The Joint EEAE/IAEA-RER9155-2022-NORM Intercomparison Exercise on the Radioanalytical Characterization of NORM Samples (Phosphate Ore & Phosphogypsum)

Laboratory's Final Report
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Comments:	**teleDOS Laboratories SM PC - teleDOS Nuclear Tech 102, Apostolou Paulou Str., Corinth GR20131, Greece, T: (+30) 6974 867 477** **In this report version: Results were NOT decay corrected after equilibria status determination!** **Results do not contain the inhomogeneity of the whole batch of each material (7.5% for phosphate ore and 15% for phosphogypsum); they concern only the samples that were delivered for analysis in our lab. For the characterization of each batch as a whole, the respective inhomogeneity should be added in quadrature to the uncertainty of each radionuclide. The same stands and should take place, if the inhomogeneity is not included in the MARB criterion that will be potentially used for the IC excersise results evaluation.** **The analyses were implemented in collaboration with Ms. Sofia Con. Papadopoulou - Radioanalytics SM PC**

Sample 1: Phosphate Ore

Humidity (%)	**(2.10 ± 0.30) %**

Describe any sample preparation performed
for gamma spectrometry:
The sample was homogenized throroughly. Three small aliquots were used for the determination of wet/dry ratio with the utilization of a thermobalance @105°C. An aliquot was used to fill 105ml of our standard counting container, with the aid of a special pressing tool. The prepared source was weighed, immobilized and epoxy-aluminum sealed. In our lab, the spectrometric data acquisition for NORM samples is taking place at least 30days after source sealing; for this specific sample (01/bottle 24), measurement happened to take place 57days after sealing. In general, the analytial method applied (after optimization modifications) is described in ISO 18589:3 and ISO 20042 standards.
for alpha spectrometry:
We did't perform alpha spectrometry for this sample.
for LSC measurement:
We did't perform LS spectrometry for this sample.

Sample 2: Phosphogypsum

Humidity (%)	(25.6 ± 5.7) %

Describe any sample preparation performed
for gamma spectrometry:
The sample was homogenized throroughly. Three small aliquots were used for the determination of wet/dry ratio with the utilization of a thermobalance @105°C. An aliquot was used to fill 105ml of our standard counting container, with the aid of a special pressing tool. The prepared source was weighed, immobilized and epoxy-aluminum sealed. In our lab, the spectrometric data acquisition for NORM samples is taking place at least 30days after source sealing; for this specific sample (02/bottle 24), measurement happened to take place 59days after sealing. In general, the analytial method applied (after optimization modifications) is described in ISO 18589:3 and ISO 20042 standards.
for alpha spectrometry:
We did't perform alpha spectrometry for this sample.

for LSC measurement:

We did't perform LS spectrometry for this sample.

Reporting Results

Sample 1: Phosphate Ore

Isotope	Activity (Bq/kg dry mass)	Activity Uncertainty 1σ (Bq/kg dry mass) (combined standard uncertainty)	MDA (Bq/kg dry mass)
K-40	30.7	7.2	25
U-238	606	27	11
Th-234	606	27	11
Ra-226	603	25	5.3
Pb-214	598	30	5.3
Bi-214	598	32	6.7
Pb-210	563	28	29
U-235	29.8	1.8	2.4
Ac-227	29.0	1.4	5.9
Th-227	28.6	1.6	5.9
Ra-223	29.4	2.2	6.0
Rn-219	28.7	3.4	7.7
Th-232	48.6	1.9	1.9
Ra-228	45.0	2.8	16
Ac-228	45.0	2.8	16
Th-228	49.6	2.0	1.9
Ra-224	49.7	2.0	1.9
Pb-212	50.3	2.2	1.9
Bi-212	49.1	9.7	40

Tl-208	17.2	1.1	2.4

C_m(K-40):	970	250	800	mg/kg dry
C_m(U-238):	48.7	2.2	0.85	mg/kg dry
C_m(U-235):	0.373	0.022	0.030	mg/kg dry
Enrichment:	0.760	0.055	-	%
Equilibria status:	The members of each one of the U-238, U-235 and Th-232 series were found to be in secular equilibrium. Equilibrium test was performed @ 95% CL.			
Separation/Disturbance date best estimate:	-			

Sample 2: Phosphogypsum

Isotope	Activity (Bq/kg dry mass)	Activity Uncertainty 1σ (Bq/kg dry mass) (combined standard uncertainty)	MDA (Bq/kg dry mass)
K-40	-	-	36
U-238	33.3	3.7	9.8
Th-234	33.3	3.7	9.8
Ra-226	393	24	6.3
Pb-214	391	37	6.3
Bi-214	393	38	8.6

Pb-210	316	29	21
U-235	1.53	0.17	0.45
Ac-227	12.8	1.3	6.3
Th-227	12.2	1.7	6.3
Ra-223	13.6	1.9	6.3
Rn-219	13.3	3.2	9.1
Ra-228	34.7	3.9	15
Ac-228	34.7	3.9	15
Th-228	19.0	1.7	2.3
Ra-224	19.0	1.7	2.3
Pb-212	19.2	2.0	2.3
Tl-208	6.7	1.1	3.0

C_m(K-40):	-	-	1120	mg/kg dry
C_m(U-238):	2.67	0.29	0.79	mg/kg dry
C_m(U-235):	0.0192	0.0021	0.0057	mg/kg dry
Enrichment:	0.71	0.11	-	%
Equilibria status:	None of the U-238, U-235 and Th-232 series was found to be in equilibrium. Equilibrium test was performed @ 95% CL.			
Separation/Disturbance date best estimate:	23.11.2020 ± 234 days (@ 95% CL)			

Questionnaire

1	**Which calibration method is used for determination of the detector efficiency?** *If Monte Carlo simulation is used, please specify the software used*	EGSnrc & Penelope MC calibration. Detector parameters were extracted from CT scan and the standard measurement geometry was fine-tuned with the utilization of CRMs. QC of each calibration and spectrometer in general is taking place periodically.
2	**What is the relative efficiency of the detector used for the analysis?**	26%
3	**Which is the type detector used?**	Broad energy HPGe
4	**Which type of sample container is used for the measurement (i.e. volume, dimensions etc.)?**	In-lab designed and custom produced cylindrical container, of optimized geometry and material for the larger spectrometers-detectors available in our lab. Standard sample volume used: 105ml, container internal diameter: 8.33cm, sample is pressed (if solid) and immobilized in the container by special tool and circular polymer-coated aluminum sheet, void volume above the sample is filled with epoxy resin and the cap is glued too.
5	**Gamma analysis softaware**	Canberra G2K v3.4 (full suite)
6	**Counting time (sec)**	150000
7	**Was a true coincidence correction applied?** *If yes, which software/method did you use?*	True coincidence correction was applied with the use of Canberra LabSOCS in communication with the G2K gamma analysis module. Detailed counting-sample geometry and composition data was inserted in the LabSOCS module.
8	**Was a self absorption correction applied?**	Due to the applied calibration method, separate self-absorption correction is not required. The self-absorpion

	If yes, which software/method did you use?	is always calculated during the MC simulation-calibration of each specific sample in our standard geometry container.
9	**Describe any assumptions made for performing the calculations (e.g. equillibrium considered etc.)**	No assumptions were made, the measurement results were providing, by the first sight, enough information for a clear understanding of the reality.
10	**Does your laboratory apply a Quality Management System?**	Yes
11	**Is your laboratory accredited?**	No

Describe the uncertainties considered (type A and type B)
for gamma spectrometry:
1) uncertainty of the peak area (counting statistics in general) 2) uncertainty from the continuum and peaked background subtraction 3) uncertainty coming from the long-term stability of the spectrometer and/or resulting from its periodic QC in general 4) uncertainty of the nuclear etc. data contained and utilized by the MC codes that are used for spectrometer/sample calibration 5) uncertainty from the sample positioning and the counting geometry in general 6) uncertainty of the mass/dry content determination 7) uncertainty of the sample matrix composition 8) uncertainty due to the fitting of efficiency calibration curve 9) uncertainties on the half life and the emission probabilities of the gamma-rays of the detected/determined nuclides in the sample 10) uncertainty of the true-coincidence correction due to uncertainties in the i) nuclear data used, ii) the characterization of the generic detectors used by LabSOCS for TCS and iii) the TCS correction algorithm in general.
for alpha spectrometry:
We did't perform alpha spectrometry for this sample.

for LSC measurement:
We did't perform LS spectrometry for this sample.