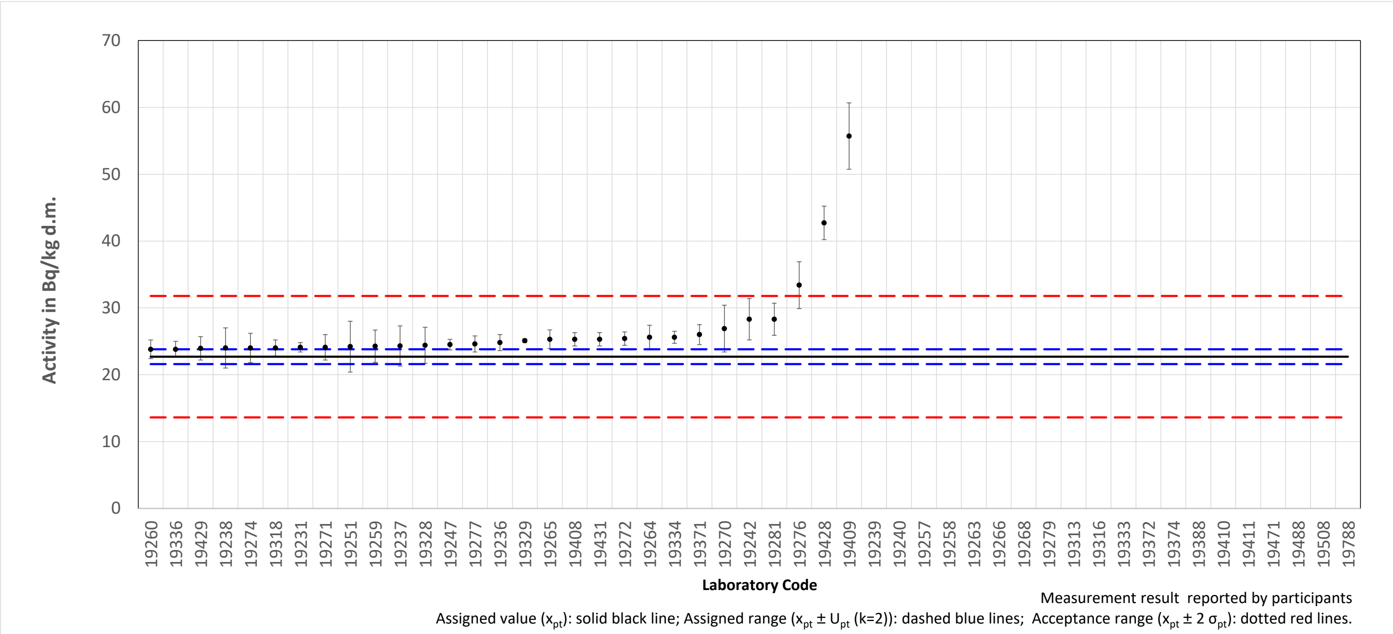
19368	22.0	1.33	2	Direct gamma-spec.	-3.1%	-0.15	-0.81
19369	21.4	0.8	2	Direct gamma-spec.	-5.7%	-0.29	-1.90
19370	21.0	3.0	1	Direct gamma-spec.	-7.5%	-0.37	-0.56
19371	26.0	1.5	1	Direct gamma-spec.	14.5%	0.73	2.06
19372							
19374							
19388							
19389	21.3	1.5	1	Gamma-spec. with chem. sep.	-6.2%	-0.31	-0.88
19391	23.4	1.6	1	Direct gamma-spec.	3.1%	0.15	0.41
19408	25.3	1.0	1	Direct gamma-spec.	11.5%	0.57	2.27
19409	55.71	4.96	2	Direct gamma-spec.	145.4%	7.27	12.99
19410							
19411							
19428	42.72	2.5	2	Direct gamma-spec.	88.2%	4.41	14.65
19429	23.947	1.748	1	Direct gamma-spec.	5.5%	0.27	0.68
19431	25.3	1.0	1	Direct gamma-spec.	11.5%	0.57	2.27
19432	16.77	0.61	2	Direct gamma-spec.	-26.1%	-1.31	-9.39
19468	18.8	2.99	2	Direct gamma-spec.	-17.2%	-0.86	-2.45
19470	22.5	1.1	1	Direct gamma-spec.	-0.9%	-0.04	-0.16
19471							
19488							
19490	23.7	1.48	2	Direct gamma-spec.	4.4%	0.22	1.08
19508							
19549	22.05	1.25	2	Direct gamma-spec.	-2.9%	-0.14	-0.78
19728	23.6	1.8	1.96	Direct gamma-spec.	4.0%	0.20	0.84
19729	23.3	1.5	1	Direct gamma-spec.	2.6%	0.13	0.38
19788							

Ra-228 in JRC-NORM-03

x_{pt} = 22.7 **$u(x_{pt})$ =** 0.6 *(k=1)* σ_{pt} = 4.5 (in Bq/kg d.m.)

z score


Activity in Bq/kg d.m.
70
60
50
40
30
20
10
0
19432 19230 19468 19249 19252 19255 19229 19370 19309 19389 19369 19288 19253 19310 19308 19235 19269 19330 19368 19549 19314 19246 19290 19234 19267 19228 19291 19470 19243 19232 19241 19254 19256 19289 19311 19261 19245 19332 19729 19273 19391 19233 19250 19278 19728 19244 19490
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.


Activity in Bq/kg d.m.
70
60
50
40
30
20
10
0
19260 19336 19429 19238 19274 19318 19231 19271 19251 19259 19237 19328 19247 19277 19236 19329 19265 19408 19431 19272 19264 19334 19371 19270 19242 19281 19276 19428 19409 19239 19240 19257 19258 19263 19266 19268 19279 19313 19316 19333 19372 19374 19388 19410 19411 19471 19488 19508 19788
Laboratory Code
Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 24: Th-228 in JRC-NORM 03

x_{pt} = 23.0 $u(x_{pt})$ = 0.5 σ_{pt} = 4.6 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	22.4	0.95	1	Direct gamma-spec.	-2.6%	-0.13	-0.55
19229	20.944	0.74	2	Direct gamma-spec.	-8.9%	-0.45	-3.21
19230							
19231	22.82	0.7	1	Direct gamma-spec.	-0.8%	-0.04	-0.21
19232	23.3	3.2	2	Direct gamma-spec.	1.3%	0.07	0.18
19233	26.9	1.9	1		17.0%	0.85	1.98
19234	19.7	1.3	1	Direct gamma-spec.	-14.3%	-0.72	-2.35
19235	23.3	1.5	1	Gamma-spec. Pb-212	1.3%	0.07	0.19
19236	22.9	1.7	1	Direct gamma-spec.	-0.4%	-0.02	-0.06
19237							
19238	25.0	4.0	2	Direct gamma-spec.	8.7%	0.43	0.97
19239							
19240							
19241	23.0	2.0	1	Direct gamma-spec.	0.0%	0.00	0.00
19242	24.3	1.7	2	Direct gamma-spec.	5.7%	0.28	1.30
19243	22.75	6.289	2	Direct gamma-spec.	-1.1%	-0.05	-0.08
19244	23.1	1.7	2	Direct gamma-spec.	0.4%	0.02	0.10
19245	24.0	1.3	1	Direct gamma-spec.	4.3%	0.22	0.71
19246	22.2	4.6	2	Direct gamma-spec.	-3.5%	-0.17	-0.34
19247	24.5	1.0	1	Direct gamma-spec.	6.5%	0.33	1.33
19249	19.5	4.2	2	Direct gamma-spec.	-15.2%	-0.76	-1.62
19250	22.4	0.8	1	Gamma-spec. Pb-212, Bi-212, Tl-208	-2.6%	-0.13	-0.63
19251	21.1	3.5	2	Direct gamma-spec.	-8.3%	-0.41	-1.04
19252							
19253	22.4	1.3	2	Direct gamma-spec.	-2.6%	-0.13	-0.72
19254	25.0	1.0	1	Gamma spectrometry	8.7%	0.43	1.77
19255							
19256	24.0	3.0	2	Alpha spectrometry	4.3%	0.22	0.63
19257	24.0	2.0	1	Direct gamma-spec.	4.3%	0.22	0.48
19258							
19259	22.97	2.88	2	Direct gamma-spec.	-0.1%	-0.01	-0.02
19260	22.4	2.1	1	Direct gamma-spec.	-2.6%	-0.13	-0.28
19261	25.66	8.72	2	Alpha spectrometry	11.6%	0.58	0.61

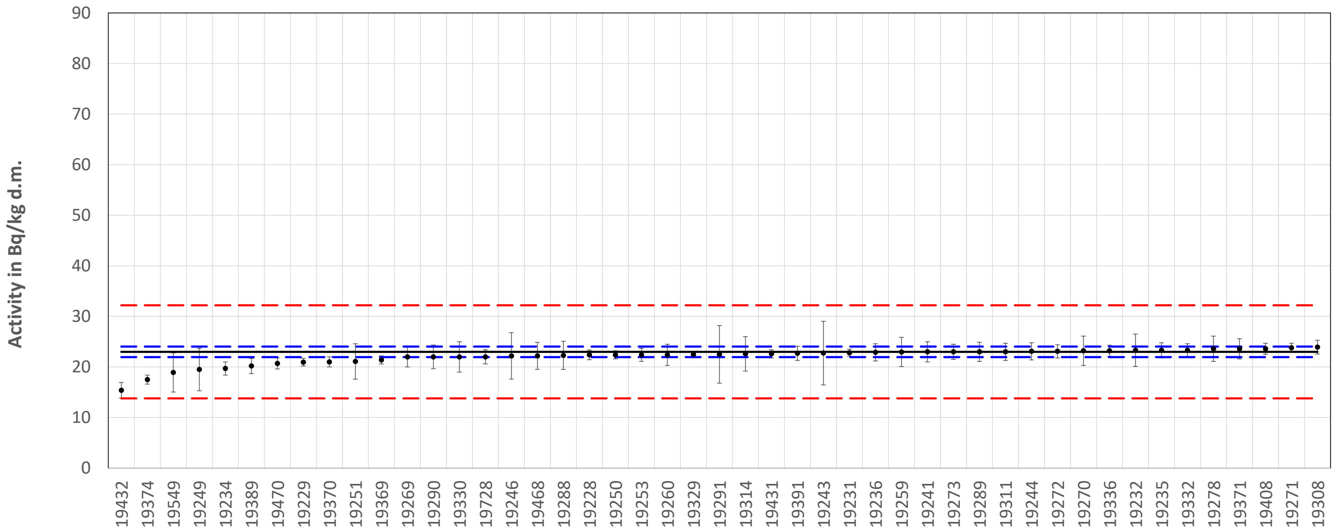
19263							
19264	26.6	1.8	1	Direct gamma-spec.	15.7%	0.78	1.92
19265	25.3	1.4	1	Direct gamma-spec.	10.0%	0.50	1.54
19266							
19267	24.6	1.6	1	Direct gamma-spec.	7.0%	0.35	0.95
19268							
19269	22.0	2.0	1	Direct gamma-spec.	-4.3%	-0.22	-0.48
19270	23.2	2.9	2	Direct gamma-spec.	0.9%	0.04	0.13
19271	23.8	0.9	1	Direct gamma-spec.	3.5%	0.17	0.77
19272	23.1	1.3	2	Direct gamma-spec.	0.4%	0.02	0.12
19273	23.0	1.5	2	Direct gamma-spec.	0.0%	0.00	0.00
19274	25.1	1.9	1	Direct gamma-spec.	9.1%	0.46	1.07
19276	77.6	24.9	2	Direct gamma-spec.	237.4%	11.87	4.38
19277	26.7	1.6	2	Direct gamma-spec.	16.1%	0.80	3.87
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	23.6	2.5	2	Direct gamma-spec.	2.6%	0.13	0.44
19279							
19281	27.7	2.2	2	Direct gamma-spec.	20.4%	1.02	3.86
19288	22.3	2.8	2	Direct gamma-spec.	-3.0%	-0.15	-0.47
19289	23.0	1.9	1	Direct gamma-spec.	0.0%	0.00	0.00
19290	22.0	2.35	2	Direct gamma-spec.	-4.3%	-0.22	-0.78
19291	22.5	5.7	2	Direct gamma-spec.	-2.2%	-0.11	-0.17
19308	23.93	1.37	1	Direct gamma-spec.	4.0%	0.20	0.63
19309	24.8	2.9	2	Alpha spectrometry	7.8%	0.39	1.17
19310							
19311	23.0	1.7	1	Direct gamma-spec.	0.0%	0.00	0.00
19313							
19314	22.6	3.4	2	Gamma spec. Pb 212 at To	-1.7%	-0.09	-0.22
19316							
19318	24.1	2.2	2	Alpha spectrometry	4.8%	0.24	0.90
19328	24.4	2.7	2	Direct gamma-spec.	6.1%	0.30	0.97
19329	22.49	0.2	2	Direct gamma-spec.	-2.2%	-0.11	-0.96
19330	22.0	3.0	2	Gamma-spec. with chem. sep.	-4.3%	-0.22	-0.63
19332	23.3	1.3	1	Direct gamma-spec.	1.3%	0.07	0.21
19333							
19334	25.0	0.7	1	Direct gamma-spec.	8.7%	0.43	2.29
19336	23.2	1.1	1	Direct gamma-spec.	0.9%	0.04	0.16

19368							
19369	21.4	0.8	2	Direct gamma-spec.	-7.0%	-0.35	-2.43
19370	21.0	1.0	1	Direct gamma-spec.	-8.7%	-0.43	-1.77
19371	23.6	2.0	1	Direct gamma-spec.	2.6%	0.13	0.29
19372	65.0	14.0	2	Direct gamma-spec.	182.6%	9.13	5.98
19374	17.5	0.9	1.76	Direct gamma-spec.	-23.9%	-1.20	-7.52
19388							
19389	20.2	1.5	1	Gamma-spec. with chem. sep.	-12.2%	-0.61	-1.76
19391	22.7	1.4	1	Direct gamma-spec.	-1.3%	-0.07	-0.20
19408	23.6	1.1	1	Direct gamma-spec.	2.6%	0.13	0.49
19409	97.64	29.36	2	Direct gamma-spec.	324.5%	16.23	5.08
19410							
19411							
19428	41.49	3.0	2	Direct gamma-spec.	80.4%	4.02	11.64
19429	24.705	1.786	1	Direct gamma-spec.	7.4%	0.37	0.92
19431	22.6	0.8	1	Direct gamma-spec.	-1.7%	-0.09	-0.42
19432	15.39	1.54	2	Direct gamma-spec.	-33.1%	-1.65	-8.17
19468	22.2	2.66	2	Direct gamma-spec.	-3.5%	-0.17	-0.56
19470	20.7	1.1	1	Direct gamma-spec.	-10.0%	-0.50	-1.89
19471							
19488							
19490							
19508							
19549	18.91	3.87	2	Direct gamma-spec.	-17.8%	-0.89	-2.04
19728	22.0	1.4	1.96	Direct gamma-spec.	-4.3%	-0.22	-1.13
19729	24.4	1.7	1	Direct gamma-spec.	6.1%	0.30	0.79
19788							

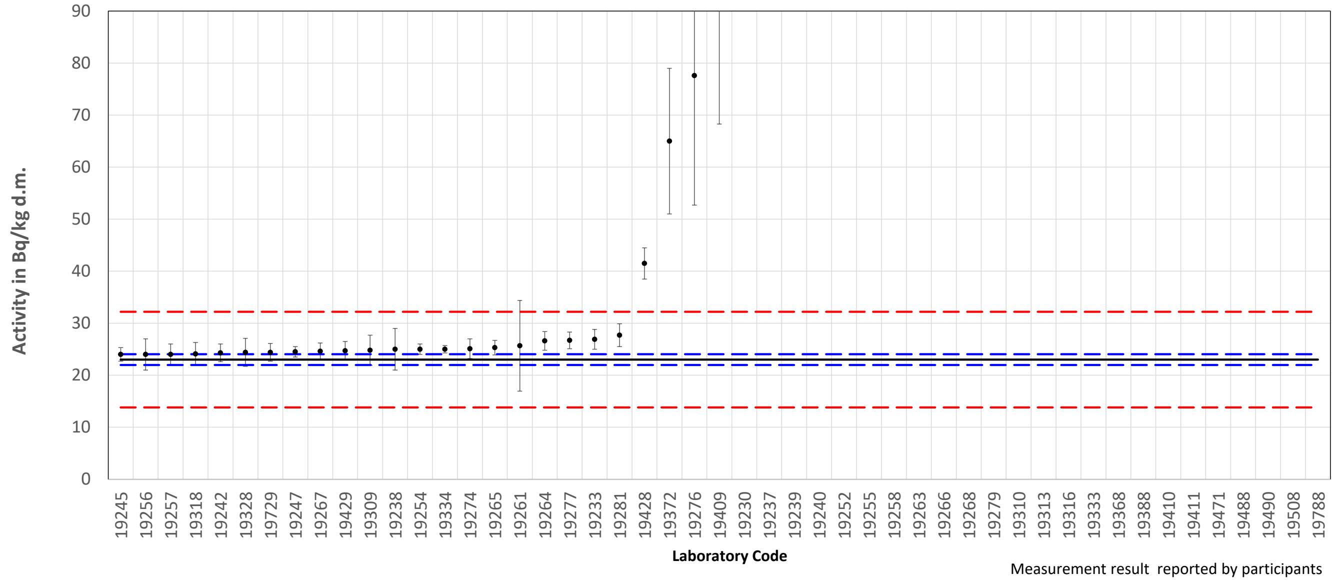
Th-228 in JRC-NORM-03

x_{pt} = 23.0 $u(x_{pt})$ = 0.5 *(k=1)* σ_{pt} = 4.6 (in Bq/kg d.m.)

z score



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 25: Th-232 in JRC-NORM 03

x_{pt} =	22.7	$u(x_{pt})$ =	0.5	σ_{pt} =	4.5	(in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	22.5	0.85	1	Direct gamma-spec.	-0.9%	-0.04	-0.20
19229	20.944	0.74	2	Direct gamma-spec.	-7.7%	-0.39	-2.87
19230	21.3	1.65	1	ICP-MS	-6.2%	-0.31	-0.81
19231	23.29	0.7	1	Direct gamma-spec.	2.6%	0.13	0.69
19232	22.8	2.5	2	Direct gamma-spec.	0.4%	0.02	0.07
19233	23.5	1.5	1		3.5%	0.18	0.51
19234	22.0	1.2	1	Direct gamma-spec.	-3.1%	-0.15	-0.54
19235	21.9	1.8	1	Gamma-spect. Ra-228	-3.5%	-0.18	-0.43
19236							
19237							
19238	25.0	5.0	2	Alpha spectrometry	10.1%	0.51	0.90
19239							
19240							
19241	23.0	2.0	1	Direct gamma-spec.	1.3%	0.07	0.15
19242							
19243							
19244	23.3	1.4	2	Direct gamma-spec.	2.6%	0.13	0.70
19245							
19246	22.2	4.6	2	Direct gamma-spec.	-2.2%	-0.11	-0.21
19247	24.5	0.9	1	Direct gamma-spec.	7.9%	0.40	1.76
19249							
19250	23.5	1.2	1	max activity Th-228, Ra-228	3.5%	0.18	0.62
19251	24.2	3.8	2	Direct gamma-spec.	6.6%	0.33	0.76
19252							
19253							
19254	22.0	1.0	1	Alpha spectrometry	-3.1%	-0.15	-0.63
19255	20.63	10.93	2	Direct gamma-spec.	-9.1%	-0.46	-0.38
19256	25.0	3.0	2	Alpha spectrometry	10.1%	0.51	1.46
19257	23.0	3.0	1	Direct gamma-spec.	1.3%	0.07	0.10
19258	22.0	4.1	2	Direct gamma-spec.	-3.1%	-0.15	-0.33
19259	23.69	2.2	2	Direct gamma-spec.	4.4%	0.22	0.82
19260	23.8	1.4	1	Direct gamma-spec.	4.8%	0.24	0.74
19261	20.66	7.92	2	Alpha spectrometry	-9.0%	-0.45	-0.51

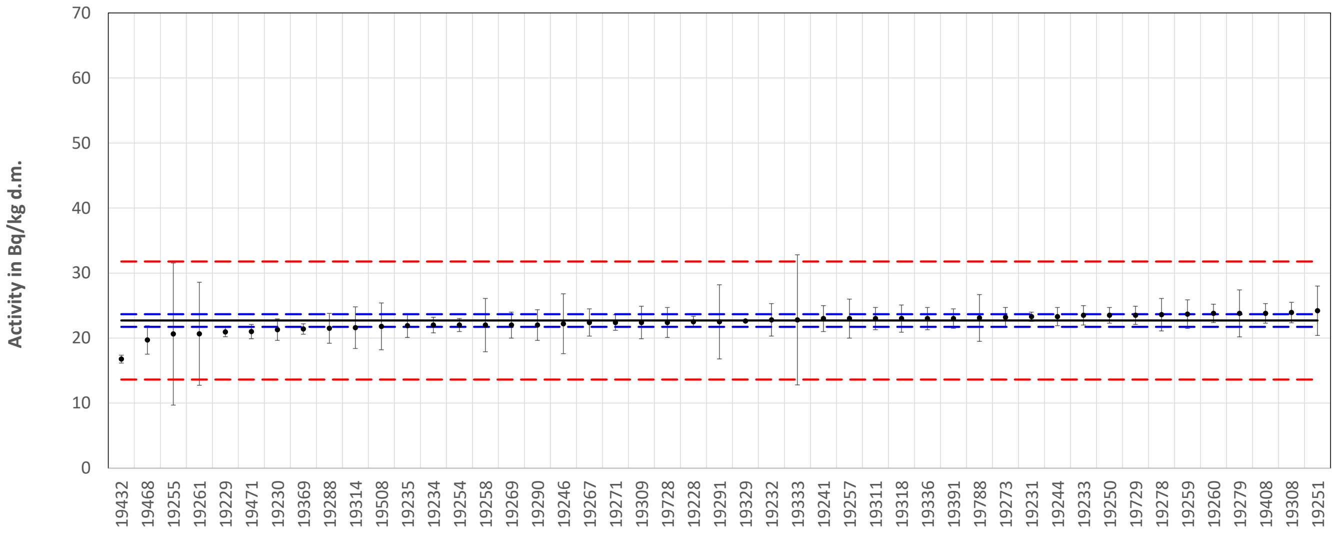
19263	78.4	22.7	2	ICP-MS	245.4%	12.27	4.90
19264							
19265	25.3	1.4	1	Direct gamma-spec.	11.5%	0.57	1.75
19266							
19267	22.4	2.1	1	Direct gamma-spec.	-1.3%	-0.07	-0.14
19268	327.395	0.664	1.05	ICP-OES	1342.3%	67.11	381.96
19269	22.0	2.0	1	Direct gamma-spec.	-3.1%	-0.15	-0.34
19270	26.9	3.5	2	Direct gamma-spec.	18.5%	0.93	2.31
19271	22.4	1.2	1	Alpha spectrometry	-1.3%	-0.07	-0.23
19272				Direct gamma-spec.			
19273	23.2	1.5	2	Direct gamma-spec.	2.2%	0.11	0.56
19274	24.6	2.1	1	Direct gamma-spec.	8.4%	0.42	0.88
19276	1466.9	341.3	2	Direct gamma-spec.	6362.1%	318.11	8.46
19277	51.3	2.8	2		126.0%	6.30	19.30
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278	23.6	2.5	2	Direct gamma-spec.	4.0%	0.20	0.67
19279	23.8	3.6	2	Direct gamma-spec.	4.8%	0.24	0.59
19281							
19288	21.5	2.3	2	Direct gamma-spec.	-5.3%	-0.26	-0.96
19289							
19290	22.0	2.35	2	Direct gamma-spec.	-3.1%	-0.15	-0.55
19291	22.5	5.7	2	Direct gamma-spec.	-0.9%	-0.04	-0.07
19308	23.93	1.57	1	Direct gamma-spec.	5.4%	0.27	0.75
19309	22.4	2.5	2	Alpha spectrometry	-1.3%	-0.07	-0.22
19310							
19311	23.0	1.7	1	Direct gamma-spec.	1.3%	0.07	0.17
19313							
19314	21.6	3.2	2	Direct gamma-spec. Ac 228	-4.8%	-0.24	-0.66
19316							
19318	23.0	2.1	2	Alpha spectrometry	1.3%	0.07	0.26
19328	24.4	2.7	2	Direct gamma-spec.	7.5%	0.37	1.18
19329	22.63	0.16	2	Direct gamma-spec.	-0.3%	-0.02	-0.14
19330							
19332	24.4	1.7	1	Alpha spectrometry	7.5%	0.37	0.96
19333	22.8	10.0	2	Direct gamma-spec.	0.4%	0.02	0.02
19334	25.6	0.9	1	Direct gamma-spec.	12.8%	0.64	2.83
19336	23.0	1.7	1	Direct gamma-spec.	1.3%	0.07	0.17

19368							
19369	21.4	0.8	2	Direct gamma-spec.	-5.7%	-0.29	-2.06
19370	25.0	3.0	1	Alpha spectrometry	10.1%	0.51	0.76
19371	25.3	1.5	1	Direct gamma-spec.	11.5%	0.57	1.65
19372	< 370.0			Direct gamma-spec.			
19374							
19388							
19389							
19391	23.0	1.5	1	Direct gamma-spec.	1.3%	0.07	0.19
19408	23.8	1.5	1	Direct gamma-spec.	4.8%	0.24	0.70
19409	55.71	4.96	2	Direct gamma-spec.	145.4%	7.27	13.06
19410	28.38	3.56	0.892	Direct gamma-spec.	25.0%	1.25	1.41
19411	25.5	2.0	2	Direct gamma-spec.	12.3%	0.62	2.52
19428	42.22	1.92	2	Direct gamma-spec.	86.0%	4.30	18.14
19429							
19431	24.3	3.0	1	Direct gamma-spec.	7.0%	0.35	0.53
19432	16.77	0.61	2	Direct gamma-spec.	-26.1%	-1.31	-10.33
19468	19.7	2.18	2	Direct gamma-spec.	-13.2%	-0.66	-2.51
19470	27.9	1.9	1	Alpha spectrometry	22.9%	1.15	2.65
19471	21.0	1.1	1	Direct gamma-spec.	-7.5%	-0.37	-1.41
19488	24.9	3.0	2	Direct gamma-spec.	9.7%	0.48	1.40
19490							
19508	21.8	3.6	2	Direct gamma-spec.	-4.0%	-0.20	-0.48
19549	< 25.0			Direct gamma-spec.			
19728	22.4	2.3	1.96	Direct gamma-spec.	-1.3%	-0.07	-0.24
19729	23.5	1.4	1	Direct gamma-spec. Th-232 decay products in equilibrium.	3.5%	0.18	0.54
19788	23.1	3.6	2	Alpha spectrometry	1.8%	0.09	0.21

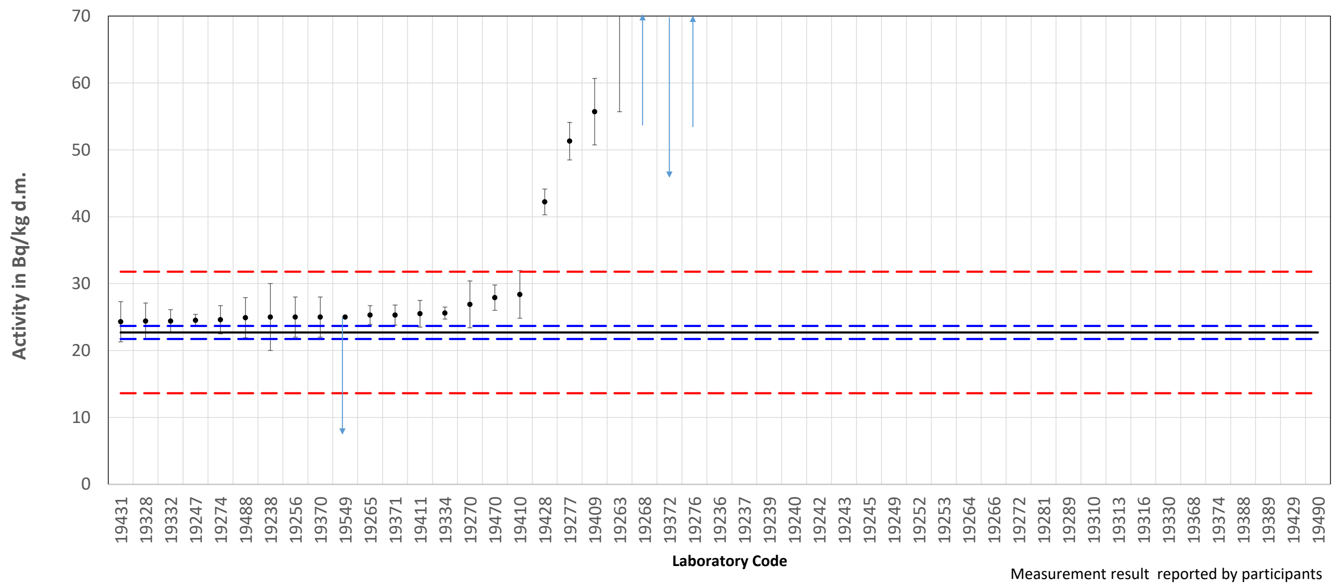
Th-232 in JRC-NORM-03

x_{pt} = 22.7 $u(x_{pt})$ = 0.5 *(k=1)* σ_{pt} = 4.5 (in Bq/kg d.m.)

z score



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.



Measurement result reported by participants
Assigned value (x_{pt}): solid black line; Assigned range ($x_{pt} \pm U_{pt}$ (k=2)): dashed blue lines; Acceptance range ($x_{pt} \pm 2\ \sigma_{pt}$): dotted red lines.

Annex 26: U-238 in JRC-NORM 03

x_{pt} = 33.8 $u(x_{pt})$ = 1.2 σ_{pt} = 10.1 (in Bq/kg dm)

Lab.Code	x_i	±	k	Technique	$D\%$	z score	ζ score
19228	43.0	3.5	1	Direct gamma-spec.	27.2%	0.91	2.48
19229	29.622	0.74	2	Direct gamma-spec.	-12.4%	-0.41	-3.21
19230	33.1	2.3	1	ICP-MS	-2.1%	-0.07	-0.27
19231	33.69	2.94	1	Direct gamma-spec.	-0.3%	-0.01	-0.03
19232	30.8	9.7	2	Direct gamma-spec.	-8.9%	-0.30	-0.60
19233	21.9	4.0	1		-35.2%	-1.17	-2.84
19234	31.9	6.3	1	Direct gamma-spec.	-5.6%	-0.19	-0.30
19235	35.6	3.6	1	Gamma-spect. Deconv. U235/Ra226. Faktor 21.73 U238/U235	5.3%	0.18	0.47
19236	27.2	2.7	1	Direct gamma-spec.	-19.5%	-0.65	-2.22
19237							
19238	36.0	7.0	2	Direct gamma-spec. 234Th	6.5%	0.22	0.59
19239							
19240							
19241	31.0	3.0	1	Direct gamma-spec.	-8.3%	-0.28	-0.86
19242							
19243	38.86	8.711	2	Direct gamma-spec.	15.0%	0.50	1.12
19244	29.7	4.5	2	Direct gamma-spec.	-12.1%	-0.40	-1.59
19245	29.8	4.8	1	Direct gamma-spec.	-11.8%	-0.39	-0.81
19246	43.3	28.2	2	Direct gamma-spec.	28.1%	0.94	0.67
19247	30.9	2.7	1	Direct gamma-spec.	-8.6%	-0.29	-0.98
19249							
19250	37.3	3.0	1	calculated from the peak 186 keV	10.4%	0.35	1.08
19251	29.3	6.9	2	Direct gamma-spec.	-13.3%	-0.44	-1.23
19252							
19253							
19254	30.0	2.0	1	Alpha spectrometry	-11.2%	-0.37	-1.61
19255							
19256	32.0	4.0	2	Alpha spectrometry	-5.3%	-0.18	-0.76
19257	31.0	6.0	1	Direct gamma-spec.	-8.3%	-0.28	-0.46
19258	25.2	5.2	2	Direct gamma-spec.	-25.4%	-0.85	-2.98
19259	34.3	9.05	2	Direct gamma-spec.	1.5%	0.05	0.11
19260	33.3	4.8	1	Direct gamma-spec.	-1.5%	-0.05	-0.10

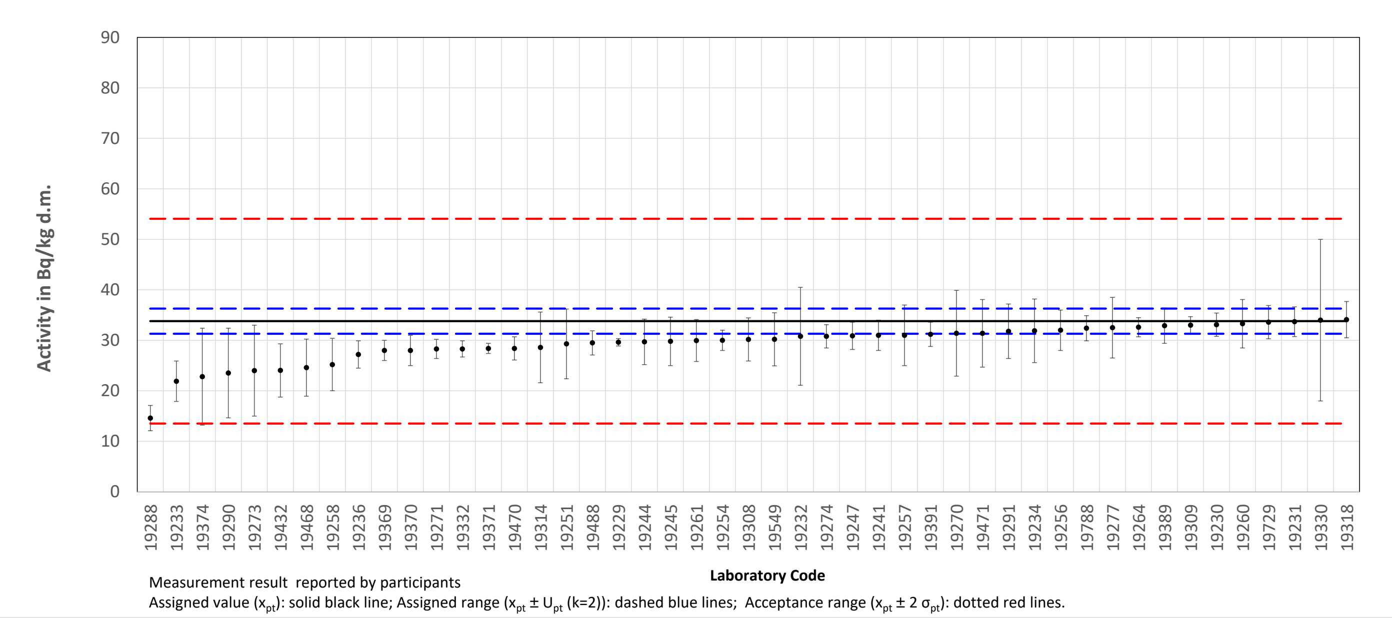
19261	29.96	4.15	2	Alpha spectrometry	-11.4%	-0.38	-1.59
19263	35.6	9.7	2	ICP-MS	5.3%	0.18	0.36
19264	32.6	1.9	1	Direct gamma-spec.	-3.6%	-0.12	-0.53
19265	41.0	4.0	1	Direct gamma-spec.	21.3%	0.71	1.72
19266							
19267	41.6	9.0	1	Direct gamma-spec.	23.1%	0.77	0.86
19268				ICP-OES			
19269	36.0	6.0	1	Direct gamma-spec.	6.5%	0.22	0.36
19270	31.4	8.5	2	Direct gamma-spec.	-7.1%	-0.24	-0.54
19271	28.3	1.9	1	Alpha spectrometry	-16.3%	-0.54	-2.42
19272	50.9	5.9	2	Direct gamma-spec.	50.6%	1.69	5.34
19273	24.0	9.0	2	Direct gamma-spec.	-29.0%	-0.97	-2.10
19274	30.8	2.3	1	Direct gamma-spec.	-8.9%	-0.30	-1.15
19276	79.7	33.9	2	Direct gamma-spec.	135.8%	4.53	2.70
19277	32.5	6.0	2	Direct gamma-spec.	-3.8%	-0.13	-0.40
Lab.Code	x_i	±	k	**Technique**	$D\%$	z **score**	ζ **score**
19278							
19279	50.5	20.6	2	Direct gamma-spec.	49.4%	1.65	1.61
19281	37.6	3.7	2	Direct gamma-spec.	11.2%	0.37	1.70
19288	14.6	2.5	2	Direct gamma-spec.	-56.8%	-1.89	-10.88
19289	42.0	5.2	1	Direct gamma-spec.	24.3%	0.81	1.53
19290	23.54	8.88	2	Direct gamma-spec.	-30.4%	-1.01	-2.22
19291	31.8	5.4	5	Direct gamma-spec.	-5.9%	-0.20	-1.21
19308	30.17	4.27	1	Direct gamma-spec.	-10.7%	-0.36	-0.82
19309	33.0	1.7	2	Alpha spectrometry	-2.4%	-0.08	-0.53
19310							
19311	< 70.0			Direct gamma-spec.			
19313							
19314	28.6	7.0	2	Direct gamma-spec Th234 (63keV)	-15.4%	-0.51	-1.40
19316							
19318	34.1	3.6	1	Direct gamma-spec.	0.9%	0.03	0.08
19328	52.0	24.0	2	Direct gamma-spec.	53.8%	1.79	1.51
19329	38.82	0.52	2	Direct gamma-spec.	14.9%	0.50	3.94
19330	34.0	16.0	2	Gamma-spec. with chem. sep.	0.6%	0.02	0.02
19332	28.3	1.6	1	Alpha spectrometry	-16.3%	-0.54	-2.71
19333	44.0	10.0	2	Direct gamma-spec.	30.2%	1.01	1.98
19334	37.6	3.5	1	Direct gamma-spec.	11.2%	0.37	1.02

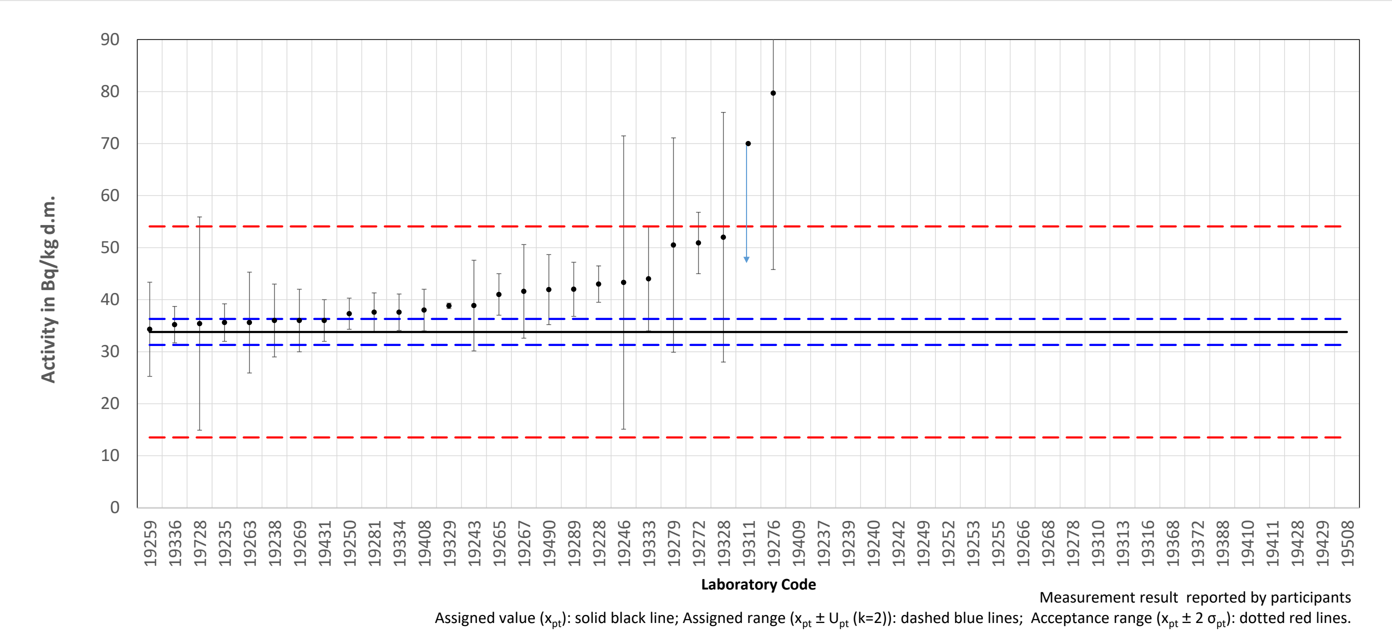
19336	35.2	3.5	1	Direct gamma-spec.	4.1%	0.14	0.38
19368							
19369	28.0	2.0	2	Direct gamma-spec.	-17.2%	-0.57	-3.63
19370	28.0	3.0	1	Alpha spectrometry	-17.2%	-0.57	-1.79
19371	28.4	1.0	1	Direct gamma-spec.	-16.0%	-0.53	-3.38
19372							
19374	22.8	9.6	1.73	Direct gamma-spec.	-32.5%	-1.08	-1.93
19388							
19389	32.9	3.5	1	Gamma-spec. with chem. sep.	-2.7%	-0.09	-0.24
19391	31.2	2.4	1	Direct gamma-spec.	-7.7%	-0.26	-0.96
19408	38.0	4.0	1	Direct gamma-spec.	12.4%	0.41	1.00
19409	858.0	157.37	2	Direct gamma-spec.	2438.5%	81.28	10.47
19410							
19411							
19428							
19429							
19431	36.0	4.0	1	Direct gamma-spec.	6.5%	0.22	0.53
19432	24.04	5.28	2	Direct gamma-spec.	-28.9%	-0.96	-3.34
19468	24.6	5.66	2	Direct gamma-spec.	-27.2%	-0.91	-2.98
19470	28.4	2.3	1	Alpha spectrometry	-16.0%	-0.53	-2.06
19471	31.4	6.7	1	Direct gamma-spec.	-7.1%	-0.24	-0.35
19488	29.5	2.4	2	Direct gamma-spec.	-12.7%	-0.42	-2.49
19490	41.93	6.73	2	Alpha spectrometry	24.1%	0.80	2.27
19508							
19549	30.2	5.26	2	Direct gamma-spec.	-10.7%	-0.36	-1.24
19728	35.4	20.5	1.96	Direct gamma-spec.	4.7%	0.16	0.15
19729	33.6	3.3	1	Direct gamma-spec. U238 in equilibrium with Pa234m and Th234	-0.6%	-0.02	-0.06
19788	32.4	2.5	2	Alpha spectrometry	-4.1%	-0.14	-0.79

U-238 in JRC-NORM-03

x_{pt} = 33.8 $u(x_{pt})$ = 1.2 *(k=1)* σ_{pt} = 10.1 (in Bq/kg d.m.)

z score





Annex 27. List of participating laboratories

AUSTRIA

AGES - Austrian Agency for Health and Food Safety
Radon and Radioecology
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4020 Linz

Austrian Agency for Health and Food Safety
Radiation Protection Radiochem
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1220 Vienna

BELGIUM

IRE
IRE Lab
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6220 Fleurus

SCK-CEN
LRM
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2400 Mol

BULGARIA

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8000 Burgas

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Regional Laboratory – Montana
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3400 Montana

Executive Environment Agency
Regional Laboratory – Plovdiv
1 Perushtica Street
4002 Plovdiv

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Radiation Protection
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1606 Sofia

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Radioactive Measurements
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Radiation Control
Bregalnitsa 3
9000 Varna

Executive Environment Agency
Regional Laboratory Vratza
Exarh Josif 81
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CROATIA

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Occupational Health
Radiation Protection Unit
Ksaverska cesta 2
10000 Zagreb

Rudjer Boskovic Institute
Laboratory for radioecology
Bijenicka cesta 54
10000 Zagreb

CYPRUS

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Radioactivity Lab
Kimonos 44, Acropoli
1451 Nicosia

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Pileticka 57/15A
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Public Research Institutions
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16000 Prague 6

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Institute of Physics
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78110 Le Vésinet

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68163 Mannheim

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15780 Athens

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54124 Thessaloniki

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Clonskeagh Road
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70126 Bari

ARPA Lombardia
U.O. CRR
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24121 Bergamo

ARPAS - Laboratorio di radioattività ambientale
Viale F. Ciusa, 6
09131 Cagliari

ARPA Molise
Centro Radioattività
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86100 Campobasso

Eurolab srl
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36022 Cassola

Arpa Sicilia
UOS Agenti Fisici Orientale
via Varese 45
95123 Catania

ARPAT- Environmental Protection Agency - Tuscany Region
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50144 Florence

Istituto Zooprofilattico Sperimentale della Puglia e della Basilicata
CRN –Radioattività
Via Manfredonia, 20
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71121 Foggia

ARPAL - Agenzia Regionale per la Protezione dell'Ambiente Ligure
Via Bombrini 8
16149 Genova

ARPA Piemonte
Physical Technological Risks
Via Jervis, 30
10015 Ivrea (TO)

ARPA Lazio
Stato dell'Ambiente
C/O Istituto Agrario "San Benedetto"
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04100 Latina

ARPA Lombardia
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20129 Milano

ARPA UMBRIA
Servizio Radiazioni Ionizzanti
Via Pievaiola 207 B-3
San Sisto
06132 Perugia

ARPAE Emilia Romagna
CTR Radioattività ambientale
Via XXI Aprile, 48
29121 Piacenza

ARPACAL Agenzia Regionale Protezione
Amnbiente
Reggio Calabria
via Troncovito snc
Gallico Superiore
89135 Reggio Calabria

ISIN - National Inspectorate for Nuclear
Safety and Radiation Protection
Radiometric Laboratories
Via di Castel Romano, 100
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ARPA Valle d'Aosta
Environmental Radioactivity
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APPA TN
Settore Laboratorio
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ARPAV
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37135 Verona

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Meteorology Centre
Laboratory
Maskavas street 165
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LITHUANIA

Radiation Protection Centre
Kalvariju street 153
LT-08352 Vilnius

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Ministère de la Santé
Division de la Radioprotection
Villa Louvigny, Allée Marconi
2120 Luxembourg

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Antonie van Leeuwenhoeklaan 9
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44-100 Gliwice

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LPPN
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03-194 Warsaw

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Environmental Radioactivity
Plac Gwarkow 1
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Campus Tecnológico e Nuclear
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Environmental Radioactivity Laboratory
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077125 Magurele-Bucharest

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Iza 1A
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National Research and Development Institute for Cryogenic and Isotopic Technologies – ICSI Rm. Valce
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Faculty of Experimental Sciences
Dept. of Integrated Sciences
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NORM Technology Consulting
Dpto. Ciencias Integradas
Facultad CC. Experimentales
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Medical Physics – Laruc
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Universidad de Santiago de Compostela
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Nuclear Energy Research Institute
TENMAK-NÜKEN
Saray Mah. Atom Cad. No:27
06980 Ankara

Annex 28. The responsibilities amongst the involved staff of the organiser

- Katarzyna Sobiech-Matura: PT coordinator until 1 September 2022, test item responsible, gamma-ray spectrometry.
- Mikael Hult: RN team leader, PT coordinator as from 1 September 2022, gamma-ray spectrometry and quality control.
- Petya Malo: logistics assistant, administration, quality control.
- Heiko Stroh: packing, gamma-ray spectrometry analysis.
- Gerd Marissens: packing, sample preparation, gamma-ray spectrometry.
- Jan Paepen: packing.
- Ulf Jacobsson: G.II.6 Unit Quality Officer, developer of the REMPES application.

Advisory group members: Arjan Plompen Head of Unit, Petya Malo ISO/IEC 17043 Quality management, Mikael Hult as Team Leader, Jan Paepen and Stefaan Pommé as Statistical advisors, Piotr Robouch and Håkan Emteborg as external (JRC Directorate F) advisor. There were also synergies with the collaborative trial to test the new CEN standard EN 17216, which was organised by Raf Van Ammel and Jan Paepen.

Additional in-house contributions were performed by

- Håkan Emteborg (JRC-Geel, F.6 Reference Materials Unit): PT test item processing, packing and providing sample storage rooms. JRC-Geel Dir.F.6 is an accredited Certified Reference Materials producer according to ISO 17034:2016.
- Piotr Robouch (JRC-Geel, F.5 Food and Feed Compliance Unit): Data evaluation and quality control, data validation of participants' performance. JRC-Geel Dir.F.5 is an accredited ILC provider according to ISO/IEC 17043:2016.

These two contributions, albeit "in-house" at JRC-Geel are formally outside the G.II.6 unit and considered as external in the ISO/IEC 17043 point of view.

Annex 29. External laboratories contributing to the assigned value

- SCK CEN (Belgian Nuclear Research Centre in Mol, Belgium), accredited lab: Alpha-particle spectrometry and gamma-ray spectrometry to contribute to the assigned value.
- IAEA (Monaco), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.
- CEA-LNHB (Paris, France), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.
- IJS (Ljubljana, Slovenia), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.
- Environmental Board (Estonia), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.
- AGES (Vienna, Austria), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.
- TENMAK (Ankara, Türkiye), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.
- ARPA (Milan, Italy), accredited lab.: gamma-ray spectrometry to contribute to the assigned value.

Annex 30. REMPES – distribution of participants' results and assigned values

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EUROPEAN COMMISSION
DIRECTORATE-GENERAL
JOINT RESEARCH CENTRE
Directorate G - Nuclear Safety and Security (Geel)
JRC.G.II.5 Nuclear Data and Measurement Standards

Geel, 14/03/2023

REM 2020 PT on Naturally Occurring Radionuclides

in Building Materials

Dear colleague,

Thank you for participating in the REM 2020 PT[1] on naturally occurring radionuclides in building materials.

With this message we distribute the assigned value, x_{pt}, for each radionuclide and test item (7 radionuclides × 3 test items = 21 values) together with the uncertainty, $u(x_{pt})$, and the standard deviation of the PT, σ_{pt}. Like in the previous REM PTs, we do so in an excel-file called REMPES (Radioactivity Environmental Monitoring Performance Evaluation Spreadsheet). By entering your laboratory's code in the box, your submitted results will be displayed together with your scores (zed- and zeta-scores according to ISO 13528:2015) and three PomPlots (https://link.springer.com/article/10.1007/s00769-007-0319-9). **Your laboratory code will be received in a separate email in the coming days**.

As soon as you get your laboratory code, we ask you to check that your submitted results are correct and contact us (JRC-GEE-REM-COMPARISONS@ec.europa.eu) in case you find any error. Note that reporting is part of the exercise and we do not try to interpret the results when calculating scores. The results were evaluated as they were reported.

Please also note that we report median and MAD (Median absolute deviation, see e.g. https://en.wikipedia.org/wiki/Median_absolute_deviation) of the participants' results, as they are more robust than the arithmetic mean which is highly influenced by erroneous reporting results and outliers.

We do apologise for the long period between the deadline for submission of results and receiving these scores. It is directly linked to the cut in the Euratom budget and the loss of essential staff. In the transition period after losing staff, we have given priority to quality and integrity of data, which negatively affected the data processing period. Thanks to the strong support we received from monitoring labs and national Article 35 Experts, we will continue to keep organising these REM PTs albeit somewhat less frequently than in the past. We will keep you updated by email and on the REMON website about further developments: https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/Proficiency-Tests.

We have started to draft the final report in which you will get additional information like S-plots (plotting the scores of all labs) and information on the test items, and some analysis on

[1] REM = Radioactivity Environmental Monitoring; PT= Proficiency Test

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how different methods (gamma-ray spectrometry, alpha-particle spectrometry, ICP-MS) scored.

In case you still require a written confirmation of your results, you can contact us and we will provide it.

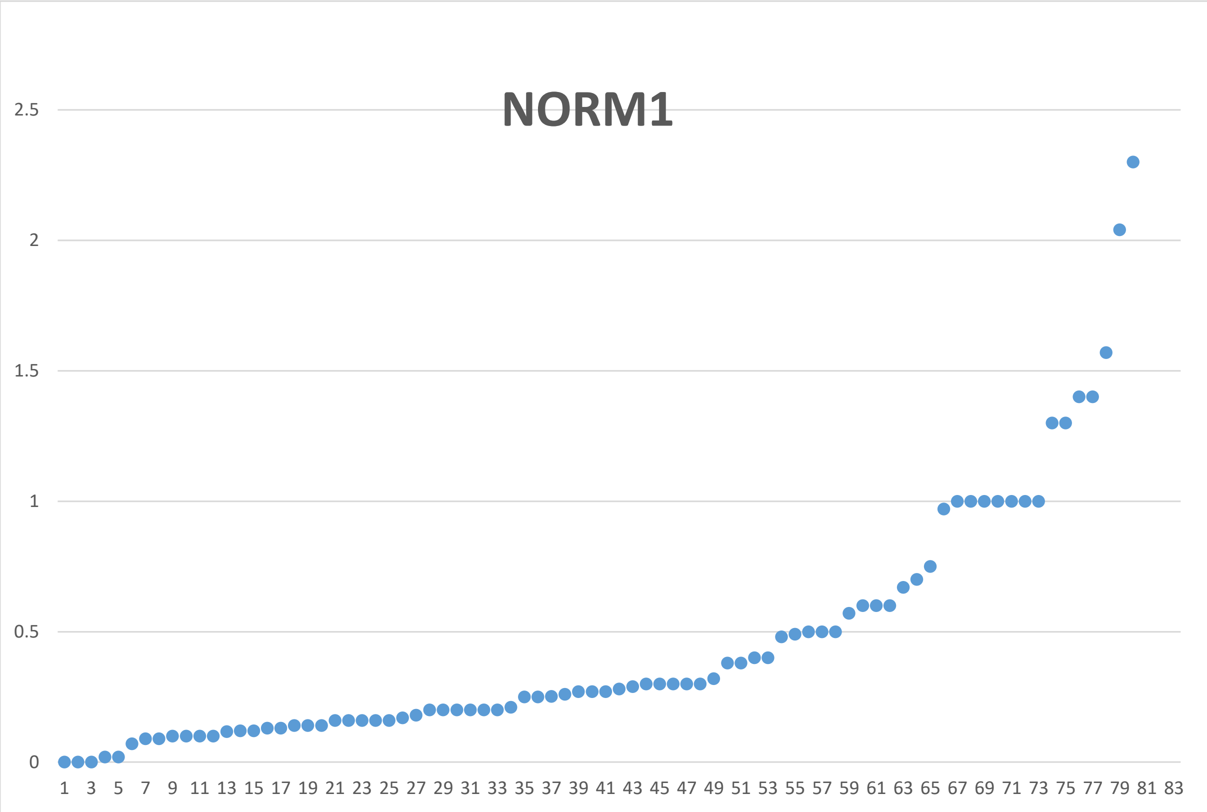
We thank you very much for your efforts in participating in this PT. We are particularly thankful to those participants that did the extra effort and performed sample preparation of the expanded clay block and reported values for the NORM2 test item. We hope the PT is helpful for you and your laboratory's capacity to monitor environmental radioactivity. We also hope to be able to use the vast amount of data collected in this PT to identify best practices and possibly as input to new standardisation work, so your work as participant in this PT will be of great value to many. Finally, we hope to be able to organise a workshop combined with training linked to the techniques used in this PT in 2024. We will inform you by email as soon as we know more about that event. After the previous online workshop, we plan to host a physical workshop here on site at JRC-Geel.

Many thanks again for your participation.

Kind regards,

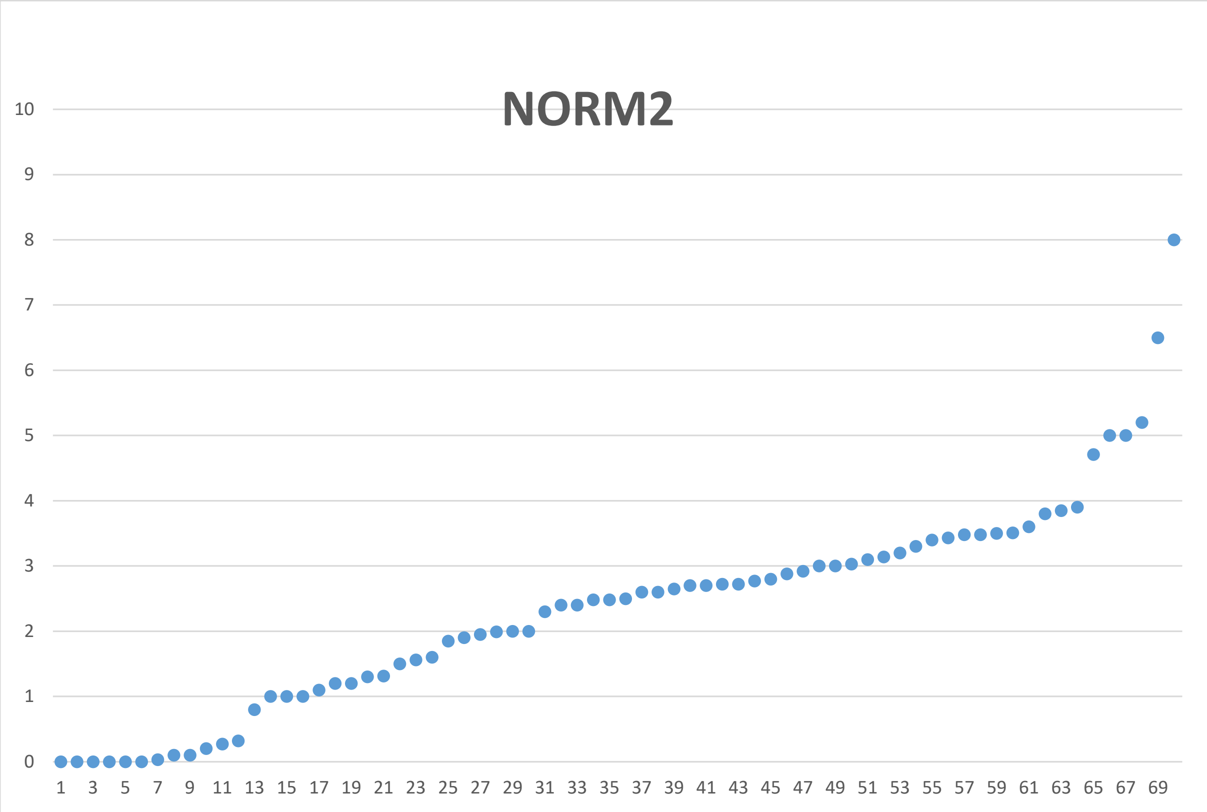
Mikael HULT	Petya MALO
Project Coordinator	Logistics assistant

Annex 31. Moisture content reported by participants for test item NORM1 (cement).



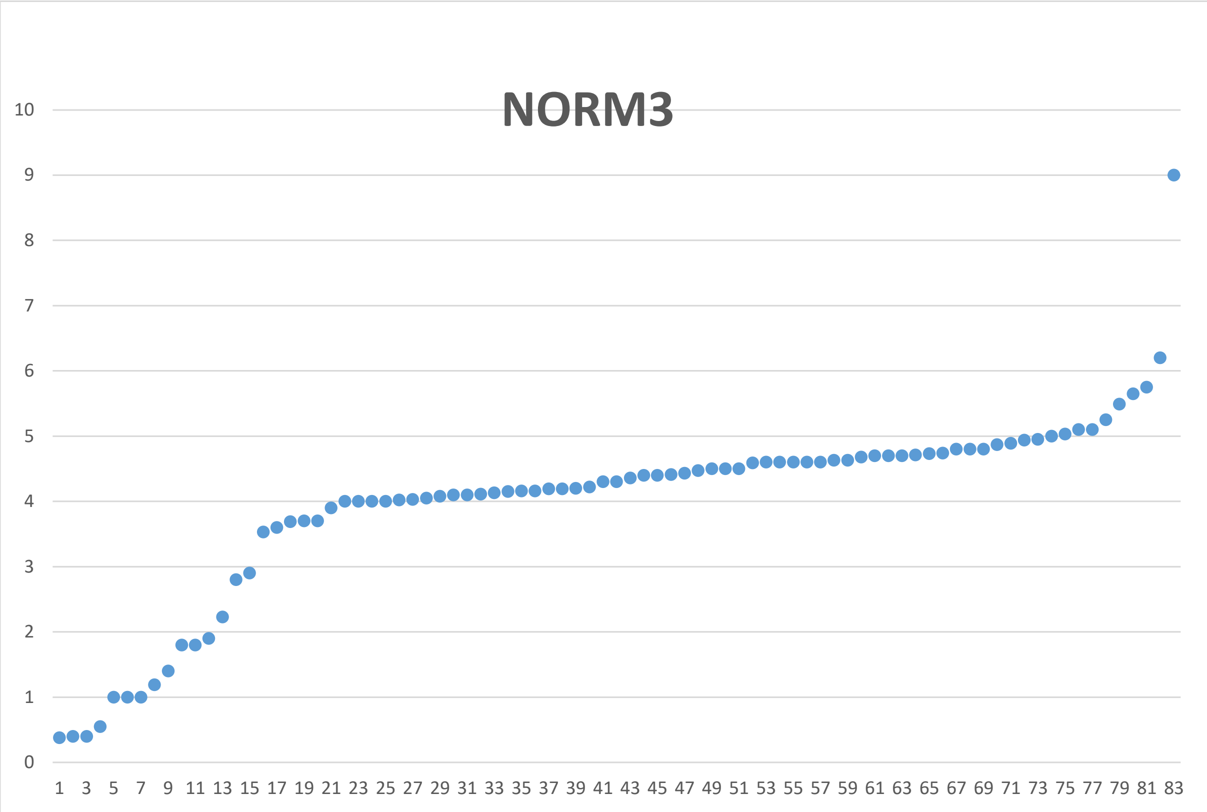
The unit of the y-axis is mass%. The number on the x-axis is not related to any lab-number.

Annex 32. Moisture content reported by participants for test item NORM2 (expanded clay block).



The unit of the y-axis is mass%. The number on the x-axis is not related to any lab-number.

Annex 33. Moisture content reported by participants for test item NORM3 (pulverized expanded clay block).



The unit of the y-axis is mass%. The number on the x-axis is not related to any lab-number.

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