ENVIRA 2023

7th International Conference
on Environmental Radioactivity

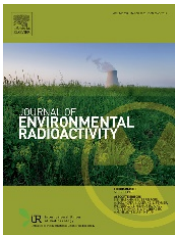
New challenges in the determination of environmental radioactivity

17 – 22 September 2023
Seville, Spain

BOOK OF ABSTRACTS

Organization

Cooperation



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Conference site

Hotel Meliá Sevilla in Seville, Spain
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Programme at a Glance

DAY 1	*Sunday, 17 September 2023*
17:00 – 20:00	Registration
20:00 – 20:30	Welcome party
DAY 2	Monday, 18 September 2023
07:30 – 08:30	Registration
09:00 – 09:30	Opening
09:30 – 11:00	ENVIRA 2023 Award
11:00 – 11:30	Coffee break
11:30 – 13:00	Plenary Session I
13:00 – 14:00	Lunch
14:00 – 16:00	Parallel session 1A
14:00 – 16:00	Parallel session 1B
16:00 – 16:30	Coffee break
16:30 – 18:45	Parallel session 2A
16:30 – 18:45	Parallel session 2B

DAY 3	*Tuesday, 19 September 2023*
08:30 – 11:00	Plenary Session II M. Aoyama Memorial Session I
11:00 – 11:30	Coffee break
11:30 – 13:00	Plenary Session III M. Aoyama Memorial Session II
13:00 – 14:00	Lunch
14:00 – 15:00	Poster session I
15:00 – 16:30	Parallel session 3A
15:00 – 16:30	Parallel session 3B
16:30 – 17:00	Coffee break
17:00 – 18:45	Parallel session 4A
17:00 – 18:45	Parallel session 4B
20:00 – 22:00	Visit and reception Reales Alcázares

DAY 4	*Wednesday, 20 September 2023*
08:30 – 11:00	Plenary Session IV
11:00 – 11:30	Coffee break
11:30 – 13:00	Parallel session 5A
11:30 – 13:00	Parallel session 5B
13:00 – 14:00	Lunch
19:30 – 22:00	Visit and reception Former Tobacco Factory University of Seville

DAY 5	*Thursday, 21 September 2023*
08:30 – 11:00	Plenary Session V
11:00 – 11:30	Coffee break
11:30 – 13:00	Parallel session 6A
11:30 – 13:00	Parallel session 6B
13:00 – 14:00	Lunch
14:00 – 15:00	Poster session II
15:00 – 16:30	Parallel session 7A
15:00 – 16:30	Parallel session 7B
16:30 – 17:00	Coffee break
17:00 – 18:45	Parallel session 8A
17:00 – 18:45	Parallel session 8B
20:30 – 23:00	Gala dinner

DAY 6	*Friday, 22 September 2023*
08:30 – 10:30	Plenary Session VI
10:30 – 11:00	Coffee break
11:00 – 12:30	Parallel session 9A
11:00 – 12:30	Parallel session 9B
12:30 – 13:00	Plenary Session VII
13:00 – 13:30	Closing ceremony Student awards for the best oral and poster presentation ENVIRA 2023

ORAL SESSIONS

01 PLENARY SESSION I

What has been revealed tracing trace radioactive elements after 12 years of Fukushima Nuclear accident

T.M. Nakanishi

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Keywords: Fukushima nuclear accident, agricultural contamination, radioactive cesium movement, 10 years survey, soil and water contamination, mountain contamination

More than ten years has passed sine Fukushima Nuclear Accident occurred. We, researchers in agriculture department in the University of Tokyo, have begun to work right after the accident to know the effect of radioactive materials on agricultural production and still now we are continuing the research, how radioactive cesium has been moving or what kind of the problems are left in the environment, etc. The radioactive contamination was found everywhere in the environment after the accident. However, during these years, radioactivity of the soil, rivers or mountains were gradually decreased. One of the reasons is decontamination of the place. Since the radioactive cesium hardly move from the place where it was adsorbed, the removal of the surface soil could reduce the radioactivity. The mixing the surface soil with the deeper soil could also reduce the radioactivity in the field. The radioactivity of the agricultural products grown in the field was hardly detected a few years after the accident. Now, the only place where decontamination activities were difficult to perform is the mountain area because the area is huge, covering about 70 % of Fukushima prefecture. Therefore, the radioactivity in the mountain is one of the issues gathering the attention of the people now and more research results related to the mountains arecollected.

During these investigation of radioactive cesium in the field, we could develop our own imaging system. Through this system, the real-time dynamic imaging of cesium movement from soil to the plant was visualized. Not only cesium but also the real-time imaging of carbon dioxide movement within the plant was also able to show, which might provide some clue to lead more less energy requirement of the agricultural products.

Fukushima Nuclear Power Plant accident was the first accident occurred at monsoon zone on earth. Though the nuclear power plant accident must not be occurred again, when it happened at template region, the results we presented in the series of 4 books (2013, 2016, 2019 and 2023 from Springer, Co.) will provide the proper way to understand the behaviour of the fallout.

Overview of neutron activation analysis for environmental radioactivity measurements

S. Landsberger[1], N. Kaitschuck[1], G. Bátor[2], T. Kovács[2]

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Keywords: Neutron activation analysis, decay series, uranium, thorium, potassium-40

We determined uranium, thorium and potassium-40 in soil and geological samples through a combination of thermal and epithermal neutron activation analysis (NAA) using the $^{238}U(n,\gamma)^{239}U$, $^{238}U(n,\gamma)^{239}U \rightarrow ^{239}Np$, $^{232}Th(n,\gamma)$ ^{233}Th, and $^{41}K(n,\gamma)^{42}K$ reactions, respectively. In addition NAA was successfully employed to estimate the potential bioconcentration or transfer factors of ^{137}Cs and ^{90}Sr fissions products from soil, to crops, to animals and humans, using the $^{133}Cs(n,\gamma)^{134}Cs$ and $^{86}Sr(n,\gamma)^{87m}Sr$, $^{84}Sr(n,\gamma)^{85}Sr$, reactions respectively. Sample sizes are typically less than a gram with a fast turnaround especially when compared to passive gamma-ray spectrometry counting, and the radionuclides suffer from little or no spectral interferences when using Compton suppression techniques and no nuclear. While disequilibrium may exist in water or technologically enhance naturally occurring radioactive materials (TENORM), these NAA methods are very useful for estimating the gamma-ray emitting radionuclides in the decay series in soil and geological specimens. An overview of these methods will be presented.

Challenges associated with source term and particle releases

B. Salbu

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Keywords: Source term, radionuclides speciation, impact assessments, uncertainties

A series of sources (e.g., nuclear weapons and fuel cycles, NORM) have contributed to release of radionuclides into the environment. To assess environmental impact and risks associated with radioactive contamination, links are usually established between the source term and deposition, ecosystem transfer, biological uptake and effects in exposed organisms. The source term is therefore the starting point in all transport, dose, impact and risk models. The source term is a qualitative and quantitative description of release conditions including emitted radionuclides (% of inventory), and information on the amount (Bq) and physico-chemical forms of key radionuclides released are needed in the assessments. In contrast to aerosol releases, a major fraction of refractory elements such as U and Po is associated with particles, ranging from submicrons to fragments. The particle characteristics will depend on the source and the release scenarios, and localised heterogeneities such as particles will be unevenly distributed in the environment. Representative sampling can be questionable, dissolution of radionuclides from inert particles may be partial, and contamination of ecosystems can be underestimated. The impact and risk assessments may therefore suffer from unacceptable large uncertainties if radioactive particles are ignored. The present paper will focus on sources contributing to releases of radioactive particles and will summarize key factors contributing the most to the overall uncertainties in impact and risk assessments if particles are omitted from models.

02 PARALLEL SESSION 1A

Mass Spectrometry and Radiometrics

High Sensitivity Measurement of ^{238}Pu in Environmental and Nuclear Forensics Collections by Thermal Ionization Mass Spectrometry

K. Hinrichs[1], D. Gurganus[1], A. Price[1], S. Goldstein[1], S. LaMont[1]

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Keywords: Plutonium-238, mass spectrometry, isotope dilution, ratio measurements, alpha spectrometry

Nuclear forensics, nuclear treaty monitoring, and environmental monitoring programs are all interested in measurement of ^{238}Pu with a wide range of potential ^{238}Pu / ^{239}Pu ratios. Measured quantities of ^{238}Pu, especially when considered alongside ^{239,240,241,242}Pu, provide valuable information about the history of a sample, including the type of reactor/event that may have produced it, and/or the age since last purification (via the ^{234}U / ^{238}Pu chronometer). For high level collections, (e.g., bulk plutonium samples), measurement by either alpha spectrometry or various types of mass spectrometry are feasible. However, for low level collections in which total Pu is too low to precisely measure by alpha counting, current practice is to either exclude ^{238}Pu, or to split samples and measure part for ^{238}Pu by alpha spectrometry (due to its shorter half-life) and the other part for ^{239,240,241,242}Pu by mass spectrometry. Splitting samples to accommodate two measurements raises detection limits and increases sample processing efforts. To mitigate these issues, our team has developed a thermal ionization mass spectrometry (TIMS) technique to simultaneously collect data for six Pu isotopes (including ^{244}Pu tracer) along with mass ^{235}U for correction of background ^{238}U interfering on ^{238}Pu. The technique is applied to femto- and picogram levels of purified plutonium in which we have reduced the average background ^{238}U content to ~15 fg. We present data for detection limits and accuracy of the measurement with a comparison to alpha counting, and provide results for environmental reference material ^{238}Pu measurement by TIMS.

Enhancing Field-Deployable Detection Technologies for Nuclear Forensics

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Abstract

Post-explosion forensics of a radiological dispersive device aims to connect people, places, and events for law enforcement and security through the examination of radiological and explosive residue. While quick analysis of the area debris is important for forensic work, the post-explosion and/or radiological residues may be hazardous to personnel who collect and transport samples to laboratories for testing. To enhance nuclear preparedness and emergency response capabilities, Canadian Nuclear Laboratories is advancing portable detection system capabilities to perform in-field, fast, and high quality analysis of samples. High quality preliminary analysis of samples in the field helps ensure the protection of individuals on site while potentially accelerating the forensics analysis process.

The results from the benchmark experiments performed with the cart-portable high-resolution mass spectrometer system in a variety of field environments will be presented. In addition, preliminary comparisons with the portable gamma-ray spectroscopy system will also be presented.

Keywords: Portable mass spectrometry, Portable gamma-ray spectroscopy, Nuclear forensics

Integration of the corrections related to the self-attenuation and true coincidence summing effects in the gamma-ray spectrum analysis software Genie2000

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Keywords: Gamma-ray spectrometry, detection efficiency corrections, Genie2000, environment radioactivity, self-attenuation, true coincidence summing

The Corana tool (Macro Excel VBA) has been developed to process and analyse gamma-ray spectra with the software Genie2000 (Mirion) by integrating both corrections of the effects of self-attenuation and true coincidence summing (TCS) on the detection efficiency, far from being negligible (up to several tens of percent).

The self-attenuation correction factors FC_{att} depend on the photon energy, the sample matrix and the counting geometry size. They have been determined analytically using experimental attenuation coefficients determined for 1000 samples measured over the lats 10 year, and equivalent thicknesses accounting for the close-detector measurement configuration. FC_{att}'s have been determined for 7 sample categories (biological/mineral, dry/ashes…), energies from 30 to 1700 keV and 7 counting geometries. The TCS correction factors FC_{coinc} depend on the radionuclide decay scheme and on the emission energy. They have been calculated by simulation using a photon transport Monte Carlo type code for 90 emissions of 56 radionuclides, 3 detector types representative of 15 HPGe detectors and 7 counting geometries.

The corrections are made on the emission intensities of the nuclides directly in the nuclide library used by Genie 2000. The spectrum analysis is then performed using a temporary library containing the "corrected" intensities allowing a better interference management and giving activities by emission more consistent and finally a more robust mean activity value. The tool has been validated with the measurements of 38 radionuclides in different samples, before being used in the framework of international proficiency tests.

Optimization of a liquid scintillation spectrometer Quantulus GCT 6220 for the measurement of environmental levels of tritium in water samples

J. L. García-León[1,2], G. Manjón[1], M. García-León[2], J. Rivera-Silva[3]

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Keywords: Environmental applications, liquid scintillation counting, tritium

Some environmental studies involve the measurement of low levels of tritium in water samples. Liquid scintillation counting (LSC) is a technique traditionally used to determine these levels of tritium. In this work, a liquid scintillator spectrometer Quantulus GCT 6220, from CITIUS was optimised for the determination of environmental levels of tritium in water samples.

A new scintillation cocktail, Hidex ProSafe LT+, was used as it is recommended for the measurement of low levels of tritium due to its higher capacity for aqueous samples compared to conventional scintillators.

The different background reduction systems of the Quantulus GCT 6220 were studied and their impact on the counting efficiency and the minimum detectable activity (MDA) addressed. The resulting background reduction procedure is presented in this work.

The optimization of MDA was successful, achieving a typical value of 0.10 Bq/ℓ for a measurement time of 10h, with an efficiency of 0.174±0.017. The MDA reached using this new procedure was compared to those obtained with a Quantulus 1220, a well-known liquid scintillation spectrometer.

With the background reduction procedure proposed in this work, the Quantulus GCT 6220 becomes a competitive solution when environmental levels of tritium must be measured.

Exploratory Analysis of Gamma Spectrometry and EDXRF Applied to Soil Redistribution Evaluation in Agricultural Areas

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Keywords: EDXRF, gamma spectrometry, principal component analysis, soil erosion

With the population continuous growth worldwide, studies focused on agriculture and food production became more common. In this context, it is fundamental to evaluate soil loss caused by erosion, since it greatly impacts on crops productivity. Gamma-ray spectrometry and energy dispersive X-ray fluorescence (EDXRF) are two techniques that are commonly applied to soil analysis. In this study, both techniques were employed to understand the erosion effects occurred in a no-tillage cultivation area.

This research aimed to determine the macro and micro-nutrients found in soil and compare them with the ^{137}Cs distribution. We hypothesized that it is possible to study the erosive effects experienced through soil's composition and profile analysis using EDXRF, which is faster and cheaper than gamma-ray spectrometry. From the agricultural field, nine spots were selected and 300 g soil samples were collected in three different depths ranging from 0 to 30 cm. Performing the analysis over three soil profiles instead of just one sample per spot makes it possible to get more detailed informations about the cumulative erosion and deposition effects over the years. Approximately 10 g of each sample was taken to perform EDXRF and determine its composition. The quantified elements were Al, Si, P, S, K, Ca, Ti, Mn, Fe, Cu, Zn, Sr and Zn.

Once the ^{137}Cs amount on each sample was determined, exploratory analysis was performed over all the data regarding the soil composition. The Principal Component Analysis (PCA) is a chemometric technique that reduces the dimensions of large datasets and allow the researcher to evaluate the influence of each variable and group samples based on their similarity. The PCA findings corroborated the results determined by the ^{137}Cs inventory analysis. Moreover, PCA evidenced the tendencies of dependence between the detected elements and ^{137}Cs. The results also showed that two of the analyzed spots suffered so much erosion in the past few decades that their horizon profile shifted from organic to mineral.

By excluding the ^{137}Cs contribution in the PCA, the samples distribution did not change. Therefore, this result implies that soil erosion evaluation may be performed by analyzing soil's macro and micro-nutrients through EDXRF. These findings indicate the EDXRF quantification results can lead to conclusions about the soil redistribution which were confirmed by the inventory analysis. Therefore, EDXRF combined with PCA may be an alternative method for soil loss and erosive processes evaluation.

A practical and general methodology for efficiency calibration of coaxial Ge detectors by using NORM standards

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Keywords: Gamma-ray spectrometry, Efficiency calibration, Artificial and natural radionuclides, True coincidence summing, Self-absorption, Dead time

The proper measurement of natural and artificial radionuclides (such as ^{152}Eu, ^{137,134}Cs, ^{60,57}Co, ^{234,228}Th, ^{228,226}Ra, ^{210}Pb and ^{40}K) is very important for many research fields related to Environmental Radioactivity. Therefore, the aim of this study is to develop a practical methodology in order to obtain a general function for the full-energy peak efficiency (*FEPE*) by gamma-ray spectrometry using coaxial Ge detectors, which allows us to determine both artificial and natural radionuclides. For this, calibration standards containing only natural radionuclides were used, where certified reference materials such as RGU-1, RGTh-1 and RGK-1, provided by the International Atomic Energy Agency (IAEA), were selected containing only radionuclides belonging to the ^{238}U- and ^{232}Th-series, as well as ^{40}K, respectively. Firstly, for the calibration standards, an efficiency function depending on standard thickness (h) and energy (E_γ) was obtained, which was validated for several sample types which contain artificial and natural radionuclides. However, for energies affected by true coincidence summing (TCS) effects, the results were not proper. Consequently, a methodology to correct TCS effects was developed varying the distance between the sample bottom and the detector window (d), obtaining a general efficiency function $\varepsilon_c(E_\gamma, d)$ for h = 25 mm. By using this methodology, it was also possible to improve the self-absorption effect corrections provided by the Cutshall's model for very dense samples, as well as to reduce the detector dead time for very active samples. The $\varepsilon_c(E_\gamma, d, h = 25\text{ mm})$ function was validated using a very wide variety of samples containing artificial and natural radionuclides.

Major elements, radioactivity assessment and the dose rate in arable and grazing land from south-eastern part of Romania

Ileana Radulescu[1], Rasvan Stochici[2], Antonio-Andrei Sofron[1], Dragos Alexandru Mirea[1]
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[2]Institute of Geodynamics of the Romanian Academy, Bucharest, Romania

Keywords: Distribution of NOR; radon; uranium; thorium; arable and grazing land

Results from in situ and laboratory measurements on soil samples from south-eastern part of Romania are presented in this paper. Since there is a lack of data for Romania in the European Atlas of Natural Radiation (EANR) regarding concentration of the natural occurring radionuclides (NOR) and possible artificial contamination in Romanian arable and grazing land, campaigns to collect and provide these data have been started in 2022. Thus, using a portable gamma ray spectrometer, but also collecting soil samples for laboratory measurements for detailed data have been considered using techniques such as XRF and ICP-MS for the determination of different elements: Mg, Al, Si, P, S, K, Ca, Ti, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, As, Rb, Sr, Y, Zr, Nb, Mo, Ba, Pb, Th. In addition, in situ levels of radon were measured and correlation were performed for each type of soils.

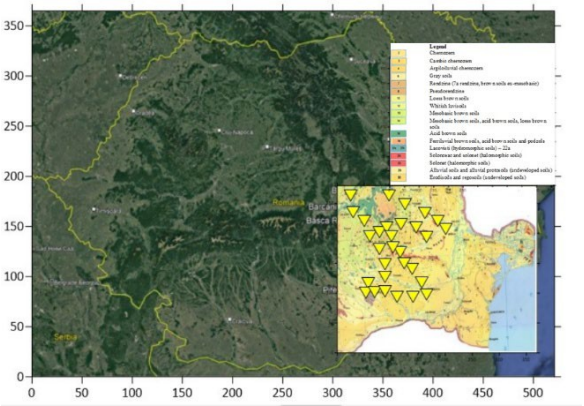

Figure 1 – The soil area investigated in the first campaign

The creation of distribution maps for radiometric and chemical data represents a starting point to address the missing data for Romania from EANR. The need for the results of these remeasurements rise from the Articles 2 and 30 of the Euratom Treaty (European Union, 2016) which empower the Community to establish uniform basic safety standards to protect the health of the general public against dangers arising from ionizing radiations.

03 PARALLEL SESSION 1B

The role of soil weathering on radiocesium (^{137}Cs) soil-plant transfer: a pot trial study with soil toposequences

M. Vanheukelom[1,2], P. Steegmans[1,2], A. Van Gompel[1], M. Van Hees[1], J. Wannijn[1], T. Al Mahaini[1], L. Sweeck[1], E. Smolders[2]

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Keywords: Concentration Ratio (CR), Radiocesium Interception Potential (RIP), soil toposequence, ryegrass, soil development.

Process-based models to predict the transfer of radiocesium (^{137}Cs) from soil to plants are made after the Chernobyl and Fukushima accidents. These models are unlikely to make predictions worldwide because they only consider soils at similar stages of development, and do not cover soils contrasting in parent material and weathering degree. Topsoils of seven different toposequences (N = 51 soil samples) were selected from Chile, France, Guatemala, Kenya, Philippines, Spain and Vietnam so that the role of weathering stage on the fate of ^{137}Cs could be elucidated. Relevant soil properties, such as mineralogy and *radiocesium interception potential* (*RIP*), i.e. ^{137}Cs selective adsorption, were determined. Next, a pot experiment was set up in which ryegrass grew on ^{137}Cs-spiked soils from Kenya and the Philippines that exhibited the best weathering sequence. Because K competes with ^{137}Cs for plant uptake, soils were studied both with and without K fertilization. The soil RIP varied from 45.3-5680 mmol kg^{-1} and more importantly, the RIP per unit clay varied strongly between 142-36000 mmol kg^{-1} (Figure 1). Indeed, the role of weathering stage was confirmed as younger soils, i.e. higher altitude on the toposequence, had 10–fold smaller RIP per unit of clay than at the base. In youngest soils with limited clay mineral weathering, the ^{137}Cs adsorption and K-buffer capacity is limited. As the soil develops, more weathered edges develop and K-buffering increases while in highest weathered soils, these layered minerals have disappeared and K-buffering again drops. In K-deficient, young and

highly weathered soils, more ^{137}Cs will be taken up by plants and countermeasures like K fertilization will have less effect. This implies that the ^{137}Cs contamination scenarios as we know from temperate regions are very different from those in tropical regions. Practically, our findings can be used to adjust ^{137}Cs transfer models to effectively predict the risk of ^{137}Cs entering our food chain in case of nuclear incidents worldwide.

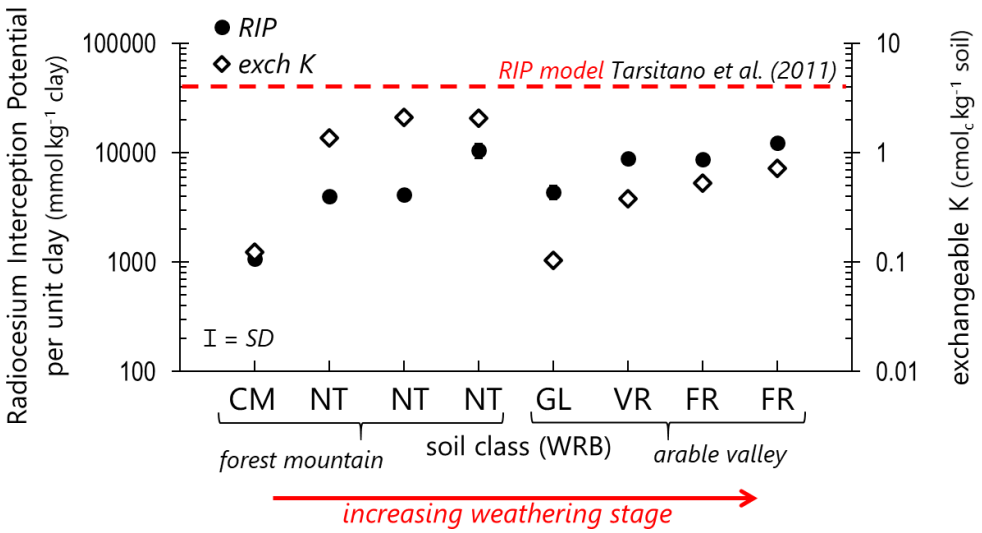

Figure 1. ^{137}Cs adsorption (left) and K-buffering (right) in Kenyan soils vary with soil development.

Isotopic signatures of plutonium in the global cryosphere

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Keywords: Plutonium, Isotopic ratio, Mass ratio, Cryoconite, Glaciers

This work provides new insights about the accumulation and source of Plutonium isotopes found in cryoconite, the sediment forming on the melting surface of glaciers. Plutonium isotopes (^{238}Pu, ^{239}Pu, ^{240}Pu) have been measured in cryoconite collected from 11 glaciated regions of the Earth, providing for the first time a global overview on the distribution and source of this artificial radioactive element. Results confirm a widespread occurrence of Pu isotopes in cryoconite from the two hemispheres, confirming the unabated efficiency of cryoconite in accumulating fallout radionuclides. In cryoconite the activity concentration of plutonium is orders of magnitude higher than those detected in other environmental matrices, raising issues on the role of glaciers, and specifically cryoconite, in concentrating legacy radioactive pollutants released by glaciers in the context of climate change and glacier retreat. The inspection of activity ratios (^{238}Pu/$^{239+240}$Pu) allowed to gather information about the original source of Pu found in cryoconite. Results show that the plutonium-related radioactivity of cryoconite from the considered glaciers is mostly compatible with the global signal of stratospheric fallout. An excess of ^{238}Pu is observed in cryoconite from the Exploradores Glacier in the Chilean Patagonia. We hypothesize that this could be associated with satellite “Mars’96” which was launched on 16 November 1996, an event whose isotopic signature had never been observed before.

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Kinetic reactive transport of radionuclides at the sediment-water interface: Numerical model and applications

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Keywords: Surficial sediments; uptake kinetics; reactive transport; early compaction; eddy diffusivity.

This work aims to improve our understanding of the distinct behaviour of different radionuclides at the sediment-water interface (SWI). A numerical model has been developed to this end. Its formulation merges early diagenetic processes and box-models for the uptake kinetics, and it has been applied to synthetic scenarios. The kinetics of the uptake of pollutants by solids interacts with the transitional eddy diffusivity in the pore fluid, leading to different depth-distribution patterns. The model has been applied to study: i) ^{210}Pb and Chernobyl fallout radionuclides in Lake Sniardwy; ii) ^{7}Be in sediments from Tema Harbour; iii) ^{236}U, ^{137}Cs, and ^{239,240}Pu in the Esk estuary.

Transitional eddy diffusivity explains the observed large penetration depths for ^{137}Cs and ^{7}Be, while high particle-reactive elements, such as ^{210}Pb, ^{144}Ce, and ^{239,240}Pu, are retained in thinner sediment layers. The desorption of ^{137}Cs from the Sniardwy sediments occurs through the pore fluid as diffusive fluxes. Transient depth profiles of ^{137}Cs concentrations can last from months up to a year, and they can show subsurface maxima at positions unrelated with the accretion rate. The model has been adapted to simulate the transition from mobile U(VI) to highly particle-reactive U(IV) in the anoxic zone of the sediment, producing a subsurface deposition pattern, as shown in the sediment core from the Esk estuary.

A detailed chronology of the sedimentation in the Danube abyssal fan records the major episodes of the late-Holocene Black Sea evolution

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Keywords: AMS, Anoxic sediments, Sedimentation rate, Marine radioactivity, Black sea, Late holocene

The construction for the high-resolution Bayesian sedimentation model spanning the last 5500 years based on 25 AMS radiocarbon dated sediments of bulk organic matter (OM) sampled from the NW Black Sea anoxic waters of the continental slope is presented in this paperwork. The corrections for the 14C ages due to marine reservoir effect (MRE) and detritus organic carbon are correlated with exogenous information such as 210Pb dating, metallurgy pollution and human-induced soil erosion, highlighting the Danube influence on the geochemistry and chronology of the NW Black Sea sediments thro ugh the input of terrigenous organic matter.

The results show excellent agreement with some of the previous studies, supporting a total age offset for the bulk OM of 60 years as MRE and 580 years as detritus organic carbon influence. The revisited chronology pinpoints the first and second invasion of the coccolitho-phores Emiliania huxleyi at 2524 ± 87 and 625 ± 65 years cal. BP. The sedimentation rate shows an increase of about three times with the starting of the late Medieval, which corresponds to the highest observed sediment discharge of the Danube as are considered the last 500-300 years. This type of high-resolution sedimentation model is an important step for constructing the carbon budget in bottom waters of variable oxygen concentration.

Pioneering tracer application of anthropogenic U-233 and U-236 in the marine environment

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Keywords: ^{233}U, ^{236}U, tracer application, marine environnement

In recent years, the application of anthropogenic ^{233}U-^{236}U as a new tracer pair has been increasingly adopted, especially in the marine environment. This is due to their conservative behavior, long residence time in the ocean (10^5y) and unique fingerprint of their isotopic ratios. Since 2013, we have carried out a series of studies on the tracer application of anthropogenic ^{233}U-^{236}U in the Baltic Sea, the Pacific Ocean and the Arctic Ocean. Our findings demonstrate the potential of this tracer pair in identifying radioactive source terms, reconstructing historical nuclear activities, benchmarking age-depth model for sediment chronology, tracing ocean circulation pathways and transit times, quantifying water mass composition and estimating pollutant/nutrient dynamics. This paper presents an overview of our research on ^{233}U-^{236}U tracer application, and discusses the implications for future environmental tracer studies.

Field studies on the influence of environmental factors on I - 131 interception and weathering loss in grass

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Keywords: I-131 tracer, grass, interception fraction, weathering loss

A series of ^{131}I tracer experiments have been conducted at two research stations in Norway, one coastal and one inland to study radioiodine transfer and dynamics in boreal, agricultural ecosystems. The hypothesis tested was that site specific and climatological factors, along with growth stage, would influence foliar uptake of ^{131}I by grass and its subsequent loss. Climatological factors (precipitation, wind-speed and temperature) appeared to affect the dynamics of ^{131}I in the system, however the decomposition of these collective influences into specific contributions from each factor remains unresolved and requires further study. The study produced a wide range of interception fractions and revealed a strong positive correlation between those fractions and stage of growth. The role of stable iodine on uptake of ^{131}I was also investigated. Whilst stable iodine concentrations in grass and soil were significantly higher at the coastal compared to the inland site, it was not possible to deconvolute the influence of this factor on the temporal behaviour of ^{131}I. The outcomes of this study have provided new knowledge on the interception and weathering of radioiodine in boreal, agricultural ecosystems which is a substantial contribution to the modelling toolbox available for Norwegian emergency preparedness in the event of a nuclear accident.

Phosphorus turnover in the Yangtze estuary and adjacent East China sea using Cosmogenic ^{32}P and ^{33}P

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Keywords: Phosphorus; ^{32}P; ^{33}P; turnover time; Yangtze estuary

Phosphorus is an essential bio-limiting macronutrient required for living organisms in marine ecosystems. However, research on the controls of P turnover rate in the eutrophic and hypoxic aquatic environments of the Yangtze estuary is so far missing, and the regulate mechanism is still unclear. Here, we have estimated in situ phosphorus-turnover rates by measuring the activities of two cosmogenic radionuclides ^{32}P ($t_{1/2}$ = 14.3 days) and ^{33}P ($t_{1/2}$ = 25.3 days) in total dissolved P (TDP), suspended particulate matter (SPM), net-plankton and rainwater during the spring of 2022. A two-dimensional model was used to evaluate the setting or resuspension flux of particles in the wate column in the Yangtze estuary, the scavenging time of ^{32}P and ^{33}P were 0.59 and 0.54 days, and the removal times of ^{32}P and ^{33}P were 2.7 and 3.0 days. A continuous steady-state model was used to estimate residence times of various phosphorus pools and uptake rates of the biological food chain in the Yangtze estuary and adjacent East China sea. The residence times of P in the dissolved pools gradually increased from 4.6 days in the estuarine to 8.6 days in the open sea, which suggests that TDP has rapid turnover rates in the estuary water, and even if low TDP concentrations can support relatively higher levels of primary productivity. $^{33}P/^{32}P$ ratios increased from the dissolved pools to SPM and to net-plankton, indicating that P turnover time increased as one moved up through the food chain. In addition, $^{33}P/^{32}P$ ratios of small particle size SPM is significantly higher than that of large particle size SPM in the mixed area of saltwater and freshwater in estuaries, indicating that the age of small particle size SPM is older than that of large particle size SPM, which likely due to the hydrodynamic effect and sediment resuspension delay the residence time of small particle size particles in the nearshore waters of estuaries.

Transport and transformation of ^{137}Cs from freshwater to coastal water

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Keywords: ^{137}Cs, speciation, transport, transformation, river, coastal water.

Norway was heavily affected by fallout of ^{137}Cs after the Chernobyl accident and recent studies have shown that the Vefsnfjord is among the fjords with the highest activity concentrations in the water column and sediments. The Vefsna river flows into the Vefsnfjord, forming an estuarine circulation environment with brackish surface layer with increasing salinity from the inner to the outer part of the fjord above a sub-surface high-salinity countercurrent flow restricted by several threshold sills.

In this study, we have characterized ^{137}Cs contamination in lakes in the Vefsna catchment area, in the river Vefsna and in the Vefsnfjord during three field campaigns (2020-2022). Results show that the activity concentration of ^{137}Cs in four of the lakes located in the upper part of the catchment ranged from 8 to 50 Bq/m^3 in water and 3 to 10 kBq/kg in surface sediments. The activity concentration of dissolved ^{137}Cs in river water ranged from 2 to 10 Bq/m^3 and ^{137}Cs associated with particles suspended in the river water ranged from 130 -500 Bq/kg (0.2-3.2 Bq/m^3) and both the dissolved and the particulate ^{137}Cs were highly variable during flooding events. During low flow, ^{137}Cs was mainly present as LMM species (>85 %) in the river water, while during high flow a larger fraction was associated with the colloidal fraction (32 %) and the particulate fraction (20-39 %).

In the Vefnsfjord, however, the activity concentration of ^{137}Cs was observed to be lower than in river Vefsna, decreasing with increasing salinity, reflecting mixing with fjord water and dilution. In the brackish water, only ^{137}Cs associated with LMM fraction and particulate fraction was observed, indicating both aggregation and remobilization of ^{137}Cs from the colloidal fraction. In Vefsnfjord, the particulate fraction of ^{137}Cs in the estuarine water was significant after periods with flooding events in river Vefsna, the ^{137}Cs in sediments was significant and seaweed samples showed bioaccumulation of ^{137}Cs, and the activity concentrations decreased outwards the fjord. Results indicate that more than 30 years after the deposition, ^{137}Cs is still transported from the catchment via river water to coastal water, and that ^{137}Cs is redistributed from the colloidal fraction to the LMM rather than particulate fractions in the coastal water. The work contributes with information about the transport of ^{137}Cs from freshwater to coastal water and the impact of environmental factors which is important to take into account in marine transport models.

04 PARALLEL SESSION 2A

Quality Assurance and Quality Control

Lessons learned by PT organizer and how can be used by the laboratories in the processes of their improvement

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Keywords: water, sea, environmental samples, gross alpha and beta activity, high resolution gamma spectrometry, liquid scintillation spectrometry, tritium, radiocarbom, gamma emitters, proficiency test, certifie reference material, IARMA, QA/QC

Today, PTs (Proficiency tests) and CRMs (Certified Reference Matrials) are an indispensable component of both commercial and research laboratories, as they must constantly prove the quality of their analyzes and their traceability to basic units. CRMs are used to check their calibrations while analytical methods are tested by PTs. Good results on PT tests are proof of the good work of the laboratory, while poor results are a new challenge and an opportunity for improvement. As a rule, results with a grade of W (worning) or N (not acceptable) are sporadic and often difficult to compare with each other, so that the cause of them is sometimes difficult to discover. A set of results suitable for statistical processing could be useful in this regard. An individual laboratory needs many years or even decades to acquire enough data of this kind. The PT organizer can help with this, as he collects data from many laboratories for each PT. How should the organizer prepare the PTs and what information should he obtain from the participants in order to be able to constructively and actively participate in the evaluation of results, improvement of methods, QA/QC systems and the entire performance of the laboratories? We will answer these questions and comment other dilemmas on the example of IARMA, a relatively young and small PT organizer and CRM provider. It has been on the global market for 10 years. During this time, 148 different samples of various types of waters and other matrices (hay, seagrass, soil, mushrooms) were prepared, for which around 7700 results were collected.

Characterization of Am-241 spiked concrete samples as reference material for an alpha emitter remote sensing system

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Keywords: Alpha radiation, Radioluminescence

The project *RemoteALPHA* focuses on the detection of alpha radiation in the environment. Until now, contaminations by purely alpha emitting radionuclides were measured by hand causing considerable risk to the emergency team. In air, alpha particles have a range of only a few centimetres, making it difficult to detect them in a topological area such as the environment. As a possible solution we take advantage of a secondary effect of alpha radiation in air. Alpha particles interact with atmospheric gases, mainly with nitrogen due its share of 78%. By relaxation of the electron from the excited nitrogen, a UV-photon is emitted. An optical system mounted on a drone, which detects these UV-photons, will overcome many problems. To test the optical system, common environmental surfaces were contaminated with ^{241}Am and characterized using conventional alpha detection methods.

This presentation will focus on the measurement of contaminations of concrete samples. The amount of detectable alpha particles depends on various parameters of the concrete, surface roughness being the most relevant one. The rougher the surface, the lower the recovery. Also the water-to-cement-ratio and the way of radionuclide deposition on the surface affect the recovery rate. Concrete samples with varying amounts of activity and a known surface count rate were measured with the optical detection system to test and further improve its sensitivity.

Development of Voluntary Consensus Standards and Measurement Support for NORM/ TENORM Applications

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In the United States, Naturally Occurring Radioactive Materials (NORM) and Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) are predominantly regulated by the state in which the organization is managing the material. This can result in a wide variety of approaches to NORM / TENORM across the United States. Our ASTM International D19.04 Subcommittee (Water / Methods of Radiochemical Analysis) is primarily focused on voluntary consensus standards to assist in appropriately characterizing the radioactive constituents of NORM / TENORM.

The ASTM D19.04 Subcommittee has been advised that organizations needing to manage (NORM) and (TENORM) may benefit from using existing approved standards and the development of new voluntary consensus standards on the topic. As may be needed by a relevant sector, specific collections of applicable ASTM standards can be periodically made available in hard-copy or digital formats for easier use.

To support traceable measurements for NORM/TENORM characterization, Eckert and Ziegler Analytics, Inc. (EZA) has established a program for providing relevant reference materials, calibration standards, and proficiency testing samples. Uranium, thorium, radium and 210Pb containing materials can be available for NORM/TENORM applications. Uranium and thorium materials in equilibrium with their respective decay products are under evaluation.

EZA pitchblende material is analyzed at Oak Ridge National Laboratory for uranium content, isotopic abundance and trace element content. Uranium concentration was measured by Davies and Gray titration and the isotopic abundance by thermal ionization mass spectrometry (TIMS). Trace elements were quantified by first removing the uranium matrix on a UTEVA column followed by analysis by inductively coupled plasma-mass spectrometry (ICP-MS) or ICP-optical emission spectroscopy.

Solid matrices for the preparation of calibration standards and proficiency testing samples are available in a 0.5 – 3.5 g/cm3 density range, including Olivine (low NORM material, Σ NORM isotopes < 12 mBq/g).

There is a capability to manufacture 1mx1m flat sources to facilitate custom indoor/outdoor in-situ calibrations and proficiency testing measurements. The possibility of needing to calibrate and perform measurements with drone-based instrumentation will also be considered. The EZA NORM Program is being developed under an ISO 9001, ISO 17025, ISO 17034 and ISO 17043 environment. MARLAP, MARSSIM and MARSAME recommendations are also being considered.

ASTM D19.04 and EZA are determined to assist the organizations managing NORM / TENORM to do so in a consistent and responsible manner.

Preparation of polonium-210 and carbon 14 seafood reference material and the labs intercomparison radiochemical analysis

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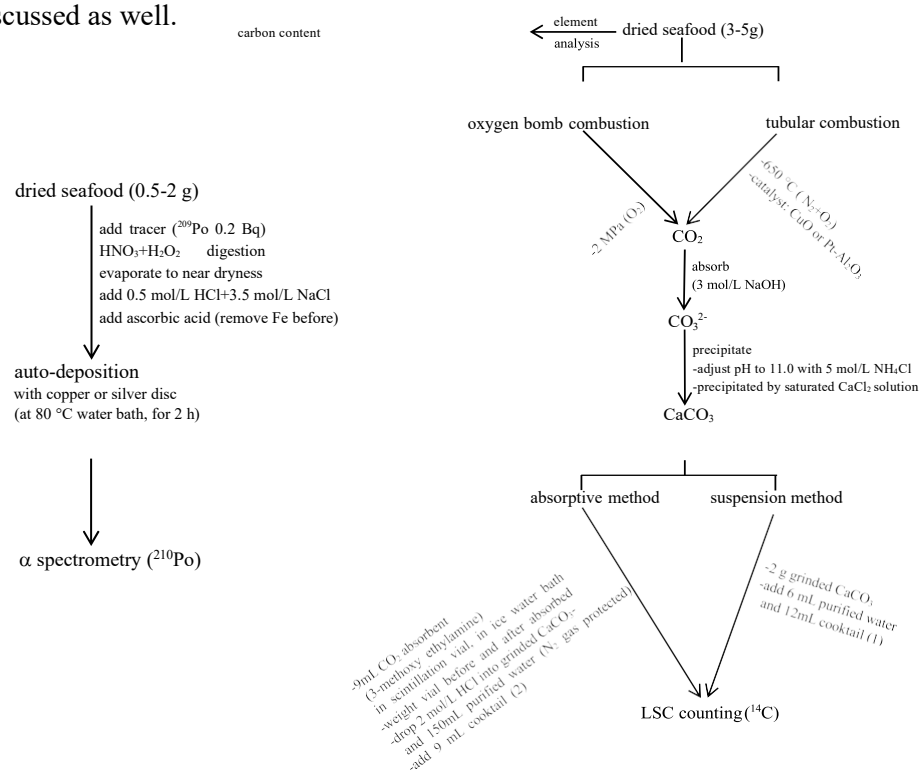
Keywords: Po-210, C-14, seafood, radionuclides, quality control

The natural radionuclide ^{210}Po (T1/2 = 138.4 d) is one of the decay products originating from ^{238}U. Owing to its relatively high activity concentrations in certain foods (such as accumulated in sea fish and mussels) and its relatively high ingestion dose coefficient, ^{210}Po has been of great concern from the viewpoint of a radiation protection to the human body. IAEA summarised that contributions to annual ingested dose from radionuclides in diet (excluding ^{40}K), ^{210}Po is about 52%, the main three artificial radionuclides included carbon 14 (3%). Regarding 14C (T1/2 = 5730 y), it has been considered a key radionuclide from the discharge of NPPs, as well as the waste after a nuclear accident (i.e. Fukushima Daiichi NPP in 2011). The both ^{210}Po and ^{14}C activity concentrations are important for establishing the relevant standards for the limits/reference level of radionuclides in foodstuff. This work is for the purpose of quality control to precisely determine both ^{210}Po and ^{14}C in seafood, while organized nationwide radioactivity monitoring in foodstuffs samples in China. The sample of oysters was selected from the Fujian coast, China. After shelled, water cleaned, dried at 80 °C, jet milled and blended at about 250 m, filled bottles and gamma ray irradiation sterilized with a total dose of 25kGy using a 60Co source. A unit of the sample consists of approximately 150 gram of dried oyster powder. The activity concentration of ^{210}Pb and ^{210}Po were pre-measured by LSC to confirm the ^{210}Pb less interference to ^{210}Po.

The batch experiments for the stability and uniformity performed using spontaneous auto-deposition onto metal surfaces and the spectrum about ^{210}Po,

combustion and LSC measurement about ^{14}C, respectively. The minimum sample amount for the measurement is about 0.5 gram for ^{210}Po, 3.0 gram for ^{14}C under the satisfaction uncertainty. The innovative procedure of determination of ^{14}C in seafood will be presented.

A description of the material collection and preparation, uncertainty analysis and the defined results of the 6 labs interlaboratory comparison will be presented and discussed as well.



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Development and application of a passive monitoring network for mapping 3D profiles of airborne HTO inside a nuclear facility

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Keywords: Tritium, Passive sampler, LSC, Nuclear facility

Global warming is driving a renaissance of civil nuclear energy use, but it may also lead to more complicated tritium contamination issues in the near future. It is thus imperative to comprehensively understand the airborne tritiated water vapor (HTO) dynamics in nuclear facilities for better radiation protection management and accident preparation. Despite great effort, mapping the 3D profiles of HTO inside nuclear facilities with a high temporal resolution remains greatly challenging due to the technical limitations in representative sampling and rapid HTO analysis.

In this study, a new passive monitoring network, including a modifiable passive sampler and a rapid method for passively-collected HTO analysis, was developed and optimized. Bench-scale experiments showed our sampler can representatively collect sufficient samples under different monitoring demands, and the method is able to simultaneously prepare a large number of samples in about one day. In addition, we validated the network's feasibility and sensitivity by implementing the passive matrix in multiple tritium-contaminated rooms. By constructing a 3D monitoring network in a nuclear reactor hall, we obtained the spatial profiles of HTO with a daily resolution for the first time. The tritium release rate estimated by measured date agreed well with the theoretically-derived one, suggesting no tritium leakage problem in investigated hall. Overall, we present a new framework for the rapid identification of tritium sources and characterization of tritium contamination profiles in any indoor environment, which will provide fundamental information for future prevention and control of tritium contamination in nuclear facilities.

A thermoluminescent dosimeter (TLD) method for ^{137}Cs activity concentration profiling

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Keywords: Vertical distribution, Inversion, Bayesian, characterization, Tikhonov

This study introduces a cost-effective dosimetry-based method for assessing the activity concentration depth-profiles in soils, which is crucial for site characterization. Traditional techniques are labor-intensive and expensive. The proposed method employs lithium fluoride (LiF) based thermoluminescent dosimeters (TLDs), which are passive, compact, and sensitive. To address the inability to detect individual radionuclides from dosimetry data, the natural background dose is calculated using the TLDs' dose uptake efficiency and activity concentration of natural radionuclides from soil samples. Monte Carlo simulation with the PENELOPE code is used to estimate the TLD dose uptake efficiency. The net dose from the contaminant, mainly ^{137}Cs in the presented case study, is obtained by subtracting the natural background dose from the measured doses. Tikhonov regularization and Bayesian inversion using a Gaussian process prior are employed to calculate ^{137}Cs activity concentration-depth profiles. A strong agreement between soil sample lab analyses and the TLD dosimetry-based results was observed when comparing the obtained ^{137}Cs activity concentrations. Additionally, ^{137}Cs activity concentration from the dosimetry method mostly fell within the 95% credible interval of in situ gamma spectrometry results. While Tikhonov regularization produced over-regularized profiles in some cases, the Bayesian inversion method produced realistic profiles and uncertainty estimates. The TLD dosimetry-based method proves effective for determining radioactivity concentration distribution in soils when prior information about the natural background and radionuclide composition is available.

Harmonization of detection limits for radioactivity concentrations in water in D&D situations

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Keywords: Radioactivity, Water, D&D, Detection limits

The decommissioning that is being initiated and/or scheduled for a large part of the nuclear power plants (NPP) reaching the end of their operative life, poses several challenges for radioactivity measurement laboratories involved in environmental radiation monitoring plans. One of them is the definition of the detection limits to be reached for the radionuclides analysis in different samples.

The detection limit established should be able to meet the goal of the monitoring plan so that the measured concentration values are easily distinguished from certain maximum activity concentration levels for each radionuclide. These maximum activity concentration levels are usually set in view of the respective dose contributions from each radionuclide.

Having a look at the detection limits required for water, we can find the WHO values for drinking water, accepted for most national legislations. But, if we look at detection limits required for groundwater or superficial water, there is no regulation containing neither maximum activity concentration levels nor detection limits. This way, different institutions or companies require very different detection limits for radioactivity concentration assessment in those kind of water associated with dismantling and decommissioning (D&D) activities.

In this work we focus on the detection limits required for the D&D activities in surface and groundwater. We propose detection limits obtained by applying the methodology developed by WHO and compare with those requested by radioactive waste management agencies or regulatory agencies, paying special attention to Ni-63 and Fe-55. Conclusions concerning the advantages and disadvantages of the different approaches are derived.

Variation of photon absorption and the buildup factors in GSO(Ce) Scintillation Detectors.

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Keywords: GSO(Ce), Effective atomic number, Exposure buildup factor EBF.
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Abstract;
Radiation measurements by scintillation detectors is an important issue used in various fields especially in health sectors. GSO(Ce) is an effective scintillation detector widely used for their mechanical and radiation characteristics. The precise of radiation measurements is affected by the buildup factors generated when radiation penetrated the material. Experimentally, the buildup factor is defined as the ratio of the collided radiation to the un collided measured radiation. And theoretically, different techniques were developed to ease these factors calculations. In this work, we estimate the photon absorption and their buildup factors for GSO(Ce) detectors as a function of Ce concentrations (0.5, up to 5 mole) for selected energies using Phy-X /PSD software and MNCP Monte Carlo codes. The results show that both Exposure build-up factors (EBF) and Energy absorption buildup factors (EABF) decreased with increasing photon energies and increasing with increasing detector thickness. Moreover, increasing the Ce concentration in the GSO crystal increased the buildup factors for incident photons with energies up to (1MeV) and decreased these values for higher photon energies.
The present calculations are essential in estimating the optimum composition of GSO(Ce) useful in photon detection.

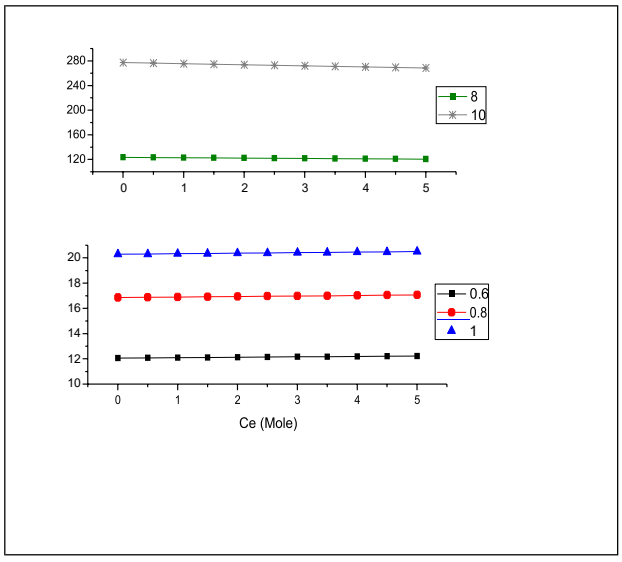

Figure 1. The Exposure Buildup Factors for GSO(Ce) detectors with different Ce concentration using photons with energies (0.6, 0.8, 1, 8, 10)MeV

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IAEA-coordinated Research Helps to Improve Quality of Radionuclide Measurements in Arid and Semi-Arid Environments

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Keywords: Radioecology, radionuclides, transfer factors, arid and semi-arid environments, proficiency testing

Assisting its Member States in enhancing their radioanalytical capacities and assuring the quality of radioecological data are important programmatic activities of the International Atomic Energy Agency (IAEA). Since 2021, the IAEA has run a coordinated research project (CRP) K41022 on 'Transfer of Radionuclides in Arid and Semi-Arid Environments for Radiological Environmental Impact Assessment'. The CRP focuses on obtaining radioecological data via experimental and field studies related to transfer of radionuclides in arid and semi-arid climatic conditions and involves 12 Member States. The main project activity will be to enhance soil-to-plant transfer parameter datasets which are required for radiological environmental impact assessments (REIA) and support effective decision-making for radiological protection of the public and the environment. The targeted radionuclides include natural isotopes of Th, U, Ra, Po and anthropogenic isotopes of Cs, Sr, Pu, Am. This will be supported through the establishment of mutually developed protocols for soil and plant sampling, sample preparation of plant matrices and for transfer factor determination in arid/semi-arid regions. To ensure fit-for-purpose and high-quality results and parameter values for REIA, the IAEA provided a proficiency testing (PT) exercise in 2022 for the CRP participants. The participating laboratories analyzed sets of well-characterized test samples using their usual procedures and reported radionuclide activity concentration results back to the IAEA. All received results, including uncertainties of measurement, were rated against pre-determined target values and performance criteria for trueness and precision. Most reported results were scored 'accepted'. In addition to ratings, advice on improving performance and possible corrective measures was provided. The outcomes of the PT exercise provide important information to the participating laboratories and assists them with checking and improving their analytical performance. This will contribute to ensuring adequate quality and comparability of the radioecological data collected whilst improving radioanalytical capacities in the Member States. The CRP will be described, providing details of the PT scheme and the results.

[i] This work was conducted while at the IAEA, Terrestrial Environmental Radiochemistry Laboratory, Seibersdorf

05 PARALLEL SESSION 2B

Natural Radionuclides

Investigating the geogenic origin of atypical U characteristics-– elevated U content, low ($^{234}U/^{238}U$) activity ratio – of groundwater in Beauce Limestone Aquifer System, France

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Keywords : Uranium isotopes, groundwater, Beauce aquifer, selenium, trace elements, ^{14}C

Atypical uranium (U) characteristics - elevated U content ($U \geq 15$ µg L^{-1}) and low ($^{234}U/^{238}U$) Activity Ratio ($AR \leq 0.5$) - were locally detected in the Seine river headwaters (South of Paris Basin)[1]. Since the stream water gets enriched in U and depleted in ^{234}U when originating from the groundwater discharge of the regional multi-layered Beauce Limestone Aquifer System (BLAS), we conducted in 2022 large hydrogeochemical investigations in both other surface and ground waters draining the BLAS in order (1) to delimit the spatial extent of these atypical U characteristics, and (2) to constrain the origin of the latter. Our results indicate wide variations of U content (0.013 – 13.4 µgL^{-1}) and AR (0.43 – 1.73), with all groundwater dating from the Holocene (0 – 10 ka B.P., according to ^{14}C dating method). The atypical U content and AR values are not widespread throughout the Beauce area (*ca*. 9,500 km^2). They are somewhat restricted to the headwaters of two river catchments (Œuf and Juine rivers). We demonstrate that the atypical AR values have a geogenic origin by evidencing groundwater discharge from two different BLAS aquifer sublayers (Pithiviers and Etampes limestones) and discarding U anthropogenic contribution from fertilizer application in Beauce soils (cereal plain). The occurrence of high U content with low AR likely originates from U-enriched detrital and organic- rich sediments interspersed in the limestone, which were deposited during the Low Miocene or that filled buried karstic cavities later.

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Radioactivity monitoring in drinking water in Greece

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Keywords : drinking water, uranium isotopes, alpha and beta activity, indicative dose

The ingestion of water is one of the pathways of incorporation of radioactive substances into the human body. For this reason, radioactivity monitoring programs to check the quality of drinking water are systematically in place in many countries in the last years. The requirements for monitoring levels of radioactive substances in water intended for human consumption are adopted from the Council Directive 2013/51/EURATOM of 22 October 2013. The Directive lays down values for radon, tritium, and the indicative dose, which covers many other radionuclides.

The aim of this project is to give a summary of information regarding the radioactivity on Greek waters and present its radioactivity monitoring program in the country. This program has been developed by the Greek Atomic Energy Commission (EEAE), the competent authority for nuclear safety and radiation protection, in cooperation with the ministry of health and the municipalities of the country.

The main sources of drinking waters consumed by the population of Greece are spring water, ground and surface water.

The survey refers to systematic measurements of the alpha and beta activity, the activity concentration of the uranium isotopes (U-238 & U-238) and periodic random checks of tritium and radon. More than 8000 samples have been analysed in the last five years by means of a-spectrometry, ICP-MS and liquid scintillation counting. The results are presented and discussed in this study.

Long-term and continuous field measurements of radon in atmosphere, soil and water

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Keywords: Radon and its progeny, continuous measurement, air, soil, water,

Radon(^{222}Rn) is a naturally occurring noble gas, ubiquitous and radioactive with a half-life of 3.8 days. Radon has received much attention over the last hundred years due to the fact that it is not only the greatest contributor to the ionizing radiation dose received by the public among natural radioactivity, but also has been epidemiologically proved to be the second cause of lung cancer after smoking. In addition, as a radioactive and noble gas, radon is also widely used as a valuable tracer for studies in the fields of atmosphere, ocean system, groundwater, environments, earthquake prediction and so on.

Long-term and continuous field measurement of radon concentration is the prerequisite for radon application as a tracer. To meet the needs, electrostatic collection coupled with Si-PIN alpha spectrometry was adopted due to its discrimination of ^{222}Rn and ^{220}Rn, and wider range of measurement sensitivity which mainly determined by the volume size of measurement chambers. Measurement instruments for radon in atmosphere, soil and water were developed respectively with specific technical for avoiding the influence of air humidity which is the own characteristic of electrostatic collection method. Measurement sensitivity and lower limit of detection with uncertainty of each kinds of instruments are given, and hourly monitoring results of radon in atmosphere, soil and water for long-term unattached operation are introduced as well.

Reference: 1. https://doi.org/10.1080/00223131.2021.1961638;

2. https://doi.org/10.1016/j.apradiso.2022.110320;

3. https://doi.org/10.3390/atmos12101257; 4. https://doi.org/10.14407/jrpr.2020.45.3.95

Investigation of boundary layer height evolution and its implication for air pollution monitoring: a long-term study based on radon in Bratislava, Slovakia

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Keywords : Outdoor radon, boundary layer height, box model, air pollution monitoring

The boundary layer height (BLH), which is the lower portion of the troposphere, plays an essential role in the dispersion of atmospheric compounds near the ground. Many atmospheric studies, including air pollution monitoring, require data on the evolution of BLH. The purpose of this study is to investigate the evolution of BLH and its implications for air pollution monitoring in Bratislava, Slovakia, using radon as a tracer of atmospheric processes. The so-called box model based on radon was utilized to calculate the BLH. In this study, we considered the seasonal variation in radon flux rather than a constant value for the whole year. When compared with BLH data based on the ERA-5 reanalysis dataset, it was observed that employing the constant radon flux for the entire year results in BLH overestimation in the winter months and underestimation in the summer months, respectively. If variable radon flux was used, the BLH values obtained in this way were consistent with those based on the ERA-5 reanalysis dataset. The applicability of radon-based BLH for air pollution monitoring was examined, and it was found that the evolution of BLH is one of the main factors influencing urban air quality. This study also demonstrates that radon can be employed as a suitable tracer of atmospheric processes. Our findings provide valuable information that can be used to improve air pollution monitoring and atmospheric research.

This work was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (VEGA project No. 1/0019/22 and No. 1/0086/22) and the Slovak Research and Development Agency (project No. APVV-21-0356). The authors would especially like to thank the Slovak Hydrometeorological Institute for providing data on the concentrations of air pollutants.

Radon behaviour due to “Galerna” in Bilbao (Northern of Spain)

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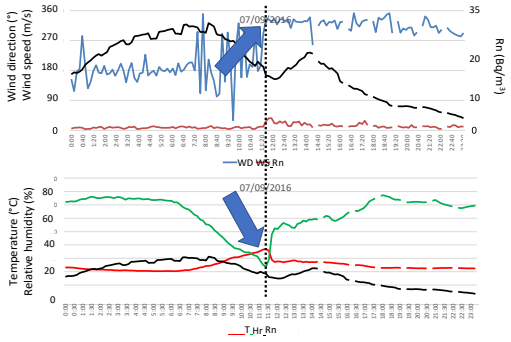
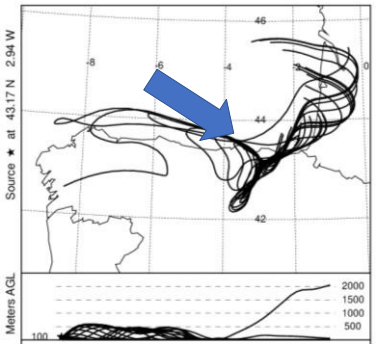
Keywords: Radon, Wind, Galerna, Dose Rate

Ten years of radon observations (2009-2019) at the radiological station of Bilbao, which is part of the Automatic Radiological Surveillance Network of the Autonomous Community of the Basque Country (Spain), are used to understand and characterize the influence of “galerna” (abrupt westerly change over the northern coast of Spain) in the intensity and daily variability of radon concentrations. In total, 48 periods of one day have been analysed. The cluster analysis reveals that short increases in radon concentrations are associated with the occurrence of “galerna”. However, not all these periods reflect this increase because Bilbao is located along the Nervion valley and 16 km far away from the coast. Five of these periods have been analysed in detail, on the basis of 10 minutes surface meteorological and radon data together with backward air mass trajectories, and different radon behaviours have been registered under this local change in meteorological conditions. This analysis helps to understand an anomalous radon increase under the arrival of maritime winds.





The influence of soil characteristics on radon exhalation rate and in ambient air in Kuwait

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Keywords: outdoor radon, radon exhalation, Kuwait

The influence of soil characteristics on radon exhalation rate from soil and outdoor radon concentrations were investigated in Kuwait. The measurements were carried out using AlphaGuard radon monitor in 20 locations beset with different types of soil. Grain size analysis of the collected soil samples were performed, moisture content and soil porosity were determined.

The grain size analysis revealed that the soils belong to gravelly sand and muddy sand category. The results showed that the study area is characterized by low levels of outdoor radon concentration with a mean value of 9 Bq/m^3, and low radon exhalation rates range from 2.84 to 18.16 mBq/m^2s with a mean value of 9.70 mBq/m^2s. Correlation of studies show that the radon exhalation rate is influenced by the soil type, moisture content, compaction and effective porosity. The relatively high exhalation rates were recorded in the dry, friable gravelly sand soil, while the lower values were recorded in the wet, compacted muddy sand soil.

Environmental reconstruction in the Oualidia – Sidi Moussa lagoon complex (western Morocco) using radiometric dating combined with geochemical approaches

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Keywords: Sediment dating, ^{210}Pb and ^{137}Cs, coastal management, radioactive and metallic pollution, sedimentation rates.

The Oualidia - Sidi Moussa lagoon complex is located on the Atlantic coast of Morocco and constitutes an important area of large potential for economic development. The lagoons are affected by increasing industrial activities, having NORM as a by-product, due to their proximity to the biggest phosphate processing plants. The present work addresses the assessment of present and past environmental conditions in the study area by investigating five sediment cores as environmental archives for recent pollution history. The cores were analysed by gamma spectrometry, ICP-MS and INAA for radionuclides, trace and rare earth element determination, and dated using ^{210}Pb and ^{137}Cs profiles. Maximal concentrations of elements were recorded in the profiles at depths matching, according to the obtained chronologies, the launching of the plants of phosphate processing. Decreasing concentrations in recently deposited sediment revealed the confirmed effect of the environmental policy implemented since early 2000s by the phosphate industrial operator. Element geochemical approaches were used to determine some features in relation to the lagoons functioning in terms of sedimentation rates and conditions of sediment deposition.

Assessment of ^{238}U and ^{226}Ra activity concentration along the Amazon Tall Tower Observatory site

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Keywords: 226-radium, 222-radon, ATTO tower, soil analysis

The Amazon Tall Tower Observatory (ATTO) site is a region located within the Uatumã Sustainable Development Reserve (USRD), approximately 150 km northeast of Manaus city, in the Brazilian state of Amazonas. At the ATTO site, there are 3 tall towers, which are used for studies on the Amazon rainforest and its interaction with the soil and the atmosphere. The activity concentration of ^{238}U and ^{226}Ra was determined in soil samples collected in the footprint of the ATTO site by gamma spectrometry. The activity concentration of these radionuclides is important for understanding the ^{222}Rn exhalation rate and ^{222}Rn flux from soils. Knowledge of the ^{222}Rn flux at the ATTO site can be useful for applications in atmospheric research, e.g., the ^{222}Rn tracer method can be used to estimate local and regional emissions of greenhouse gasses; simulating ^{222}Rn transport is a powerful tool for evaluation and validation of transport schemes in atmospheric chemical transport models. In this study, 39 samples collected from 13 sampling sites along a transect from the ATTO site to the river were analyzed. The highest activity concentrations were found in the Igapó forest (69 ± 2 Bq/kg for ^{238}U and 47 ± 5 Bq/kg for ^{226}Ra), a region near the Uatumã river with prevailing flooded black-water forest, whereas the lowest activity concentrations occurred in the Campina (Savanna on white-sand soils) and Campinanara (white-sand forest) ecosystems (18 ± 1 Bq/kg for ^{238}U and 13 ± 2 Bq/kg for ^{226}Ra), a transition area located between river terraces and the Terra Firme forest.

06 PLENARY SESSION II

M. Aoyama Memorial Session I

Temporal changes of ^{137}Cs activity concentrations in bottom waters and sediments in the Far Eastern Seas: Partitioning of ^{137}Cs between bottom waters and sediments

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Keywords: Partition coefficients, Far Eastern Seas, ^{137}Cs, sediment,

Deep ocean sediment, as did seawater, is one of the important reservoirs of ^{137}Cs, an anthropogenic radionuclide with long half-live found in the earth system. To better understand geochemical behaviour of ^{137}Cs in the ocean, we examined temporal changes of ^{137}Cs activity concentrations in bottom waters and sediments of the Far Eastern Seas (Sea of Japan, SOJ, and Okhotsk Sea, OS) during the period of 1998 to 2021. The ^{137}Cs activity concentrations in bottom waters and sediments showed exponential changes during observed periods. Radioactive decay-corrected change rates of ^{137}Cs in SOJ exhibited slow increase during the observed period, whereas ^{137}Cs in seawater and sediment in OS decreased gradually. This reflects a topographical difference, as SOJ is a semi-closed sea, whereas OS receives continuously inflow of sub-arctic waters. To elucidate the transfer processes of ^{137}Cs from seawater to sediment, we discussed temporal changes of partition coefficients (K_d) of ^{137}Cs between overlying water and surface sediment. In shallow areas (< 2000 m depth), K_d values were almost constant within the sampling periods, although the temporal changes of K_d values occurred in deeper waters (> 2500 m depth). The K_d values increased with increasing depth, which may reflect a pressure effect as possible mechanism. These findings suggest that chemical processes may be important as factors controlling movement of ^{137}Cs between seawater and sediment in deep waters (> 3000m depth).

Evaluating the global scale transport of surface seawater from 1956 to 2021 using ^{137}Cs released in the global ocean

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Keywords: ^{137}Cs, Global Ocean, surface seawater, apparent half residence time, inventory

The spatiotemporal variations in the ^{137}Cs activity concentrations in global ocean surface seawater from 1956 to 2021 using the Historical Artificial radioactivity database in Marine environment, Global integrated version 2021 and other published data. The global ocean was divided into 37 boxes. The 0.5-yr median value of ^{137}Cs, inventory, and apparent half residence time in the surface seawater in each box were investigated. The ^{137}Cs inventory in the surface mixed layer in 1970 was estimated to be 184 ± 26 PBq. The inventory reached to the maximum value, 214 ± 11 PBq, in 1980, due to direct discharge from the nuclear fuel reprocessing plants. In 2011, the ^{137}Cs inventory in the global ocean mixed layer increased to 50.7±7.3 PBq compared to that before the F1NPS accident, in which the contribution from the accident was estimated to be approximately 15.5 ± 3.9 PBq. Mass balance analysis indicates that ^{137}Cs deposited by the global fallout in the western North Pacific Ocean moved to the eastern North Pacific Ocean. Subsequently, ^{137}Cs was transported southwards, followed by westwards transport in the subtropical and equatorial Pacific Ocean and inflowed into the Indian Ocean via the Indonesian Archipelago. The longer apparent half residence times in the Indonesian Archipelago (36.7 years) and Central Atlantic Ocean (38.0 year) also support the interpretation of the global-scale transport of ^{137}Cs from the western North Pacific Ocean to the Indian (20-30 years) and Atlantic Oceans (30-40 years). In the northern North Atlantic Ocean and its marginal sea, ^{137}Cs discharged from nuclear reprocessing plants is transported to the North Sea, Barents Sea and coast of Norway, and Arctic Ocean on a decadal scale.

Ocean simulations for assessing the impact of ^{137}Cs derived from the Fukushima Daiichi Nuclear Power Plant accident

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Keywords: ^{137}Cs, Fukushima Dai-ichi Nuclear Power Plant accident, Regional ocean model, direct release

The Fukushima Dai-ichi Nuclear Power Station (F1NPS) accident resulted in contamination of the oceans by radioactive materials (mainly ^{137}Cs). The major pathways to the ocean were direct release and atmospheric fallout. The ^{137}Cs that deposited on land were supplied to the ocean through rivers. The ^{137}Cs supplied to the oceans was transported eastwards across the North Pacific by the Kuroshio Current. A part of ^{137}Cs was transferred to the sediment. A series of ocean model simulations were conducted to understand the impact off the coast of Fukushima. Direct release rates were estimated by a regional ocean model using monitoring data adjacent to the F1NPS. The oceanic simulation with the estimated direct release rates were validated by monitoring data. Estimates of deposition to the ocean by the regional atmospheric models varied widely, but were found to be underestimates overall. Due to the unresolved distribution of atmospheric fallout into the North Pacific, the reproducibility of recirculation to coastal areas of Japan in the North Pacific model has not been satisfactory; direct emissions from the F1NPS continue, but since 2014 the impact of river runoff has also been observed in coastal areas away from the F1NPS. The impact of dissolved 137Cs from rivers is small, while the impact of particulate 137Cs is significant. Modelling of particulate 137Cs supplied to the ocean is needed. The transfer from seawater to sediments is about 5%, but the process of resuspension and recirculation from the sediments also needs to be clarified. Although 12 years have passed since the accident, the levels are still observable and further process studies are important.

Radiocaesium derived from the Fukushima Dai-ichi Nuclear Power Station in the ocean interior as subtropical mode water in the North Pacific

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Keywords: Radiocaesium, North Pacific, subtropical mode water

This study summarizes the spatiotemporal variation in the distribution of Fukushima Daiichi Nuclear Power Station (F1NPS)-derived radiocaesium in the ocean interior of the North Pacific Ocean from 2011 to 2017. The majority of F1NPS-derived radiocaesium in the ocean interior was found to be contained in subtropical mode water (STMW), with the intrusion of F1NPS-derived radiocaesium into the ocean interior particularly likely to have occurred in March 2011 and winter 2011/2012. Such F1NPS-derived radiocaesium in STMWs in the subtropical western North Pacific was confirmed until 2017. The total amount of F1NPS-derived ^{137}Cs in STMW estimated based on the data from 2013, when wide-area observations were conducted, $\approx 4.3 \times 10^{15}$ Bq, was almost the same as the estimated value in 2012. Therefore, it is considered that there was no further intrusion of F1NPS-derived ^{137}Cs into the STMW after 2013. In addition, the distribution of F1NPS-derived ^{137}Cs within the STMW in 2013 was more uniform than in 2012. From 2013 to 2017, a gradual decrease in F1NPS-derived radiocaesium in the southwestern STMW region was observed. Part of this decrease may be attributed to transport outside the STMW, such as the East China Sea and the Sea of Japan, or F1NPS-derived radiocaesium may have been accelerated to circulate within the STMW distribution area or diluted with radiocaesium from global fallout between 2013 and 2017.

Role played by rivers in the supply of Fukushima Daiichi–Derived radionuclides in the coastal zone of Japan

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Keywords: River, Coastal zone, radioactivity, accident

Rivers are major links between the continents and the oceans. Indeed, they are vectors to the oceans of many elements from their watersheds, through weathering and biogeochemical cycles such as nutrient but also since the Anthropocene era of many pollutants. If we stick to artificial radioactivity, rivers receive controlled discharges from various nuclear facilities, mainly power plants and spent fuel reprocessing plants installed on their banks.

In the event of an accident, even if they are not subject to direct releases, they contribute to the input of radioactivity to the coastal zone from contaminated watersheds. Even if these contributions are often small compared to other sources, they are part of the long term.

A review of the situation of the coastal area around Fukushima, characterized on the one hand by the presence of many rivers, some of which drain areas heavily contaminated during the Fukushima Daiichi nuclear power plant accident in 2011, and on the other hand by the seasonal influence of typhoons, will be presented.

07 PLENARY SESSION III

M. Aoyama Memorial Session II

Recent investigations of anthropogenic radionuclides in seawater of the western North Pacific Ocean

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Keywords: North Pacific Ocean, Seawater, Fukushima accident, Tritium, Radiocarbon,

During the nuclear weapon testing period in the 1950s and 1960s, significant quantities of anthropogenic radionuclides (e.g., ^{3}H, ^{14}C, ^{90}Sr, ^{137}Cs, ^{239,240}Pu) were deposited on the surface of the North Pacific Ocean, and consequently became part of its inventory. The scientists dealing with the environmental radioactivity and oceanography soon realized that although global fallout radionuclides can be recognized as a radioecological threat, they represent a useful tool in tracing transport and circulation of seawater masses and studying physical, geochemical and biological processes in the marine environment. As a consequence of natural stratosphere-troposphere exchange and high wet deposition rates, the most of the global fallout radionuclides were injected into the western part of the Pacific Ocean which has been later impacted also by the Chernobyl accident, nuclear fuel reprocessing and by the Fukushima Dai-ichi Nuclear Power Plant (FDNPP) accident. Here we present recent observations of anthropogenic radionuclide inventories in the western part of the North Pacific Ocean, with the focus on tritium and radiocarbon. Natural background of the region of interest is discussed as well.

Temporal variation of Cs-137 in the seawater from the East Sea/Sea of Japan (from the Fukushima nuclear power plant accident to the present)

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Keywor ds: Cs-137, seawater, East Sea/Sea of Japan, Fukushima, Kuroshio Current

After the Fukushima Daiichi nuclear power plant disaster in 2011, the activity concentration of Cs- 137 in surface seawater showed slightly high concentration in the north-eastern part of the East Sea/Sea of Japan, but overall there was not a significant difference in Cs-137 activity concentratio n compared to previous measurements in the entire area.

However, when looking at the activity concentration of Cs-137 in 2014-2015 in the surface seawater, higher levels of Cs were observed than before, and it is believed that this is due to the Fukushima Daiichi nuclear power plant accident via the Kuroshio Current entering the East Sea.

In recent years, the Cs-137 activity concentration in surface seawater has decreased compared to 2015, and the concentrations are similar to those concentration observed in 2010.

While average activity ratio of $^{137}Cs/^{90}Sr$ measured from 1996 to 2010 in surface seawater was approximately 1.79, the average activity ratio of $^{137}Cs/^{90}Sr$ in surface seawater of the East Sea from 2013 to 2015 was about 3, indicating that Cs-137 from the Fukushima Daiichi nuclear disaster was flowing into the East Sea via the East China Sea.

Since 1980, the effective half-life of ^{137}Cs in the surface water from the East Sea recorded 18 to 19 years and is consistent with other findings.

Non-destructive γ-spectrometry of ultra-low background level for small size sample enabled clarification of specific radio-caesium transfer along food chain off Fukushima after 2011

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Keywords: Low background γ–spectorometry, Marine fish, ^{137}Cs

Radioactivity concentration of ^{137}Cs in Japanese marine biota was measured by radiochemical separation before 2010. After the Fukushima Dai-ichi Nuclear Power Station (1FNPS) accident, the ^{137}Cs content in raw marine biota sample of coastal water was satisfactory level for measurement by γ-spectrometry of the environmental monitoring to check the radioactivity levels to be within the food safety regulations. However, for scientific study, those data sets were not usable due to designating the true radioactivity concentration below detection limit (<10 Bq/kg-ww). To clarify the mechanism of ^{137}Cs transfer along food chain, radioactivity measurement of small amount of sample was necessary, e.g. stomach content of fish; benthos such as mysid, however the determination limit by conventional γ-spectrometry was not sufficient level. Therefore, to handle small size sample, the low background measurement was carried out using seven high purity Ge detectors equipped inner shield of >200 years old lead took from roof tile which came out during rebuilding of the Kanazawa castle, those placed in the Ogoya tunnel (546 m length, 135m underground). Since the benefit of non- destructive measurement, dried marine sample can be subjected to following

sequential treatment to derive so called “bio-available” fraction which is realistic to evaluate ^{137}Cs transfer along food chain. As result, the reasons of slower depuration of ^{137}Cs in fish than those in macro-algae and invertebrates, even though the radio-caesium in seawater decreased in the Pacific coastal waters of eastern Japan, were derived as follows. Particularly in rockfish, the affecting factors were demonstrated to be due to their sedentary habits causing the fish being exposed to the initial high radioactive water plume; the slower metabolism in rockfish, and slower generational exchange of the population than other fish. In case of some demersal fish of active sediment feeder, the radio-caesium transfer from the bottom environment was exhibited. With regards to surface water fish, the ^{137}Cs radioactivity concentration was not decreased to the radioactivity levels of those before 2010, due to the trace radioactivity still introduced to the coastal water. It was considered to kept the radioactivity levels in biota of food chain being enhanced even twelve years after the F1NPS accident. Although the ^{137}Cs radioactivity, especially in plankton and benthos was often observed being heterogenic distribution as 1) caesium bearing micro particle, 2) entrained radio-caesium rich inorganic particle, 3) contaminated terrigenous matter etc.. However, those were regarded to be not bio-available, thus other factors to be studied to understand further.

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Radiocesium dynamics in typical Fukushima forests

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Keywords: Radiocesium, Fukushima, Forest, Aggregated Transfer Factor.

The long-term dynamics of radiocesium in typical forest ecosystems was studied in the radioactively contaminated areas in Fukushima Prefecture. Species studied included Japanese cedar, Japanese red pine, and Japanese cypress. The ^{137}Cs concentrations were monitored in samples collected from the main aboveground biomass compartments, fresh litterfall, forest litter, and soil. Concentrations of exchangeable forms of radiocesium and stable potassium were measured in soil samples. During the observation period, the litter radiocesium inventories at all sites decreased significantly to approximately 1% or less of the total ground deposition. Approximately 80% of the total radiocesium inventory was localized in the upper 5-cm layer of soil, and downward migration of radiocesium was slow. Aboveground biomass compartments showed similar decreasing trends in radiocesium aggregated transfer factors, T_{ag}, in the compartments that were exposed to the atmospheric fallout in March 2011 (old foliage, small branches, and outer bark). The mean T_{ag} in the studied cedar stand compartments currently were in the range of 10^{-3}-10^{-2} m^2 kg^{-1} dw. However, the mean T_{ag} and their dynamic trends differed significantly in the wood compartments of the cedar stands, which may indicate differences in radiocesium root uptake between the observation sites. Local factors that may explain these differences were analysed.

08 PARALLEL SESSION 3A

Fukushima, Chernobyl and Test Ground

Local Surface and Vertical Distribution and Isotope Ratios for Radiocesium

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Keywords: Regional Distribution of Radiocesium, $^{134}Cs/^{137}Cs$ radioactive ratio, $^{135}Cs/^{137}Cs$ isotope ratio, Accident at the Fukushima Daiichi Nuclear Power Station

Because of the accident at the Fukushima Daiichi Nuclear Power Station (1F), a large area of eastern Japan was contaminated by radiocesium. There are many old nuclear facilities in the area. When the old nuclear facilities will be decommissioned in three decades, the radioactive level of radiocesium from 1F would be more than clearance level. When radiocesium would be detected at the completion of their decommissioning in the site, estimation of the origin of which is from background originated 1F and fallout of atmospheric nuclear test or from decommissioned facilities will be important. Therefore, soils of 3 sites were collected by using U8 containers and by core boring, and ^{137}Cs radioactivity, $^{134}Cs/^{137}Cs$ radioactivity ratios, $^{135}Cs/^{137}Cs$ isotope ratios were determined. Separation method of Cs from soil materials were developed based on the reported methods [1)2)]. The ^{137}Cs radioactivity concentrations were varied in not only between sites but also in the same site, however, $^{134}Cs/^{137}Cs$ radioactivity ratio was approximately constant in all sites. In case of highly contaminated soils, $^{135}Cs/^{137}Cs$ isotope ratio was almost comparable to that for the soil collected at near the 1F. On the other hand, in case of lower contaminated soils, $^{135}Cs/^{137}Cs$ isotope ratio was slightly higher than that for soil collected at near the 1F. It is possibly that fallout before the 1F accident contained ^{135}Cs to increase the $^{135}Cs/^{137}Cs$ isotope ratio. In the presentation, vertical distribution will also be discussed.

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Transfer of ^{137}Cs and ^{90}Sr from soil to potato: Interpretation of association from global fallout in Aomori to accidental released in Fukushima and Chornobyl

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Keywords: Soil-to-plant transfer, Exchangeable fraction, ^{137}Cs/Cs, ^{90}Sr/Sr

Soil-to-plant transfer changes depending on several factors including soil types, soil managements and etc. Specific activity ratios of ^{137}Cs/Cs and ^{90}Sr/Sr in exchangeable fraction were applied for more accurate estimating of activity concentration of ^{137}Cs and ^{90}Sr in potato collected from global fallout area (Aomori) and accidentally contaminated areas (Fukushima and Chornobyl). The contamination levels of ^{137}Cs and ^{90}Sr in the soils were 1.0-250,000 and 0.50- 64,000 Bq kg^{-1}, respectively. The specific activity ratios of ^{137}Cs/Cs and ^{90}Sr/Sr in exchangeable fraction were agreed with a factor of 2-3 of the ratios in potatoes over 5 orders of magnitude differences in the activity concentrations on ^{137}Cs and ^{90}Sr in the potatoes. The bioavailability of the radionuclides and their stable isotopes varied similarly depending on the factors, therefore, it suggests that the specific activity ratios are powerful tools for estimation of activity concentrations of ^{137}Cs and ^{90}Sr in crops.

How to measure the bioavailability from individual "Hot-Particles"

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Keywords: Uranium, Particles, Chornobyl, Leaching

When the Chornobyl nuclear power plant exploded in 1968, nuclear fuel was partly released as microscopic solid particles. Hot particles pose a risk to humans by inhalation. However, over the decades, weathering may lead to considerable release of radionuclides that can enter the human food chain. Since hot particles differ strongly with respect to morphology, chemical composition and stability, investigations need to be performed on single particles, rather than on bulk samples. We separate and extract the particles from the environmental matrix in a SEM with a micro manipulator. Subsequently, the particles are fixed by SEM glue on tungsten needles. Radioactive isotopes are detected by gamma spectrometry. Element composition and isotope ratios are imaged by EDX-measurements, SIMS and rL-SNMS (Bosco 2021) with a spatial resolution of up to 100 nm. Since all these methods are low invasive, the particles are available for chemical investigations. The individual particles were sequentially leached in ammonium acetate solution, hydrochloric acid, oxalic acid, nitric acid and aqua regia (based on Kashparov 2019). The solutions are then measured via gamma spectrometry and ICP-MS to analyze their U content and the amounts of leached fission and breeding products. Fuel particles are categorized in three classes (Salbu 2018) based on their appearance, dissolution rates and oxidation state.

To also investigate the inner structure of the particles, a cutting process with a focused ion beam has been developed. This way it is possible to do all mentioned measurements on the cutting edge. Furthermore, the particle can be its own reference for leaching experiments.The first leaching steps do not attack the structure of the particles, and only small fractions of Am-241 and Cs-137 were leached under mild conditions, indicating a low bioavailability.

Contamination of STS soil with tritium

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Keywords: Semipalatinsk Test Site, nuclear tests, soil, ^{3}H.

The paper presents research findings on the content and distribution of ^{3}H in soils of the Semipalatinsk Test Site (STS). Because STS soil can be a source of secondary contamination of environmental compartments with ^{3}H, research was undertaken at different radiation hazardous sites: the 'Experimental Field', 'Sary- Uzen', 'Balapan', 'Degelen', Telkem' and in the territory of the 'Atomic Lake'.

Areas of the maximum contamination with radionuclides, ground zeros and areas with increasing distance were surveyed.

^{3}H in the soil of areas selected was researched in the topsoil (down to 10 cm deep). To determine the content of ^{3}H, soil samples were prepared using an autoclave digestion technique. ^{3}H activity concentration was determined by carrying out a beta-spectrometric analysis with a liquid scintillation spectrometer.

Research undertaken allowed for a general assessment of tritium soil contamination in study areas. As a whole, the content of ^{3}H in the topsoil of study areas was found to reach up to 240,000 Bq/kg. The contamination with tritium is related to types of tests conducted, and tritium distribution may depend on the yield of a charge and other characteristic features of a test.

Residual radionuclide concentrations at the Bokak and Bikar Atolls, Northern Marshall Islands

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Keywords: anthropogenic radionuclides, pacific proving ground, Marshall Islands

Here we report activity concentrations of artificial radionuclides (e.g., ^{236}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{244}Pu, ^{241}Am, ^{243}Am, ^{137}Cs and ^{90}Sr) in marine and terrestrial samples collected at Bikar and Bokak Atolls, northern Marshall Islands. We observed low levels of artificial radionuclides in soil from Bokak, but significantly higher levels in soil from Bikar. The residual radioactivity in the Bikar environment is comparable to the levels previously reported for other nearby atolls, including Taka and Utrik, but lower than for Rongerik, Rongelap, Bikini and Enewetak. At Bikar, the activity concentrations of ^{239}Pu, ^{240}Pu, ^{241}Pu and ^{241}Am radionuclides were found to be in the order of a few Bq kg^{-1}. ^{242}Pu, ^{243}Am and ^{245}Cm radionuclides showed much lower activity concentrations in the order of a few mBq kg^{-1}. ^{244}Pu was also detected, in the range of a few µBq kg^{-1}. An analysis of ^{240}Pu/^{239}Pu and ^{242}Pu/^{239}Pu isotope ratios indicated that Bikar Atoll was contaminated mainly with radioactive fallout from the Castle Bravo test in 1954. This was further confirmed by two different age dating approaches that estimated 1954 as the year of the contamination. We demonstrate that the use of an exponential function to approximate the yield of heavy radionuclides in thermonuclear explosions with increasing mass is a valid approach for estimating the age of a contamination. Moreover, the abundances of the transuranium radionuclides found in soil from Bikar showed the even-odd anomaly of heavy nuclei as it has been observed in other thermonuclear explosions.

Characterization of natural and anthropogenic radionuclides in sediment cores from the Black Sea by high resolution gamma spectrometry

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Keywords: Gamma Spectrometry, Sediments, ^{210}Pb dating, ^{137}Cs, Black Sea

Sediment cores provide quite valuable information from the radiometrical point of view regarding dating methods or the study of fingerprints of processes, among other applications. In addition, the Black Sea region is an important area from a strategical perspective and could be affected by several anthropogenic radioactivity sources. Because of the few results in the literature about radioactive data in the Black Sea, one of the main aims of this work is to cover this gap by performing a radiometrical background characterization based on natural radionuclides from ^{238}U and ^{232}Th series plus ^{40}K. In addition, the anthropogenic ^{137}Cs was also added to this study. For that purpose, sediment cores (10 cm long divided in 0.5 cm layers) from the Western Black Sea (sampling carried out by the National Institute of Physics and Nuclear Engineering Horia Hulubei) have been analysed. Also, a dating method has been applied to the core using the ^{210}Pb belonging to the ^{238}U series. In addition, the gamma results have been combined with AMS measurement of the ^{240}Pu/^{239}Pu ratio, as it is shown in a complementary study also presented in this Conference. Gamma Spectrometry analysis were performed using a 42% relative efficiency HpGe detector and the Quality Assurance control included selfabsortion and True Coincidence Summing correction procedures.

Disequilibrum was found in the ^{238}U series allowing the use of the ^{210}Pb for dating, and radioactive levels of ^{137}Cs were detected.

09 PARALLEL SESSION 3B

Radioanalytics and Submarine Groundwater Discharge

Progress on radioactivity tools for the deep ocean

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Keywords: in situ sensors, γ- ray spectrometry, scintillators, Deep Ocean

The new radioactivity sensor for the deep ocean consists of a detection crystal, connected with a photomultiplier tube, preamplifier, amplifier and power supply, together with a multichannel analyser for data acquisition and storage. The electronic modules are especially constructed to fit inside the detector housing and the power consumption is relevant low (~1 W) in continuous mode of operation. The energy calibration is checked using the photopeak of ^{40}K which is always present at the oceans as natural constituent of the seawater. A watertight cylindrical enclosure houses the above-mentioned modules together with the digital units. The enclosure offers continuous functionality up to 4500 m water depth and continuous operation since it is tested in a special laboratory for pressure tests. The selection criterion for the appropriate enclosure material is based on minimizing gamma ray absorption and maximizing the pressure tolerance. The subsea spectrometer was connected with a special battery to power the detection system. The enclosure of the spectrometer and the subsea battery box is also tested for high pressures using a special pressure tank. During the last face of pressure tests, the enclosure provided a tolerance up to 500 Atm. The radioactivity sensor is calibrated (energy, energy resolution and full energy peak efficiency) from energy threshold to 2800keV and tested for its stability to temperature variations. The efficiency calibration and quantification (in Bq/m^3) evaluation were also performed in the calibration tank. An efficiency transfer method based on Monte Carlo simulations was developed to extend the efficiency calibration to water environment with salinities from 0 to 400 psu using as reference detection systems the KATERINA II and GeoMAREA (low and medium gamma-ray spectrometers).

Characterization of novel instruments for radioactivity monitoring in oceanic environments

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Keywords: Marine radioactivity, CZT, HPGe, Monte Carlo simulations, Characterization

The monitoring of radioactivity in ocean waters has been a long-standing need in the international research community. This need is the main focus of the EU H2020 FET Programme RAMONES (*Radioactivity Monitoring in Ocean Ecosystems*), which aims at enabling *in-situ*, near-real-time and long-term radioactivity monitoring in the marine environment. To accomplish this, various prototype marinized radiation-sensing instruments will be developed, validated and equip both autonomous underwater gliders (AUG) and stationary seabed platforms.

In total, two classes of radiation sensing instruments will be presented. The first one is a prototype high-resolution gamma spectrometer, which will equip a benthic laboratory, allowing for long-term, *in situ* spectroscopy studies near the seabed. The second class of instruments (*γ-Sniffers*) includes specially designed CZT-based spectrometers aboard autonomous underwater gliders. The γ-Sniffers are designed to play a dual role: (a) to perform monitoring of large areas in the water column, aiming to identify marine radioactivity levels, and (b) to feed AI algorithms responsible of enabling the autonomous operation of the AUG to explore radioactivity in harsh and remote marine environments, where traditional approaches are virtually non-existent.

In the present work, experiments in the lab are coupled to detailed Monte Carlo simulations to investigate the response of the detectors and provide optimization conditions before final deployment of the instruments in the ocean. Results from test field experiments will also be presented.

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Natural occurring Ra and Rn to address submarine groundwater discharge-derived ^{90}Sr at the land-sea interface

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Keywords: Sr-90 Radionuclide, Submarine Groundwater Discharge,Coastal bays

Ra and Rn isotopes are powerful tracers to quantify the submarine groundwater discharge (SGD) and its associated flux of chemicals to coastal waters within different time scales (Moore, 2010). Environmental ^{90}Sr largely deposited on the surface of the earth as the global fallout in the 1960s is of great concern due to the relatively long half-life (28.8 a) and a high concentration factor in bone, and high radiotoxicity in wild biota and humans (Bowen et al., 1974). It is well known that ^{90}Sr migrates from the soil to groundwater and river water due to its lower sediment-water distribution coefficient. Coastal bays have been increasingly used for fish and shellfish farming industries recently. The level of ^{90}Sr may be directly related to human health via farmed fish consumption (Hirose and Povince, 2019). However, SGD-derived ^{90}Sr in the coastal waters has not been thoroughly studied. In this study, we employed the environmental Ra isotope tracers to assess the amount of SGD in the Xiangshan Bay (XSB), the Dongshan Bay (DSB), and the Qinzhou Bay (QZB) in China. We determined nutrients and carbon fluxes as well as ^{90}Sr concentrations in fresh groundwater, recirculated groundwater, river water, and seawater of these bays. Except of nutrients and carbon fluxes by SGD as general case, here we focused on the case of ^{90}Sr. We estimated the submarine fresh groundwater discharge (SFGD)-derived ^{90}Sr flux to the ocean conservatively, which is occupying for around 70%, 55% and 20% of total sources of ^{90}Sr in the XSB, DSB, and QZB, respectively. Based on the non-conservative behaviour of ^{90}Sr along the salinity gradient and the literature data of SFGD in the marginal seas of China, extrapolation of these estimates to the entire coast of China yields that the SFGD- derived ^{90}Sr flux accounts for 29-55% of the riverine input. Our results demonstrated that this subterranean pathway for ^{90}Sr transport to the coastal ocean from the land should be considered in the monitoring and risk assessment of coastal waters, especially those fish farming bays and near nuclear facilities.

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Radium-derived water mixing and submarine groundwater discharge (SGD) as sources of carbon and nutrients in the Beibu Gulf, South China Sea

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Keywords: Radium isotope, Submarine groundwater discharge, Beibu Gulf, South China Sea, Biogenic elements, Carbon

Radium isotopes are produced by the decay of their parent U-Th series nuclides from sediment and/or soil in the rivers or in the continent shelf and then transport to offshore seawater. There are four naturally occurring radium (Ra) isotopes, that is, ^{224}Ra, ^{223}Ra, ^{228}Ra and ^{226}Ra, are radiogenic with half-lives of 3.66 days, 11.6 days, 5.75 years and 1600 years, respectively, which provide the information of different water movements processes, such as water mixing and submarine groundwater discharge (SGD). SGD is a predominant pathway for carbon and nutrients to the coastal ecosystems because of its large flux and the corresponding concentrated constituents. The Beibu Gulf is a shallow semi-closed gulf in the northwest of the South China Sea (SCS) which is a traditional fishing ground. With the rapid development of industrialization and urbanization, the ecosystems of the Beibu Gulf are now facing increasing pollution stress, with frequent occurrence of red tide in recent years. However, SGD is seriously ignored due to its invisibility and the difficult of observation technology, which greatly limits the understanding of the biogenic elements cycling processes in the Beibu Gulf. In the present study, the distributions of Ra in the surface and water column of the Beibu Gulf have been investigated and then were used to assess oceanic mixing and quantify SGD-derived fluxes of nutrients and carbon in the Beibu Gulf. Results showed that Ra-traced water masses were characterized in different seasons, and the water mixing facilitated the transportation of nutrient and carbon from various sources and then modulated marine productivity in the Beibu Gulf. In addition, the SGD-derived biogenic elements (nutrient, DIC and DOC) fluxes were quantitatively estimated, and provided a new explanation for the balance of SGD contribution biogenic element budgets in the Beibu Gulf. The implementation of this study will be of great significance to the health and sustainable development of the coastal ecological environment of Beibu Gulf.

Radium and Radon isotopes as tracer study on submarine groundwater discharge and its associated nutrient/carbon fluxes along the coast regions of China: a synthesis

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Keywords: Radium, Radon, submarine groundwater discharge, nutrient/carbon flux

The tracer methodology of natural occurring radionuclides such as Ra and Rn are the most extensive and effective to study environmental processes such as submarine groundwater discharge (SGD). In this work, SGD and its associated nutrient/carbon fluxes in various types of coastal ecosystems (estuaries, bays, lagoons, mangroves and saltmarshes, continental margin seas) along the coastal regions in China have been studied by using Ra and Rn isotopes. As shown in Figure 1, continental margin sea had the lowest average SGD rate. In contrast, the mangroves and saltmarsh had the highest ones. For SGD-derived nutrient and carbon fluxes, different spatial scale shows much different fluxes (esturaine>bay and lagoon>margin sea), which lead often to the eco-environment issues in China sea such as green tidal bloom, hypoxia, ocean acidification, etc. Ra/Rn isotopes were identified to be an effective tracer for SGD-driven chemical fluxes which could not be ignored in any ecosystems along the coastal regions of China even though worldwide.

This work was supported by the National Natural Science Foundation of China (Grant No. 41906150), and the First-class Discipline Construction Project of Beibu Gulf University.

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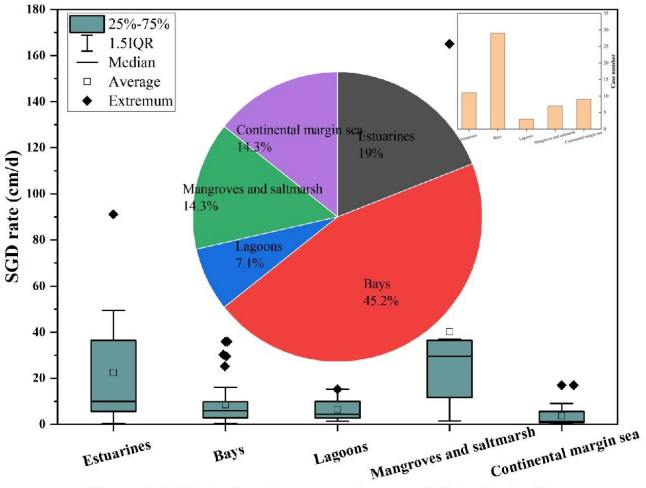

Figure 1. SGD studies along coastal areas of China by Ra/Rn

Development of a technique for the determination of ^{14}C in water by carbonate precipitation and AMS

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Keywords: Accelerator Mass Spectrometry, Radiocarbon, ^{14}C, Dissolved Inorganic Carbon, Nuclear waste.

The analysis of ^{14}C in liquid samples has applications in nuclear waste measurements, environmental studies, and radiocarbon dating. A methodology for the determination of ^{14}C dissolved in water by AMS is being developed with the objective of performing precise measurements in radioactive waste from Spain. Our sample preparation for the measurement of Dissolved Inorganic Carbon (DIC) consists in the precipitation of carbonates in an alkaline solution. The precipitate is later graphitized and measured in a MICADAS system. A similar approach for the measurement of Dissolved Organic Carbon (DOC) is currently being developed.

A reagent selection optimization was performed. Several combinations of salts, alkalizers and pH levels were studied and compared regarding chemical yield and background. Na, Ca, Ba and Sr salts were studied. The alkalizers compared were NaOH, KOH and $Ba(OH)_2$, used to reach pH levels of 10, 12 and 13. Yields obtained ranged between 13.88% and 92.06%.

Background was reduced by isolating the sample from external carbon, being atmospheric CO_2 the main source. A chamber filled with nitrogen gas was used to prevent the alkaline solutions from capturing CO_2. By using this equipment and choosing the appropriate $NaHCO_3$ blank material, a pMC of 0.37±0.05 was achieved, which is low enough for several different applications.

11 PARALLEL SESSION 4A

Modelling

Numerical simulation of particle fluxes and production of cosmogenic nuclide in the Earth's atmosphere.

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Keywords: comic rays, cosmogenic nuclide, particle flux, simulations
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Modern experimental techniques, such as Accelerator Mass Spectrometry (AMS) allow us to analyze with high resolution natural archives such as ice cores. The concentration of cosmogenic nuclides in these archives is the result of the interplay between three processes: production, transport and deposition. In order to make full use of the information stored in these archives, a detailed knowledge of the production rates of the cosmogenic nuclides is necessary.

In order to calculate the cosmogenic radionuclide production rate, models have to be developed that describe the interaction of cosmic ray particles with the main target elements of the irradiated object.

The main purpose of this talk is to provide information about the model we used in our recent simulations. Besides this, we will present how sensitive the production of cosmogenic nuclides is to various parameters or input data that have undergone changes in the recent time.

Our models are purely physical Monte Carlo models based on the codes GEANT and MCNPX. These models were used to simulate production and transport of galactic-cosmic-ray particles in the irradiated objects. The model enables us to calculate differential fluxes of secondary proton and neutron fluxes as a function of chemical composition, shielding depth and solar modulation. These particle fluxes have been used for the calculation of cosmogenic nuclide production rates in the irradiated objects. Experimental and/or evaluated excitation functions were used to calculate production rates for various extraterrestrial objects (Masarik and Beer, 1999), (Masarik and Beer 2009). Presented are the depth profiles of cosmogenic radionuclides ^{36}Cl, ^{41}Ca, ^{26}Al, ^{10}Be, and ^{53}Mn for Knyahinya (Figure 1) and lunar surface .

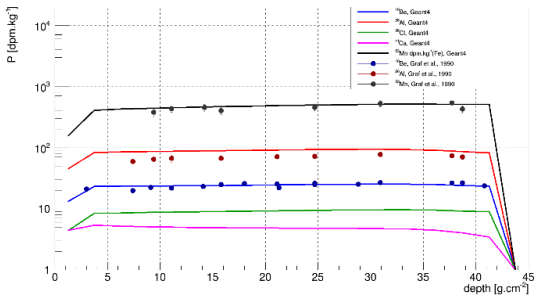

Figure 1 Calculated production rates of ^{10}Be, ^{26}Al, 36Cl, ^{41}Ca, ^{53}Mn for different depths in Knyahinya meteorite compared with points representing the measured data.

Effects of bulk chemical composition and size of irradiated objects on production processes are studied and discussed. The obtained production rates agree well with most published experimental values.

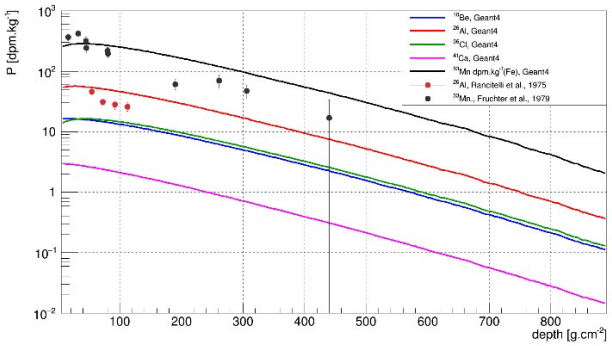

Figure 2 Calculated production rates of ^{10}Be, ^{26}Al, ^{36}Cl, 41Ca, ^{53}Mn for different depths in Moon surface compared with measured data from Apollo 17 samples

The good agreement of calculations with measured values shows that our model can be used to obtain reliable production rates of cosmogenic nuclides in extraterrestrial samples. These results provide the basis for a quantitative reconstruction of the irradiation and terrestrial history of studied objects.

This work was supported by the Slovak Research and Development Agency under grant SRDA-21-0356.

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On the use of 3D adjoint atmospheric transport modelling to simulate lower tropospheric concentration variations of cosmogenic radionuclides

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Keywords: Beryllium-7, atmospheric transport modelling, tracers, stratosphere-troposphere-exchange

Cosmogenic radionuclides are formed by the interaction between air molecules and cosmic rays. Their formation peaks in the lower stratosphere. Due to downward atmospheric motion, cosmogenic radionuclides can reach the lower troposphere, where ground-based environmental monitoring stations can measure their presence in air samples. As a results, variations in concentrations of cosmogenic radionuclides in the lower troposphere can be used to obtain information about downward vertical transport and possibly also stratosphere-to-troposphere exchange. The latter is known to impact the weather on subseasonal time scales, and hence could help enable subseasonal weather forecasting.

In this presentation, a new cosmogenic atmospheric transport modelling approach will be presented using the existing adjoint version of the Lagrangian particle model Flexpart. This novel approach can offer several benefits over current state-of-the-art modelling approaches as it does not require long spin-up times associated with other 3D models that are run forward-in-time. This makes it possible to couple Flexpart with high-resolution numerical weather data to study specific case studies (which would otherwise be computationally prohibited due to long spin-up times). The new approach will be validated using daily beryllium-7 observations at several monitoring stations that verify compliance with the Comprehensive Nuclear-Test-Ban Treaty. Examples will show how the new approach can be used to study atmospheric motion.

Topic: Radionuclides as tracers of environmental processes
Preferred type: Oral

Use of modelling results to enhance the radiological monitoring of the French Mediterranean coastal zone

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Keywords: Marine dispersion, modelling, coastal contamination, marine monitoring program

IRSN monitors radioactivity levels in the environment. The Rhône River is the main contributor to the supply of artificial radionuclides to the North-West Mediterranean Sea. These radionuclides originate mainly from authorized discharges from nuclear industries located on the course of the river but also from the drainage of the catchment area contaminated by past deposits from atmospheric nuclear tests and the Chernobyl accident in 1986. Part of the environmental sampling for monitoring is done along the Mediterranean coast. The results of past measurements have shown a labelling attributable to the contributions of the Rhône to the east of the mouth, sometimes as far as the Spanish border.

In addition, IRSN has developed modelling capacities to simulate the marine dispersion of radionuclides using hydrodynamic data. The STERNE software provides the user with assessments of the spatio-temporal evolution of contamination of seawater and living organisms. We used for that study one year of hydrodynamic data on the entire North-Western Mediterranean provided by the MARS3D model with a spatial resolution of 1.2 km and a temporal resolution of 2h. A reconstruction of the fluxes of ^{137}Cs and ^{60}Co arriving at sea was carried out from radionuclide measurement data made on the Rhône River at the SORA sampling station and river flow monitoring.

After simulating the dispersion of radionuclides chronically provided by the Rhône over a full year, a statistical study of the frequency of return of contamination on each zone of the coastal linear was carried out. Different dispersion scenarios are identified, depending mainly on wind characteristics which is the main forcing on hydrodynamic in this area. These results, extrapolated over several years, could then be compared with radiological monitoring data carried out by IRSN. This work shows the contribution of modelling to optimize the monitoring of the marine environment when levels of radioactivity in the environment make their quantification increasingly difficult.

MODELLING OF DISSOLVED ^{137}CS TRANSPORT ALONG A RIVER- SEA CONTINUUM AND DESORPTION AT THE ESTUARY

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[3]Adict solutions, Toulouse, FRANCE.
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Keywords: 137Cs, modelling, desorption, dispersion scenario, estuary

The world nuclear production will increase sharply until 2035 and most of the planned reactors will be located along a river or by the sea. Any accidental release of radionuclides into the aquatic environment may thus reach the ocean, and the need to anticipate its consequences remains more significant than ever. IRSN has developed a chain of models for simulating the behavior of a dissolved ^{137}Cs release on a river- sea continuum. Two independent models for the fluvial and marine environment were coupled using a dynamic box-model describing the hydrodynamic and geochemical estuarine processes affecting the ^{137}Cs within an estuary. The study site was the Rhone River (France, Mediterranean Sea), bordered by 4 nuclear power plants and characterized by a stratified estuary. The box model connects the flows from the river to the sea and takes into account a desorption process. Laboratory experiments were performed to specify the role of salinity in the intensity and kinetics of ^{137}Cs desorption from the particles, which starts above 3-4 PSU and decreases with the duration of the adsorption phase in the river before to reach saline areas (ageing effect). This desorption may release up to 40% of the particulate ^{137}Cs activities within the estuary, favoring thus the dispersion of dissolved ^{137}Cs at sea instead of its deposition with particles within the prodelta area. To better represent this behavior, a kinetic model involving 2 sites of different affinities for adsorption onto the particles was proposed and is still under development for other radionuclides.

A comparison of dry deposition parametrization schemes in atmospheric radionuclide prediction models. Application to the Chernobyl case.

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Keywords: Atmospheric transport models, radioactive particles, dry deposition parameterizations

Dry deposition is often described by a resistance modeling approach including aerodynamic and surface resistances and gravitational settling. However, in radioactive preparedness models, simpler approaches neglecting aerodynamic and surface resistances are often applied (e.g. Bartnicki et al., 2011) due to the need for fast calculations and lack of detailed surface information. Advances in Numerical Weather Prediction (NWP) modelling have made detailed meteorological and surface data more readily available for preparedness models and the inclusion of more detailed dry deposition schemes feasible. In the present study we implement the particle dry deposition parameterization schemes of Zhang (2002), the EMEP model (Simpson et al., 2012) and Emerson (2021) into the SNAP model (Severe Nuclear Accident Program, see Bartnicki er at., 2011) and compare with the present dry deposition approach of SNAP. The schemes are assessed for a re-run of the Chernobyl case with high resolution NWP data (2.5 km horizontal resolution) and detailed surface information (roughness, leaf-area index etc.). We describe the different dry deposition approaches, the meteorological and surface data and present a discussion of the consequences of the dry deposition parameterization for calculated deposition in the near source region and for long-range transport and deposition to Scandinavia.

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ETMOD (Environmental Tritium MODel): Version 2 Capabilities

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Keywords: Atmospheric dispersion, HT, HTO, OBT, Tritium, Model, Environmental Transport and Fate, Re-emission.

ETMOD is an environmental transport computer program used for predicting radiation doses to humans from a hypothetical or actual tritium release to the atmosphere from any tritium handling facility. Releases can be in the form of HT (tritiated gas) and / or HTO (tritiated water).

ETMOD models transport and exposure pathways including atmospheric dispersion, deposition and migration in soil, HT to HTO conversion, re-emission from soil, transfer from air/water/soil to vegetation, OBT (organically bound tritium) formation in vegetation, transfer from water/soil/plants to animals and animal products, as well as transfer to humans through inhalation, skin absorption and ingestion.

ETMOD predicts HT and HTO activity concentrations in air, HTO activity concentrations in soil, HTO and OBT activity concentrations in vegetation, and HTO and OBT activity concentrations in animals and animal products. It predicts the inhalation and skin absorption doses to humans from HT and HTO in air, and the ingestion dose to humans from HTO and OBT in vegetation and HTO and OBT in animals and animal products.

ETMOD is also useful for maintaining and enhancing knowledge about tritium transport in the environment. For example, it can help to model inter-comparisons and it can be used to refine environmental parameter values using acute release data, which can subsequently be used in routine release models. In addition, because it is possible to bypass certain submodels and override certain parameter values, the user can start calculations at intermediate points in the transport pathways for the purpose of submodel validation.

Version 2 of ETMOD saw the implementation of OBT formation in plants, as well as the modelling of HTO in animals. Accordingly, ingestion doses were modified to account for the two above-said aspects. ETMOD's Version 2 range of capabilities will be presented with a focus on the back-fitting / creation of its theory from the source code, testing done, errors corrected, modelling various scenarios with it and the results obtained.

Radionuclide and contaminant transport modeling in estuaries and fjords

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Keywords: Transport models, process investigation, fjords, small-scale

Coastal and estuarine environments constitues the interfaces between land and offshore environments. These ecosystems are important as they are key regions for sediment formation, biological production and distribution of contaminants and nutrients. Here we will present results from model studies of how small-scale processes affect the coastal transport of radionuclides and contaminants in different sites in several fjords in Norway. The impact of speciation and transformation processes was investigated in a hypothetical case study, showing a strong sensitivity to the fraction of ^{137}Cs radionuclides strongly bound to particles. Estuary processes affecting aluminium concentration were also investigated, where salinity-dependent speciation and transformation processes were implemented, and wind-driven events were shown to be able to considerably redistribute both the contaminants and the water masses in the fjord as well as to change the potential biological exposure over a short time period. Measurements and modeling work from a fjord with high river input show that the impact of the release description as well as surface mixing and stratification is crucial for the transport. Given the highly variable current patterns in coastal regions, the importance of high quality driver data is essential. In hydrodynamic ocean models, two-way nesting techniques may provide improved response of both small-scale processes near the shore and offshore dynamics at larger scales.

10 PARALLEL SESSION 4B

NORMS and Natural Radionuclides

Use of FLEXPART-WRF to investigate radon transport events associated with the impact of a NORM repository

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Keywords: Radon, Atmospheric Transport, NORM, FLEXPART-WRF

Two radon measurement stations located to the north and south of a NORM (Naturally Occurring Radioactive Materials) repository of phosphogypsum (southwest of Europe) were used to monitor radon behavior during 2018. The stations are located at opposing sides of the repository, one in Huelva City to the north and other one in a rural area to the south. This setup aimed to identify the influence of the NORM repository on each station and use radon levels as a marker of atmospheric transport in the local area.

To achieve this, a comparison was carried out with other coastal stations in the south of Spain, finding higher average concentrations in Huelva City, ~3.3 Bq m^{-3}. Hierarchical clustering was applied to identify days with different radon patterns at each Huelva station, detecting possible local radon transport events from the repository. Three events were investigated with WRF (Weather Research and Forecasting) and FLEXPART-WRF (FLEXible PARTicle dispersion model).

It was found that both sampling sites required atmospheric stagnant conditions to reach high radon concentration. However, under these conditions the urban station showed high radon regardless of wind direction while the rural station also required radon transport from the repository, either directly or indirectly.

Development of a process for removal of natural radionuclides and other pollutants in acid phosphogypsum leachates

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Keywords: Acidic leachate, Phosphogypsum, Alkaline treatment, Natural Radionuclide

In Huelva city (Spain), there are several phosphogypsum (PG) piles over the salt marshes of the Tinto River covering about 1000 ha. These deposits release natural radionuclides and other pollutants into their surrounding environment through highly acidic leachates (pH < 2). The natural radionuclides concentrations in these leachates, especially U-isotopes and ^{210}Po (^{210}Pb), exceed by 4-5 orders of magnitude the found ones in unperturbed freshwaters. Furthermore, the concentration of heavy metals (As, Cr, Cd, Cu, Ni, Zn, etc.) and anions (F^-, PO^{3-} and SO^{2-}) are also significantly higher. In this work, a cleaning process based on the neutralization of these acidic leachates was carried out by using different alkaline chemical reagents, such us $Ca(OH)_2$, $CaCO_3$, NaOH, Na_2CO_3, $Mg(OH)_2$, $MgCO_3$).

The results have demonstrated that the treatment of phosphogypsum leachates (PGL) by neutralization using $Ca(OH)_2$ is a good option for their cleaning. Regarding the solids obtained during the neutralization process by using $Ca(OH)_2$, calcium phosphate dominates the phase precipitated, where fluorapatite is formed at the most basic conditions. However, these precipitates contain high concentrations of metals, metalloids and natural radionuclides that should be reduced in order to obtain a high purity material that could be used as second source of phosphorous.

Characterization and valorization diagnosis of generated NORM wastes in the decontamination process of phosphogypsum leachate

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Keywords: NORM Waste, Decontamination, Acid Leachates, Waste Valorization

Phosphogypsum is an industrial waste generated in the production of phosphoric acid, which is considered NORM waste (Naturally Occurring Radioactive Material). Its disposal in stack and exposure to the environmental condition involve the production of acid leachate with high load of contaminant and radionuclides. This fact is a radiological and environmental concern. In this study, a sequential neutralization was applied to the leachates and the residues obtained were characterized from the physical-chemical and radiological point of view.

In the first stage, the pH is raised to 3.5, while in the second, pH 12 is reached. For this, two alkaline reagents, $Ca(OH)_2$ and $CaCO_3$, were used respectively. The residue obtained in the first stage was mostly CaF_2, while in the second stage $Ca_5(PO_4)_3(OH)$. Finally, the liquid at pH 12 is agitated, and CO_2 from the atmosphere can lower the pH to 9, obtaining $CaCO_3$. The sequential neutralization process has been shown to be effective in reducing potential contaminants of the leachate, establishing all the requirements for discharge into coastal waters.

Finally, in the recovery diagnosis of the three solids obtained, the possibility of their recovery as an additive or raw material in valorization processes are currently being analyzed.

Effects on local atmospheric environment of volcanic ash from Sakurajima volcano, inferred from atmospheric deposition of ^{40}K at Kagoshima City, Japan

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Keywords: atomospheric deposits, ^{40}K, volcanic ash, atmospheric environment

The Sakurajima volcano is one of the most active volcanoes in Japan. We examined the impact of the volcanic ash from the volcano on the atmospheric environment, referring to the monitoring data of radionuclides in the fallout in Japan since the 1960s in the Environmental Radiation Database [1]. The ^{40}K deposition amount in Kagoshima City, which hosts the Sakurajima volcano, is uniquely considerable compared to other areas in Japan. The ^{40}K, ^{214}Bi, and ^{212}Pb deposition samples in Kagoshima City correlate well with the number of eruptions of the Sakurajima volcano and its ashfall amount in Kagoshima City. On the other hand, the ^{7}Be and ^{137}Cs deposition amount in Kagoshima City does not correlate with the number of eruptions and the ashfall amount. In Uto City, located about 100 km north of Kagoshima City, no correlation was found between the number of eruptions of the Sakurajima volcano and any radionuclides deposition amount. Based on the assumed ^{137}Cs/^{40}K activity ratio in surface soil and the potassium content in volcanic ash, the proportions of sources of ^{40}K in the deposition samples were estimated from the relationship between the ^{137}Cs/^{40}K ratio of the fallout in Kagoshima City and the amount of ashfall. As a result, it is considered that the direct fallout of volcanic ash accounts for about 20%, the resuspension of surface soil for about 20%, and the rest is the resuspension of volcanic ash. Thus, the impact of the resuspension process of volcanic ash on the atmospheric environment in Kagoshima City is considerably more significant than the direct ashfall process.

[1] https://www.kankyo-hoshano.go.jp/data/database/

Development of a robust methodology to obtain the radon exhalation rate in different materials

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Keywords: Radon, Radon exhalation, Accumulation chamber, Insertion depth, Granular materials

According to UNSCEAR, 42% of the effective dose received by the public from natural sources is due to the inhalation of radon gas and its short half-life progeny, making it the second cause of lung cancer, only after tobacco. In this work, different approaches to obtain the radon exhalation rate were studied.

This is a complex task that depends on a multitude of factors, therefore, to refine the exhalation measurement method, a reference soil was made with a radon- emitting material that allows the measurement of exhalation under controlled conditions. The methodology used is based on the accumulation of radon inside a chamber, which will follow an asymptotic exponential behaviour.

The results showed that measurements performed with the system are consistent and reproducible. By using these measurements, a relationship was found between the perimeter and volume of the chamber. This led to the design and manufacturing of a set of accumulation chambers which that by increasing the insertion depth into the soil or granular material, it is possible to increase the time over which a linear approximation can be applied without losing precision.

Biodistribution of naturally occurring radionuclides in European perch (*Perca fluviatilis*) from Swedish lakes

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Keywords: Uranium, Polonium, Radium; Radiocesium; Bioaccumulation

Wild European perch (Perca fluviatilis) is one of the most important freshwater fish species, in Sweden, due to its widespread and its value for recreational fishing. However, little is known about the biodistribution of naturally occurring radionuclides in perch. Therefore, in this study, perches from five lakes located in different counties in Sweden were collected to investigate the biodistribution of ^{238}U, ^{234}U, ^{226}Ra and ^{210}Po in organs and tissues of perch as well as their radiological impact. The results showed that uranium radionuclides ranged between 0.1 and 6 Bq/kg with an average value of 1.1 ± 1.5 Bq/kg. ^{226}Ra varied from 0.4 to 8 Bq/kg with a mean concentration 1.7 ± 1.9 Bq/kg. The range of ^{210}Po was 0.5 – 250, with an average value of 24 ± 52 Bq/kg. For uranium isotopes and ^{226}Ra, uptake from water is the main source whereas for ^{210}Po the uptake is dependent on the perch diet. Perches tended to accumulate uranium isotopes in fins, gills, and skin; ^{226}Ra in bones, fins and skin and ^{210}Po in the organs linked to the digestive system. Finally, in case of consumption, it is advised to consume skinned fillets of perch due to the higher bioaccumulation of naturally occurring radionuclides in the skin and scales of the perch than in the muscles.

12 PLENARY SESSION IV

Change in airborne radioiodine physico-chemical distribution with time: a key issue for dose assessment and contamination of the environment in nuclear emergencies

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Keywords: Radioiodine, Distribution, Atmosphere, Dose, Emergencies

In the radioprotection domain, dose induced by the inhalation of radioiodine is determined through the distribution of iodine species between particulate, gaseous organic, and gaseous inorganic forms. Among them, molecular $^{131}I_2$ has the largest dose coefficient and leads to higher deposition and contamination of the environment than for gaseous inorganic and particulate iodine forms (subject to dry only deposition). At short distance from a nuclear facility, i.e., where radioiodine concentrations will be of concern in case of a nuclear accident, the assessment of the contribution of the above- mentioned iodine forms remains highly uncertain. Conversely, at long distance from a release point, the iodine distribution observed after nuclear weapons testing or nuclear accidents is rather well balanced. This equilibrium (roughly 1/3, 1/3, 1/3 for particulate, gaseous organic and gaseous inorganic radioiodine) is also observed for stable iodine. We conclude that the change in the radioiodine distribution obeys to environmental parameters. Which ones? Given its high reactivity and short atmospheric lifetime, $^{131}I_2$ should not remain in such a high proportion long after a release or at several thousand km from the emission.

The transfer kinetics between gaseous and particulate radioiodine forms is not fully understood and experimental verifications are scarce. Field experimentations conducted by Wershofen and Aumann (1989) showed that theses kinetics are rapid and prone to affect the airborne radioiodine distribution at short and medium distances. However, these authors did not consider the specific role of photolysis which may radically change the contribution of molecular iodine. This mechanism will be investigated during field experiments around the nuclear reprocessing plant of La Hague by the end of 2023.

Level and distribution of anthropogenic radionuclides in China - interaction of marine and terrestrial environment

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Keywords: Anthropogenic radionuclides, Plutonium, iodine-129, Sources, input of river flow

An overall investigation of artificial radioactivity in terrestrial and the adjunct sea environment of China has being implemented in the past years to obtain their distribution and sources, understand their dispersion and transfer pathways and environmental impact. The level and spatial distribution of ^{129}I，plutonium isotopes, ^{137}Cs and ^{90}Sr in the soil as well as vegetation and surface water and ^{14}C in tree rings in the terrestrial area of China, as well as these radionuclides with 3H in the environment of China Seas were obtained. In general, a relative higher level of anthropogenic radionuclides, e.g. ^{129}I, $^{239, 240}$Pu, ^{137}Cs, ^{90}Sr were observed in North China compared to South China (Zhang & Hou 2019; Zhang et al. 2021; Zhao et al. 2022). No significantly enhanced levels of anthropogenic radionuclides were observed in the surrounding area of Lop Nor nuclear weapons testing sites (300-600 km distance to the center of the testing site) were measured, due to the desert and hard bed of dried salt lake topography and geography in Lop Nor region. The measured ^{240}Pu/^{239}Pu atomic ratios in all environmental samples except a few samples from northeast Xinjiang were around 0.16-0.20, which are similar to the ratio of the global fallout of atmospheric nuclear weapons tests (0.18), indicating most of the plutonium and many other anthropogenic radionuclides originated from global fallout. Significantly lower ^{240}Pu/^{239}Pu ratios of 0.11-0.13 were observed in soil samples collected from northeast corner of Xinjiang, this might result from the transport of the close-in deposition of Semipalatinsk nuclear weapons tests in 1950-1963 (Zhao et al. 2000).

The ^{129}I and Pu level in the surface soil shows a gradually declined trend from North to South China, and relative higher level were observed in North China, especially in the eastern inner Mongolia at the west side of the Greater Khingan Mountains and Yinshan Mountains, this is attributed to the long-distance transport of gaseous ^{129}I by dominant westerlies wind in this region from Europe, where large amount of ^{129}I was discharged to the seas and atmosphere from Sellafield and La Hague spent fuel reprocessing plants. The mountain topography and climate condition in the eastern Inner Mongolia promoted the deposition and

retention of ^{129}I in the region. These hypotheses were confirmed by the measured distribution of ^{129}I in the sediment cores collected from Jiaozhou Bay, East China Sea and Tal lake in Philippine, which showed constantly higher level of ^{129}I in the upper layer sediment (after 1980), and the decreased inventory of ^{129}I in the sediment core from north location to south location in Asia (Fan et al. 2016; Zhang et al. 2019; Zhao et al. 2021a, b). The declined ^{129}I level from North to South China resulted from the transport of reprocessing derived ^{129}I dispersed to North China to South Asia by East Asia winter monsoon (Zhang et al. 2020).

The level of ^{129}I and ^{3}H in the China Sea shows a higher concentration in the north (Yellow Sea and Bohai) compared to the south (East China Sea and South China Sea). Meanwhile a high $^{129}I/^{127}I$ atomic ratios and ^{3}H concentration in the coastal seawater, especially the estuarine seawater were much higher than the open seawater, and in the surface seawater compared to the deep water. The $^{129}I/^{127}I$ atomic ratios in seawater is much lower than that in river or lake water. The high ^{129}I and ^{3}H in the estuarine and costal water is attributed to the terrestrial input of ^{129}I through rivers by leaching and transport of ^{129}I deposited in on the land, and the high deposition of ^{129}I in North China compared to South China. A significantly increased $^{240}Pu/^{239}Pu$ ratios (0.25-0.35) was observed in the seawater and sediment in the China Seas, clearly showing the contribution of the continuous resuspension of radioactive substance in the PPG nuclear weapons tests site and its long-distance transport through the North Equator and Kuroshio Currents. A remarkable Fukushima ^{137}Cs signal was observed in the South China Sea and West Pacific Ocean, especially in the middle and subsurface layer, which was transported to this region from Fukushima through a long-distance transport via water circulation.

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Utilities of environmental radioactivity tracers in assessing coastal carbon sequestration potential

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Keywords : Radionuclides, Chronology, sediments, organic carbon burial/sequestration

Coastal blue carbon often refers to the carbon sequestration longer than 100 years in coastal wetland vegetated ecosystems such as salt marshes, mangrove forests, and seagrass meadows. Plants take up atmospheric carbon dioxide through photosynthesis to store carbon in the above-ground and below-ground biomass and through accumulation or burial of their litters and dead branches into bottom sediments or soil sediments adjacent to them. As coastal wetland vegetated plants are mostly short-lived except mangroves (~ 100 years of life span), consequently, below-ground soil/sediments are of great interest for carbon sequestration from the atmosphere. Environmental radioisotopes (e.g., ^{7}Be, ^{137}Cs, ^{228}Th, $^{239+240}$Pu, ^{210}Pb) are widely used to estimate sediment mass accumulation rate. Stable isotope composition of C and N along with chemical elemental and organic biomarkers are used to identify sources and microbial transformation of organic matter in the below-ground sediment column. Radium isotopes and Radon are used to estimate the submarine groundwater discharge. A few examples to estimate coastal blue carbon in coastal wetlands in China are introduced here to stimulate further discussion to find novel applications of environmental radioisotopes to quantify processes occurring in the coastal blue carbon ecosystems and their interaction with terrestrial and oceanic environments. In the northern coast zone of China, the carbon sequestration flux of SOC (SF-SOC, $g \cdot m^{-2} \cdot yr^{-1}$) was 82.84 (reed marsh), 151.93 (barren intertidal flat), and 123.71 (subtidal flat), largely controlled by sediment mass accumulation rate of sediment (MAR). In the central coast of China, the MAR of Chongming East Beach (CEB), the largest tidal wetland in the Yangtze estuary, was constrained using ^{7}Be, ^{228}Th and ^{210}Pb in different time scales. The SF-SOC in ECB showed a sharp decrease from high to low tidal flats. In southern China, the Beibu Gulf coast is populated with mangrove forests, the primary source of organic carbon in the mangrove sediments was found to be terrigenous. SF-SOC was 4.0-17.8, 3.0-18.7 and 10.4 -28.1 in Qisha Harbor, Sanniang Bay, and Lianzhou Bay of the gulf. At all sites investigated, the SF-SOC reflects the anthropogenic impacts and climate change, such as dam contracture in river basin, land utilization, wetland conservation, sea level rise, etc.

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Pushing the limits of the 1 MV Accelerator Mass Spectrometry system at the *Centro Nacional de Aceleradores* to analyse ^{233}U and ^{244}Pu

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Keywords : AMS, CNA, actinides

The *Centro Nacional de Aceleradores* (CNA) hosts the first multi-elemental 1 MV Accelerator Mass Spectrometry (AMS) system by High Voltage Engineering Europa (Amersfoort, The Netherlands) since 2005. An increasing know-how on its performance and on actinides radiochemistry has made it possible the analysis of Pu, U and Np radionuclides. To date, ^{236}U, ^{237}Np and ^{239,240,241}Pu are routinely analysed at the CNA. Due to its compact design, the achieved $^{M\pm1}X/^{M}Y$ abundance sensitivities are not competitive with those offered by state-of-the-art compact AMS systems. Still, background levels at the 10^6 atoms per sample for ^{237}Np and Pu isotopes, and ^{236}U/^{238}U abundance sensitivities of 10^{-10}, have been demonstrated, opening the gate to many applications. Recently, the limelight has been put on the analysis of ^{233}U and ^{244}Pu. With extremely low concentrations and atomic abundances (global fallout ^{233}U/^{236}U and ^{244}Pu/^{239}Pu atom ratios at the 10^{-2} and 10^{-4} level, respectively (Hain et al., 2020; López-Lora et al., 2023), their AMS analysis is extremely challenging. In this work, we will evaluate the performance of the 1 MV AMS system to the analysis of ^{233}U and ^{244}Pu, and we will show a few examples illustrating the potential of the study of the ^{233}U/^{236}U and ^{244}Pu/^{239}Pu atom ratios in natural samples as a tool to unravel global fallout from nuclear industry U and Pu sources.

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Next generation of isobar suppression at the new 1 MV AMS system HAMSTER

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Keywords: Accelerator Mass Spectrometry, isobar suppression, ^{135}Cs, ^{137}Cs

The Helmholtz-Zentrum Dresden-Rossendorf (HZDR) operates the DREAMS facility based on a 6-MV tandetron and there provides state-of-the-art capabilities for measurements of ^{10}Be, ^{129}I, and a number of other isotopes routinely determined by accelerator mass spectrometry (AMS). A new compact AMS facility, HAMSTER (Helmholtz Accelerator Mass Spectrometer Tracing Environmental Radionuclides), is planned to be installed at HZDR in late 2023. There, the repertoire of measured isotopes will be expanded to actinides and furthermore to non-classical AMS radionuclides such as ^{135}Cs and ^{137}Cs by including a laser-based isobar suppressor. There, anions are slowed down in a buffer gas filled radio-frequency quadrupole to near-thermal energies and collinearly overlapped with a laser beam. This is investigated and already implemented at the AMS facility VERA (Vienna Environmental Research Accelerator) of the University of Vienna. As a practical example I will show results of measurements of the ratio of Cs isotopes ^{135}Cs and ^{137}Cs by Ion-Laser Interaction Mass Spectrometry (ILIAMS) at VERA, where different electron detachment energies of CsF_2 and BaF_2 anions allow for suppression of the Ba isobars when overlapping the low-energy anion beam with a green laser beam. Furthermore, I will present our design of the second generation of such an ion cooler and first impressions and results from the setup of this system at HZDR.

13 PARALLEL SESSION 5A

Atmosphere I

40-years 210Pb and trace elements concentrations at Helsinki, Finland

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Keywords: radioactive tracer, long-term observations, atmospheric pollutants.

Weekly air filter samples were collected from the Helsinki metropolitan area between 1962-2005. The concentrations of the radioactive isotope ^{210}Pb and of trace elements (eg. Si, Zn, Pb) were determined to evaluate the influence of different pollutants on the atmosphere and environment.

Both ^{210}Pb and Pb were studied to understand their sources, dispersion and identify the effects of anthropogenic activities. Most of Pb in the human environment is of technological origin. Pb extracted from mines has very low ^{210}Pb content. Pb concentrations have decreased since 1970s and are strongly correlated with lead smelters north of Helsinki, on-site incinerators, lead gasoline and fuel combustion. Trace elements and ^{210}Pb concentrations had decreased significantly, especially after 1980, coinciding with first regulations applied for controlling and reducing air pollution in Europe.

Seasonal differences cause significant changes in elemental concentrations. The maximum ^{210}Pb concentrations appear in the cold season. In winter, the lower troposphere becomes stratified, allowing air pollutants to stay close to the ground level. All elements present the greatest reduction in their annual atmospheric concentrations during spring.

Source apportionment study of total carbon fraction of urban aerosols in Bratislava, Slovakia

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Keywords: radiocarbon, urban aerosols, source apportionment

Carbonaceous aerosols are an important component of aerosol particles in the atmosphere due to their environmental and human health impacts. Their source apportionment is therefore of great interest. This study focuses on aerosols from the Bratislava urban area. For a period in 2022/2023, ambient aerosols were collected on quartz microfibre filters with two-week sampling period at the campus of Comenius University in Bratislava, Slovakia. Total carbon (TC) fraction, i.e. the sum of all carbonaceous particles of the collected aerosols, is used for this analysis. Based on measurements by accelerator mass spectrometry, the contribution of carbonaceous particles from fossil sources (fossil fuel burning) and contemporary biogenic sources (biomass burning, natural sources) can be determined. The presented results will illustrate the variability of total carbon content of the aerosols and also the changes in the proportion of fossil and biogenic sources of carbon particles in the air. The fossil-fuel derived aerosols are major part of the sampled aerosols, but although the sampling site is in the middle of considerably urbanized and industrialized city, biogenic carbonaceous particles make a significant part of the total carbon fraction.

Origin of atmospheric ^{129}I in Southern Spain

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Keywords: Iodine-129, aerosol, NFRP, atmosphere, Accelerator Mass Spectrometry.

^{129}I ($T_{1/2} = 15.7 \times 10^6$ y) is a radionuclide whose presence in the environment changed strongly due to the emissions from the two largest nuclear fuel reprocessing plants in Europe: Sellafield (UK) and La Hague (France). Most of the ^{129}I has been discharged to the sea, but part of it is released as gaseous ^{129}I. Liquid discharges of ^{129}I mostly travelled from these plants to the North Sea and then to the Arctic along the Norwegian coast. Gaseous discharges spread quickly over the Northern Hemisphere.

We present the results for atmospheric ^{129}I concentrations and $^{129}I/^{127}I$ isotopic ratios over two cities in Southern Spain: Seville (37°23′N, 5°59′W) and Malaga (36°43′N, 4°28′W) in 2013. The results showed gaseous ^{129}I concentrations typically in the order of 10^5 at.m^{-3} over Seville. Particulate ^{129}I concentrations were in the order of 10^4 at.m^{-3} over both cities, but typically lower in Malaga compared to Seville. $^{129}I/^{127}I$ isotopic ratios were similar in the two cities, in the order of 10^{-9} to 10^{-8}. A very good agreement was observed on the temporal evolution of the two iodine species in Seville and between particulate ^{129}I in Seville and Malaga, indicating a common origin of the ^{129}I over the two cities.

The analysis of the air masses arriving to Seville and Malaga showed that high ^{129}I levels coincided with winds coming from Sellafield and, especially, from La Hague NFRP. Direct emissions from La Hague are considered the most likely source of the atmospheric ^{129}I over Seville and Malaga during 2013.

Case study of recent radioactive contamination in the lower atmosphere of Spitsbergen, Svalbard archipelago

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Keywords:
radioactive pollution, air filters, Spitsbergen

Several unexpected signals of radionuclides have recently been detected in the atmosphere and reported by the scientific community. It is believed that these incidents could be associated with undeclared nuclear activities, not directly connected with nuclear weapons. Furthermore, the Earth's System is undergoing a distinct transformation due to climate changes, with the most rapid processes in the Arctic region. Global warming could be a significant factor triggering or enhancing air resuspension of pollutants. Therefore, continuous observation as well as the development of new monitoring strategies for atmospheric radioactivity appears nowadays of great importance. The presented research concerns analyses of selected radionuclides from aerosol samples collected at The Stanisław Siedlecki Polish Polar Station in Hornsund, Svalbard archipelago (77°00′ N, 15°33′ E) covering the years 2002-2018. Radionuclides under study represent groups of different origins, which include lithogenic (^{40}K, ^{210}Pb), cosmogenic (^{7}Be), and anthropogenic (^{137}Cs, $^{238, 239, 240}$Pu) isotopes. A long-term and multivariate analysis of their content and dynamics of changes in the ground layer of air comprises a valuable contribution to the knowledge of radioactivity in the High Arctic atmosphere.

This study was supported by the National Science Centre, Poland under research project No. 2021/43/D/ST10/02049.

A fast algorithm for real-time monitoring of artificial radioisotopes implemented in the Catalan Environmental Radioactivity Surveillance Network

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Keywords: Environmental radioactivity, gamma-ray spectrometry, analysis methods.

The Catalan Environmental Radiological Surveillance Network consists of different types of scintillation gamma spectrometry detectors for the continuous and real-time automatic measurement of environmental radiation. These following monitors generate, every 10 minutes, a gamma spectrum: 23 direct measurement monitors (13 with $LaBr_3$(Ce), 5 SrI_2(Eu) and 5 NaI (Tl) detectors), 10 particulate filter monitors (9 with $LaBr_3$(Ce) detectors and 1 with SrI_2(Eu)) and 2 river water monitors. This means that, as average, a 1.5 million spectra are recorded and need to be analysed.

A method for the automatic and real-time quantification of the activity concentration of artificial and natural isotopes was developed and tested in the laboratory and is being implemented in the network. The uncertainties in the activity concentrations, as well as the corresponding detection limits, were calculated applying the ISO-11929 standard. The method is based on the analysis by spectral regions or ROIs (Regions of Interest), eliminating from the ROIs of the artificial isotopes of study the contributions due to emissions of natural isotopes (overlapping and Compton radiation), the ambient background, the possible intrinsic background of the detector and the contributions of other possible isotopes. As a result, an equation is generated for each isotope. This equation allows us to obtain its net activity concentration (Bq/m^3). This procedure is applied to determine the activity concentration of isotopes of natural origin (^{212}Pb, ^{214}Pb and ^{214}Bi) and artificial (^{131}I, ^{137}Cs and ^{60}Co).

The method successfully eliminates the contribution (natural elements, intrinsic background and Compton). Therefore, it allows obtaining the net activity concentration of the artificial isotopes of interest. Artificial isotopes detection events recorded by the network monitors will be presented.

14 PARALLEL SESSION 5B

Accelerator Mass Spectrometry I

Extending the set of environmental tracers by the novel anthropogenic signatures $^{233}U/^{236}U$ and ^{237}Np

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Keywords: Accelerator Mass Spectrometry, environmental archives, Uranium-233, Neptunium-237

The atomic $^{233}U/^{236}U$ ratio was proposed as a superior oceanographic tracer as this signature allows to distinguish environmental emissions of civil nuclear industry from weapons fallout and uranium (U) behaves conservatively in sea water. For tracer applications, a careful characterization of the principal sources of ^{233}U including the contribution from natural production is required. $^{233}U/^{236}U$ ratios were analysed in samples from different locations, partly time-resolved or of well-known age to be able to narrow down the time span of the maximum ^{233}U release. Samples comprised a coral core (Flinders reef, Australia), a sediment core (lake Hallstatt, Austria), a peat bog core (Pürgschachen Mire, Austria) and sediment from the layered urban artificial ground of Vienna (Austria). Whenever possible, the new $^{233}U/^{236}U$ data was directly compared to other

isotopic signatures and/or mono-isotopic makers such as $^{240}Pu/^{239}Pu$ or ^{237}Np. In agreement with the results for a Baltic Sea sediment core published previously, the maximum $^{233}U/^{236}U$ ratios in the lake sediment were found to be exceptionally high, i.e. > 0.1. ^{237}Np is another promising oceanographic tracer, but its quantitative analysis by mass spectrometric techniques such as Accelerator Mass Spectrometry (AMS) is hampered by the lack of an isotopic spike. The present status of our corresponding joint project aiming at the production of a ^{236}Np spike material will be discussed. Mass 236 has been successfully produced by the irradiation of Th foils with a ^{7}Li beam in the 30-40 MeV range at the RIKEN Nishina Center. AMS measurements using fluoride molecules indicate that the observed surplus of mass 236 above background is indeed ^{236}Np.

Analysis of ^{90}Sr in environmental samples at the attogram-level by accelerator mass spectrometry

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Keywords: Strontium-90, accelerator mass spectrometry, ILIAMS

Despite its reasonably short half-life ($T_{1/2}$ = 28.9 a), radiometric detection of the radiologically relevant anthropogenic radioisotope ^{90}Sr is cumbersome and time-consuming. Detection limits of conventional mass spectrometric techniques for ^{90}Sr have been similar to the radiometric limit of 3 mBq mainly due to interferences of stable isotopes and/or the stable isobar ^{90}Zr. Here, we report on the successful detection of ^{90}Sr at the ag/g-level in environmental samples by accelerator mass spectrometry (AMS). The world-wide unique Ion-Laser InterAction Mass Spectrometry (ILIAMS) technique at the Vienna Environmental Research Accelerator AMS-facility provides unprecedented ^{90}Sr-sensitivity: the overall Sr-detection efficiency is 4×10^{-4} and the blank value ^{90}Sr/Sr < 5×10^{-16}. This corresponds to a 100-fold improved detection limit of <0.03 mBq, i.e., $4x10^4$ atoms or 6 ag of ^{90}Sr in a sample of 2-3 mg of Sr. Recently, we have successfully determined the ^{90}Sr/Sr ratio in <1 g of contemporary coral aragonite and samples of 300-500 ml of seawater, and analyzed the ^{90}Sr content in soils and other environmental archives after adding Sr carrier. Sample preparation chemistry relies mainly on column separation by Sr-resin and subsequent precipitation as SrF_2 followed by dry admixing of PbF_2. Measurement results on IAEA reference materials (bone and soil) are in good agreement with their expected values and demonstrate the robustness of the technique.

Exploring the lowest levels of environmental ^{90}Sr/Sr compared to ^{236}U/U in carbonates and seawater using a new, highly sensitive Accelerator Mass Spectrometry technique

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Keywords: marine radioactivity, ocean tracers, 90-Sr, 236-U, GEOTRACES

Strontium-90 (^{90}Sr) is an anthropogenic radionuclide, which, due to its radiological relevance, has been most intensively monitored in the past. In terms of initial activity, over 630 PBb of this radioisotope have been distributed globally from stratospheric fallout of bomb-testing, and there are more localized contributions from test, accidents, and releases from reprocessing plants. In the past massive sample sizes (up to 100 l of seawater or 100 g of coral aragonite) were required even right after the peak period of global fall-out from bomb testing. On the other hand, the high amount of strontium dissolved in seawater complicates the use of mass spectrometric methods, as an isotopic abundance sensitivity of at least $1 \cdot 10^{-15}$ is required to detect the estimated main signal. With recent advances in isobar separation technique in accelerator mass spectrometry (AMS) at the University of Vienna, this requirement has come within reach, offering new research possibilities. The new technique uses an ion-cooler and laser-photo-detachment to suppress the stable isobar ^{90}Zr almost completely. With initial test samples we could confirm an isotopic abundance sensitivity of $8 \cdot 10^{-16}$ ^{90}Sr/Sr, sufficient for application to ocean water samples. In this presentation we will show comparison of ^{90}Sr to ^{236}U, another ocean tracer that has been studied intensively recently. We will present results from contemporary coral skeleton material, the methods, requirements, and impact of sample preparation. Further, first result from ocean water samples and the sample preparation and blank levels for these types of samples will be shown.

Finally, we explain our sample preparation scheme to extract ^{236}U, simultaneously with ^{90}Sr for multi-isotope applications of both.

ALIS - a new isobar suppression setup for trace analysis of ^{90}Sr at CologneAMS

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Keywords: Strontium-90, Accelerator Mass Spectrometry, Ion cooler, Isobar suppression

Strontium-90 ($T_{1/2}$ = 28.64 a) is among the most hazardous fission products and is of great environmental interest due to its radiotoxicity as well as its potential as an environmental tracer. Accelerator Mass Spectrometry (AMS) is the most sensitive method for the detection of long-lived radionuclides. However, the interference of the highly abundant stable isobar ^{90}Zr prevented its use for ^{90}Sr. The Ion-Laser InterAction Mass Spectrometry (ILIAMS) setup at the Environmental Research Accelerator (VERA) has demonstrated to solve this problem by neutralizing the isobar via laser photodetachment in a gas-filled radiofrequency quadrupole (RFQ), achieving a detection limit for ^{90}Sr of < 0.1 mBq [1].

In a collaboration between the University of Vienna and the University of Cologne, a new advanced RFQ ion cooler for trace analysis of ^{90}Sr in environmental samples has been developed, aiming to further improve the ion-laser interaction assisted AMS measurement efficiency of ^{90}Sr and thus shorten the required measurement time. It is part of the Anion Laser Isobar Separator (ALIS), a new isobar suppression setup, at the 6 MV AMS facility of CologneAMS. An AMS measurement routine for ^{90}Sr is under development. The routine will be tested with environmental samples provided from the AVR reactor site in Jülich.

[1] M. Martschini et al., Radiocarbon, 64(3), 555-568. doi:10.1017/RDC.2021.73

Performance and first analysis using accelerator mass spectrometry in CENTA laboratory, Bratislava

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Keywords: AMS, radiocarbon, CENTA

Accelerator mass spectrometry (AMS) proved for decades the suitability and superiority in the measurement of long-lived radionuclides and stable nuclides. Therefore, it's used in many laboratories all around the world for dating purposes, environmental studies, material and health sciences, etc. The main advantages of AMS compared to radiometric methods are the smaller size of used samples (even to μg) and shorter measuring times. During AMS analysis, ions of rare isotopes are extracted from a sample material in the ion source and after energy and mass separation are accelerated by an electrostatic tandem accelerator while counting individual ions with nuclear detectors after acceleration to MeV energies.

A Centre for Nuclear and Accelerator Technologies (CENTA) was established in 2013 at Comenius University in Bratislava, comprising two ion sources, a low energy analysing and injection system, and a Pelletron accelerator with 3 MV of the maximal terminal voltage. This system was upgraded in the summer of 2022 by a high-energy analysing beam line with the end-of-line detector, together with the bouncing system for the fast switching of the isotopes. The performance characteristics of the facility and the first AMS measurements will be presented in this paper.

Status and development of ^{90}Sr soil measurements at CologneAMS

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Keywords: Sr-90, accelerator mass spectrometry, soil

^{90}Sr is produced by nuclear fission and is a prominent nuclide in nuclear waste and fallout. It plays a major role in decommissioning of nuclear facilities, e.g., for the decommissioning of the AVR Jülich prototype reactor large amounts of soil have to be analyzed. Due to its radiotoxicity, the clearance levels for unconditioned release are low. Since the state-of-the-art measurement techniques rely on the low energy β-decay of ^{90}Sr ($T_{1/2}$ = 28 y), the sample preparation and the detection are rather complex and time consuming. Using accelerator mass spectrometry (AMS) ^{90}Sr can be measured after a simplified separation. The counting does not depend on the ^{90}Sr decay, this reduces demands on sample preparation as well as the sample size. The main efforts are a high sputter efficiency and the suppression of the stable isobar ^{90}Zr.

First soil samples have been measured at the 10 MV tandem accelerator in Cologne. The sample preparation is done in a collaboration with the division of nuclear chemistry. The ^{90}Zr concentrations of standard materials can be fully separated from the radionuclide ^{90}Sr at beam energies of 80 MeV using our 10-anode gas ionization detector. The background level ^{90}Sr/Sr is below 10^{-13}. This contribution will present the status of ^{90}Sr measurements, the preparation of soil samples and first measurement results. We also will discuss the challenges related to characterizing large numbers of ^{90}Sr samples in an industrial-like setting, as required for decommissioning of e.g., the AVR Jülich.

15 PLENARY SESSION V

Identification of gaps and challenges in the management of NORM

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Keywords: NORM, gaps, chalenges, sampling, characterization, doses

During the 21st century a key role in radiation protection is being played by NORM issues. Different protocols have been developed for a proper protection of the workers, public and the environment associated to NORM activities, considering in each case their peculiarities.

However, and mostly due to the tendency to simplification, several gaps and challenges are still existing in the management of NORM. Some of them will be detailed and evaluated in this work. Special emphasis will be put in the need of proper sampling methods, in the need of proper radioactive and non-radioactive characterization of NORM samples and in the selection of no over conservatives models for NORM assessments. All these needs demand of skilled multidisciplinary personnel

Recommendations to overcome the comment gaps and challenges will be given,

Sub Surface Science - Radionuclide Research in and about the Underground

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Keywords: Underground laboratory, deep geothermal energy, alpha recoil, dating

The analysis of environmental radioactivity frequently requires low detection limits to capture the present activity range. As a consequence, contributions from external radiation sources must be minimised to achieve very low blank values. Underground laboratories provide such environments due to their reduced influence of cosmic ray contributions and the opportunity to install large scale and effective shieldings.

We present a summary of 40 years of operation of the underground laboratory Felsenkeller (Dresden, Germany). Situated at a depth of 140 m w.e. it allows for the best conditions to analyse several thousand samples per year routinely. Its main application focuses on low level gamma spectrometry but also low level tritium analyses is performed successfully.

Currently nine gamma spectrometers plus two liquid scintillation counters are installed, all at least in low level quality. The scope of applications ranges from measurements for consumer protection to analysis for science and research to environmental monitoring.

Among these, one focus in recent years included investigations on fluids and precipitates from plants for the exploitation of deep geothermal energy. Deep waters are often characterised by enhanced salinity in the order of 100 g l^{-1} and activity concentrations of the Radium isotopes ^{226}Ra and ^{228}Ra up to several 10 Bq l^{-1}. Laboratory investigations showed a stabilisation of Radium species above some 10 g l^{-1} salinity. Furthermore, Monte Carlo simulations revealed a close relationship between the ^{228}Ra/^{226}Ra activity ratio in the fluid and the Th/U concentration ratio of the aquifer rock. Thus the ^{228}Ra/^{226}Ra ratio may serve as an fingerprint of the geological formation serving as the aquifer.

Changes in the thermodynamic conditions as they occur in the plant lead to different precipitates, so called scalings. Two types are of special interest for radiation protection and waste management issues: Ba/Sr sulfates and Pb containing phases since they accumulate $^{228,\ 226}$Ra and ^{210}Pb, respectively. Moreover, the sulfate scales allow a determination of their formation age via the combination of ^{228}Ra/^{226}Ra and ^{228}Th/^{228}Ra activity ratios. The actually unwanted accumulation of natural radionuclides may serve in this case as a valuable tool for the understanding of the scale formation in the geothermal plant.

Detector radiopurity and background problems in underground experiments

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Keywords: Neutrinoless double beta decay experiment, Radiopurity, Low-background detector

The neutrino is a key particle in astroparticle physics and cosmology, but some of its fundamental properties are still not well understood. While strong evidence that neutrinos have non-degenerate mass has come from observations of neutrino flavor oscillations, neutrinoless double beta decay (0ν-DBD) is the only practical path to determine the nature of the neutrino (Dirac or Majorana) and one of the most sensitive probes of its absolute mass. Currently-running and planned 0ν-DBD experiments aim to reach an experimental sensitivity in terms of half-life at the order of 10^{27}–10^{28} yr to probe the inverted neutrino hierarchy. This became feasible mainly due to the significant progress in detector techniques (bolometers, scintillating bolometers, semiconductor detectors, scintillators, and time-projection chambers) along with the development of high quality crystalline materials with tailored characteristics such as a high purity ^{76}Ge, TeO_2, Zn^{82}Se, $^{116}CdWO_4$, Li $^{100}MoO_4$, Ca$^{100}MoO_4$, etc. At the same time, a combination of various factors, such as the availability of isotope enrichment technology or its high natural abundance, the existence of a suitable detector material and a well-established technology for its production leads to the concentration of experimental efforts on a few DBD-active isotopes – ^{76}Ge, ^{82}Se, ^{100}Mo ^{116}Cd, ^{130}Te, ^{136}Xe. Moreover, the ultimate experimental sensitivity could be achieved only in a well-shielded experimental setup located deep underground and operating a ton-scale detector. Hence, special care has to be taken at every stage of the detector development and production, in order to avoid detector radioactive contamination, to reduce contribution from environmental background and cosmogenic activation of materials.

Here we will discuss the importance of the radiopurity of the detector and construction materials, the isotope of interest selection and major related background components, dangerous cosmogenically activated nuclides and strategies to overcome all above listed factors on examples of a few low-background DBD experiments.

Accreditation of the IAEA's Environmental Laboratories for reference material production and updates on IAEA proficiency test exercises

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One of the mandates of the International Atomic Energy Agency (IAEA), and especially of the Department of Nuclear Sciences and Applications(DNSA) and its Environment Laboratories (EL) is to provide assistance to Member States' to improve the quality of measurement results they obtain using nuclear and associated analytical techniques. In this context, the IAEA provides reference materials (RMs) and certified reference materials (CRMs), characterized for activity concentrations of radionuclides, mass fractions of trace elements and methyl mercury or organic compounds and stable isotope ratios.

The use of RMs and CRMs, participation in proficiency tests and inter-laboratory comparisons allow the verification of analytical performance. RMs and CRMs are among the most important tools to improve and maintain the analytical quality of laboratories and to demonstrate the quality of measurement results. The availability of RMs and CRMs is a prerequisite for ensuring the quality of data used for various assessments, development of new measurement techniques and training, as well as to support other Agency programmes.

The presentation will focus on the accreditation of CRM production for radionuclides with gamma emitters in marine and terrestrial matrix, and in the second part on the world-wide 2022 Proficiency Test for radionuclides in sea water sample.

In the first part the DNSA-EL Quality Policy for the production of RMs within the IAEA will be covered, which ISO guides were implemented to ensure the services related to the provision of CRMs and how the NA-EL are committed to achieving these objectives through the implementation of a QMS (Quality management System) that is structured to address, as applicable, the criteria given in the international standards ISO 17034, ISO/IEC 17025 related to analytical methods used for the characterization of CRMs and other relevant international standards and guides. The achievements for accreditation of radionuclides of some CRMs through Autrian Accrediation Body Query Company (akkreditierung-austria.gv.at) or Search Companies (akkreditierung-austria.gv.at) will be presented.

In the second part, the results and evaluation for the proficiency test (PT) conducted within the IAEA-RML-2022-01 worldwide open proficiency test exercise for sea water sample will be presented. The data were evaluated by the Radiometrics Laboratory (RML) of the Environment Laboratories using its standard approach for proficiency test evaluations. In total 112 laboratories worldwide with 91 feedbacks, to which 15 participants from Spain laboratories (network with 11 feedbacks) participated in this exercise. The performance of laboratories for specific radionuclides and applied radioanalytical methods will be discussed in detail. For the futures PT any suggestions for matrix of marine samples and radionuclides studied would be welcomed.

Progresses on the ^{210}Pb-based dating of recent sediments under varying rates of supply

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Keywords: ^{210}Pb-dating, temporal variability, sedimentation rates, $^{210}Pb_{exc}$ fluxes, TERESA model.

The method based on ^{210}Pb provides absolute age determination in recent sediments (< 100-150 years), which are treated as a continuous medium. The most common sedimentary scenarios involve ideal boundary conditions and no post- depositional redistribution. However, the chronology cannot be decoded without a set of assumptions on the temporal variability of fluxes (F), initial activity concentrations (A_0), and sedimentation rates (w). The assumption of constant flux is adopted by the CRS and CFCS models, which have been of the most widely used. This work reviews recent advances that have questioned this paradigm and explores the boundaries of the state-of-the-art. A systematic survey of sediments with a varve-based chronology has shown that the most common conditions involve random and independent variability in w and A_0 that results in varying fluxes that correlate with w. This violates the assumptions of the CRS, CFCS and PLUM models. The SIT model, which claimed its ability to date sediments with independent time variability of F and w, seemed to be the definitive dating tool. However, it has been shown that this model lacks of a sound physical basis and misuses the Fourier expansion series. The new TERESA model is based on the above statistical correlation between F and w and performs the numerical simulation of tens of thousands of normal distributions of A_0 and w to decode the sediment history that best fits the experimental data. In this work, its use is demonstrated with a wide set of challenging sediment cores. However, it is far from being a definitive dating tool. Moreover, the study of model errors allows the applicability of CRS and CFCS models when the variability of fluxes is randomly distributed on the time line, or when it shows stepped changes.

16 PARALLEL SESSION 6A

Atmosphere II

Uranium and thorium airborne levels around a Yellow-cake_UF_4 conversion plant: Stack discharge and resuspension contributions

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Keywords: Uranium, Thorium, Conversion, Airborne concentration, Resuspension, Stack discharge

Ten years after a first study we provide a new insight on airborne uranium activity concentrations around a yellow-cake_UF_4 uranium conversion plant. Airborne uranium concentrations were weekly measured over a one-year period. These concentrations depend on time spent downwind of the facility, meteorological parameters (mostly rain and air mass origin) and emissions. The most impacted downwind area and the main emission and discharge sources have been characterized with regards to ambient airborne uranium concentrations. Along the past decade, a 22-fold decrease was observed in the atmospheric uranium discharge. Consequently, the airborne uranium concentration also decreased but against all odds with a much lower (7-fold) magnitude. Resuspension of formerly accumulated uranium on soils around the facility is evidenced as a secondary and delayed source. However, the respective contribution of resuspension activities, either natural (i.e., wind-induced) or anthropogenic (earth-moving, agricultural practices…) can significantly impact the ambient airborne uranium concentrations. Very sensitive ICP-MS measurements show slightly exceeding levels above the regional background in the nearest city of Narbonne but to a very low extent and similar to what was observed with marine air mass intrusions. Thanks to filter weighing, mass activity concentrations were clearly enhanced during operational periods as compared with shutdown periods. This highlights the benefit of using the mass activity concentration as a clear signature of the industrial source and independently of the atmospheric aerosol burden.

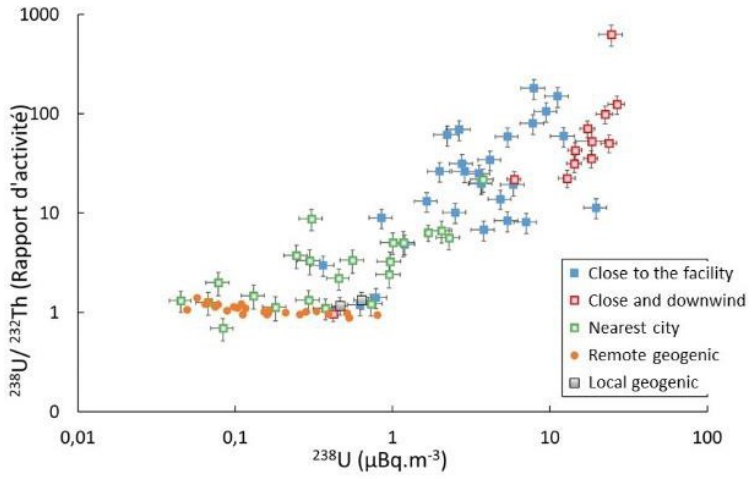

Figure 1: Uranium source apportionment around a uranium conversion plant: geogenic, soil resuspension, and stack discharge.

Impact of extreme Saharan dust intrusion on radioactive aerosols in southeast Spain

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Keywords: Atmospheric aerosols; PM_{10}; Mineral dust; ^{210}Pb; ^{7}Be; Radiocesium.

From 14 to 16 March 2022 an extreme Saharan Dust Intrusion event (SDIe) occurred, affecting Southwestern Europe, and reaching as far as northern Europe. The episode was exceptional with records of PM_{10} concentration (above 1000 $\mu g/m^3$) registered by Spanish air quality network. The impact of the episode was maximum in southeast of Spain and in the current study we analyze the influence of this extraordinary episode on radioactive aerosols collected in Granada (Spain). At the monitoring station of the University of Granada, atmospheric aerosols were weekly collected, and radioactivity levels were determined by gas flow proportional counter (Gross α and Gross β) and gamma spectrometry (^{7}Be, and ^{210}Pb). The radioactivity results of the aerosols monitoring during 1st semester of 2022 and SDIe are summarized below:

		Gross α (μBq/kg)	Gross β (μBq/kg)	^{7}Be (μBq/kg)	^{210}Pb (μBq/kg)
1st Semester	**Range**	10 – 200	190 – 700	560 – 7800	70 – 860
	Mean ± SD	90 ± 60	440 ± 150	5100 ± 2200	520 ± 230
Extreme SDIe		200 ± 10	400 ± 10	3600 ± 130	400 ± 20

The largest impact of the extreme SDIe was detected in Gross α, resulting in the highest levels detected during the first semester of 2022. Comparing the radioactivity levels during the severe episode with respect to previous week, Gross β and ^{210}Pb increased while the activity concentration of ^{7}Be aerosols decreased. Additionally, during the extreme SDIe, ^{40}K (250 ± 60 $\mu Bq/m^3$) and ^{137}Cs (4 ± 1 $\mu Bq/m^3$) were also detected. Finally, all the radiotracer analyzed decreased the week after the SDIe, being the largest fall on ^{7}Be aerosols.

Unprecedented xenon collection and separation from air on silver-exchanged zeolites

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Keywords: Xenon, adsorption, separation, silver-exchanged zeolite

Low level measurements of atmospheric radioxenon, such as for the verification of the Comprehensive Nuclear-Test-Ban Treaty, require complex collection, separation and detection systems. The collection and separation of Xe in this context is particularly challenging owing to its very low natural abundance in air (*i.e.* 87 ppb) and its inertness. For the detection part, the collected Xe gas needs also to be depleted of Rn to minimize interferences on the radioxenon detection. Historically, the collection and separation of atmospheric radioxenon has been performed with a complex succession of adsorptive columns using molecular sieves and activated carbons.

In this work, we demonstrate the potential of two silver-exchanged zeolites to collect and separate Xe directly from dry air in a single adsorptive column. These two silver-exchanged zeolites show unprecedented Xe adsorption capacities in air (> 3 cm^3_{SATP}/kg) and Xe selectivities in air (> 1000). They also allow to efficiently separate Xe from Rn and thermally recover Xe with a high purity. However, the moisture content of the gas stream can have a negative effect on the xenon adsorption properties in these adsorbents. The results are compared to a typical activated carbon, used in this context, but also to two metal-organic frameworks with promising properties for Xe/Kr separation.

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A methodology to determine ^{212}Pb, ^{212}Bi, ^{214}Pb and ^{214}Bi in atmospheric aerosols; application to precisely obtain aerosol residence times and Rn-daughters' equilibrium factors

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Keywords: ^{220}Rn – ^{212}Pb – ^{212}Bi, ^{222}Rn – ^{214}Pb – ^{214}Bi, Aerosol residence times, Equilibrium factors, Gamma-ray spectrometry

Progeny of ^{222}Rn and ^{220}Rn (^{214}Pb and ^{214}Bi, and ^{212}Pb and ^{212}Bi, respectively) are very useful to estimate atmospheric aerosol residence times and Rn equilibrium factors. However, precise measurements of these radionuclides are quite complex due to their very short half-lives (~ 20 min – 10 h). Therefore, this study aims to develop a new and precise methodology to measure these radionuclides. Radon- 222 and ^{220}Rn were measured using an atmospheric radon monitoring (ARMON) system, while their respective progenies were collected in a filter and measured by gamma-ray spectrometry using an extended range (XtRa) high purity germanium (HPGe) detector. The filters employed for the samplings and for the efficiency calibration was of propylene type (44 x 44 cm^2), using a very high-volume air sampler, model ASS-500 (air flow ~ 500-600 m^3 h^{-1}). For the XtRa efficiency calibration, RGU-1 (^{238}U-series) and RGTh-1 (^{232}Th-series) standards, provided by the International Atomic Energy Agency, were mixed and uniformly spread onto calibration filters, covering the same region as that in sample collection. Time- series aerosol samplings were carried out at "El Carmen" Campus at the University of Huelva (SW Spain), achieving precisions for the ^{222}Rn and ^{220}Rn progeny concentrations 10%, residence times about 1-3 hours, and equilibrium factors statistically compatible with 1, which is consistent with other works. In addition, a total critical time (time elapsed between sampling start and counting end) was found to be about 2-2.5 hours for the precise determination of the ^{212}Bi and ^{214}Bi.

17 PARALLEL SESSION 6B

Accelerator Mass Spectrometry II

Isobar analysis in the actinide range for the characterization of a prospective Np spike material

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Keywords: Isobar separation, AMS, Actinides, Neptunium, Uranium, Plutonium,

^{237}Np ($T_{1/2}$ = 2.1 Ma) is the second most abundant anthropogenic actinide in the environment. However, the lack of an isotopic Np spike impedes the normalization of AMS (Accelerator Mass Spectrometry) results. We consider ^{236}Np the most suitable candidate to serve this purpose. Such a spike material is currently under development, but the expected co-production of ^{236}U and ^{236}Pu necessitates an elaborate separation of U and Pu from Np by chemical means. A combination of three approaches can now be used to characterize a prospective Np spike. In the first step, the ratio of ^{236}X/^{237}Np of the prospective spike materials is determined in an AMS measurement on the actinide beamline at VERA (Vienna Environmental Research Accelerator). The isobaric analysis of mass 236 is primarily based on the element-specific formation ratio of AnF_4^-/AnF_5^- of the three actinides An in question in the AMS ion source. This separate measurement uses targets mixed with PbF_2. An isobaric interference could be identified by a deviation from the calibrated AnF_4^-/AnF_5^- formation ratio for the expected actinide.

To complement this isobar analysis for the spike characterization, the novel ILIAMS (Ion-Laser InterAction Mass Spectrometry) method for isobar separation has been applied to the actinide range for the first time. Our results indicate that ILIAMS provides an independent way to analyze the ^{236}Pu content of the prospective spike material and may expand the list of actinides accessible to AMS measurements in the coming years. The first steps towards measuring ^{238}Pu in AMS by suppressing the primordial isobar ^{238}U by up to 8 orders of magnitude will be presented, as well as the detailed procedure of the Np spike characterization.

Technetium-99: what is your environmental abundance?

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Keywords: Technetium, Accelerator Mass Spectrometry, Isobar Suppression

Concentrations of the anthropogenic radionuclide ^{99}Tc ($t^{1/2}$ = 2.1 ·10^5 yr) are rather well studied in the Irish Sea, where the Sellafield reprocessing plant is responsible for high concentrations of 0.1-10 mBq/ml. However, there is little data on the global distribution, or on the physico-chemical behavior of ^{99}Tc in the environment. Determination of the ^{99}Tc concentration in samples further away from contamination sources requires a detection method with extraordinary sensitivity of better than 1 µBq/sample. In mass spectrometric detection methods for ^{99}Tc, the stable isobar ^{99}Ru, and all molecules with a mass of 99 amu, have to be suppressed. Accelerator Mass Spectrometry (AMS) of ^{99}Tc is currently only possible at AMS-facilities equipped with large accelerators that can reach >10 MV terminal voltage. The Australian National University (ANU), uses a 14 MV tandem accelerator, so that the ions are accelerated to ~190 MeV, suppressing all molecular interferences for the selected $^{99}Tc^{13+}$ by foil-stripping. ^{99}Ru and ^{99}Tc are separated in an 8-anode ionization chamber exploiting minute differences in their energy loss characteristics, observable only at these high ion energies. The AMS technique requires normalization to an abundant isotope of the same element, which is not possible for Tc. Extracting TcO^- and NbO^- from the sputter matrix and normalizing the ^{99}Tc counts to a $^{93}Nb^{12+}$-current showed a precision of 10%. Using this approach, a ^{99}Tc dilution series of 1 mBq – 1 µBq /sample was analyzed, achieving a correlation coefficient R^2= 0.993 and a blank level of 0.2 µBq /sample. Recently, this method was applied for the first time to analyze a comprehensive set of samples from different environmental reservoirs, including 1 g peat bog samples and 10 L water samples from the Pacific Ocean and European rivers.

Exploring the limits of Accelerator Mass Spectrometry in nuclear waste characterisation

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Keywords : ^{36}Cl, ^{41}Ca, actinides, nuclear waste, Accelerator Mass Spectrometry.

At the *Centro Nacional de Aceleradores* (CNA, Sevilla), research efforts are being devoted to explore the limits of the 1 MV Accelerator Mass Spectrometry (AMS) system to analyse several long-lived radioisotopes present in nuclear waste that are a challenge for the technique due to its compact design: ^{41}Ca ($T_{1/2}$=9.94×10^4 y) and ^{36}Cl ($T_{1/2}$=3.01×10^5 y). The low energies prevent the suppression of the isobaric interferences (i.e. ^{41}K (^{41}Ca) and ^{36}S (^{36}Cl)) based on their different nuclear stopping power. Thus, our approach is focused on the removal of K (^{41}K) or S (^{36}S) through optimized radiochemical methods, and on the ^{41}K or ^{36}S indirect evaluation during the AMS analysis using other stable K and S isotopes with well-known isotopic abundances.

At this work, we will present the status of the AMS analysis and radiochemistry technique of ^{36}Cl, ^{41}Ca. First results point to background atomic ratios of 10^{-11} for ^{41}Ca/^{40}Ca, and of 10^{-9} for ^{36}Cl/Cl. In addition, the first results on real samples of different nuclear waste matrices are presented: dry sludge and ion exchange resins, as well as the results of a comparison exercise between the ETH-Zürich AMS facility and the CNA to evaluate the accuracy of our method for estimating ^{36}S during ^{36}Cl measurement.

Another field of study is the analysis of actinides radionuclides such as ^{236}U, ^{239,240,241}Pu and ^{237}Np. The focus is put here on the implementation of simplified radiochemical methods allowing the analysis of all the species from the same cathode using one single UTEVA® extraction chromatography resin.

Measurement of the ^{239}Pu, ^{240}Pu and ^{236}U in sediments from the Black Sea using the 1 MV AMS system at CNA

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Keywords: AMS, Isotopic Ratio, Sediments, Uranium, Plutonium, Black Sea

In this work novel results on anthropogenic ^{239}Pu, ^{240}Pu, ^{241}Pu and ^{236}U in sediment cores collected at the northwestern Black Sea are presented. The samples were analysed on the 1 MV AMS system at CNA, with a demonstrated capability to determine ultratrace amounts of actinides radionuclides in environmental samples. Very scarce literature has been published about anthropogenic actinides radionuclides in Black Sea sediments. To the best of our knowledge, information on the Pu isotopic composition (i.e., ^{240}Pu/^{239}Pu) and 236U is lacking, which are essential radionuclides to elucidate the influence of the Chernobyl accident in the region. The sediment cores have been dated using the ^{210}Pb method in a complementary work also presented in this conference, thus allowing the temporal reconstruction of the Pu and ^{236}U fingerprint in the area. This results are complemented with information on ^{137}Cs, also obtained by gamma spectrometry. The cores, sampled between 250 and 1000 m depth and with a length of 10 cm, were provided by the National Institute of Physics and Nuclear Engineering Horia Hulubei.

Preliminary results point out to the existence of additional sources other than Chernobyl accident, with ^{240}Pu/^{239}Pu atom ratios below the expected ones for Global Fallout.

Marine radioactivity investigations around a dumping area outside Gothenburg by Acceleratory Mass Spectrometry

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Keywords: Accelerator Mass Spectrometry, actinides, marine samples, Baltic Sea

In 1964, contaminated radioactive waste was dumped in a shallow area outside Gothenburg. The documentation about this event is limited to a few reports found at the Swedish Radiation Safety Authority, and no information about either the activity content or the specific composition of the waste is available. The radiological status of the dumped material is not known and potential leakage of radioactivity to the local marine environment has not been studied earlier. In this context, the radioecology group at Linköping University (LiU, Sweden), in collaboration with the Centro Nacional de Aceleradores (CNA, Sevilla, Spain) has performed a pilot study aimed at the evaluation of the possible impact in this area caused by those sea-dumped radioactive materials. The aim of this work is the study of ^{129}I and actinides (^{233}U, ^{236}U, ^{237}Np, ^{239}Pu, ^{240}Pu) from a series of samples of diverse matrices (seawater, seaweed, mussels and oysters) collected from the local marine environment of Gothenburg. Those analysis have been performed by using the 1M Accelerator Mass Spectrometry (AMS) system hosted at the CNA. Regarding actinides, seawater samples were processed by using a chemical procedure for the sequential extraction of U, Np and Pu [1]. Moreover, different tests have been performed to expand this method to other matrixes. The first results from this work do not reveal significant evidence of leakages of radioactivity from the dumped radioactive materials in the area.

[1] M. López-Lora, I. Levy, E. Chamizo, *Talanta*. 200 (2019) 22–30. https://doi.org/10.1016/j.talanta.2019.03.036.

A dynamic and automated dilution setup for a quantitative characterization of activated graphite material

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Keywords: ^{14}C, AMS, Gas Injection System, Nuclear Waste Management

Disposing of activated graphite from graphite moderated reactors requires a quantitative characterization of its radioactive isotope ^{14}C. At the Institute of Nuclear Physics at the University of Cologne we have developed an automated system that oxidizes and dilutes solid, activated samples, and then allows measurement of the resulting gaseous CO_2 using accelerator mass spectrometry (AMS). This system provides a high sample throughput while reducing the risk of contamination of the AMS components, which are also used for low-level ^{14}C measurements.

Our setup includes a new gas-interface (GIS) setup developed at Cologne AMS, which captures the oxidized CO_2 with a zeolite trap and transfers the sample to the AMS ion source. Mixing with non- activated CO_2 gas can be done in either the syringe or mixing volume, allowing for flexible dilution.

Compared to the established Liquid Scintillation Counting (LSC) method, our system offers the advantage of omitting elaborate chemical sample preparation, and the AMS technique can be used down to 3·10E-9 Bq/g, which is more sensitive than the LSC method at 2·10E-4 Bq/g [1]. Additionally, dilution with gas offers a more reliable process for lowering the activity than dilution with solid blank material.

In this talk we present the successful measurement of activated graphite irradiated at the TRIGA II reactor in Mainz by comparing material diluted with solid blank material to that diluted inside the GIS. Our system offers a dynamic and automated dilution setup for quantitative characterization of reactor graphite samples.

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[1] Hampe, D., Gleisberg, B., Akhmadaliev, S., Rugel, G., Merchel, S.: Determination of 41Ca with LSC and AMS: method development, modifications and applications. Journal of Radioanalytical and Nuclear Chemistry, Bd. 296, Nr. 2, S. 617–624, DOI 10.1007/s10967-012-2145-8, 2013

18 PARALLEL SESSION 7A

Marine Environment

Chemical implication of partition coefficient of ^{137}Cs between aqueous and suspended and phases in natural water

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Keywords: Partition coefficients, irrigation water, ^{137}Cs, sediment, chemical model

After the Fukushima Daiichi Nuclear Power Plant accident, terrestrial environment has been seriously contaminated by radiocesium. As a result, higher radiocesium levels in river/lake water have continued in the Fukushima area, although they exhibit gradual decline trends. To have better understanding of movement of radio- cesium in terrestrial environments, partition coefficient of ^{137}Cs between solid (suspended matter, sediments) and aqueous phases, K_d, has been introduced.
Although K_d is a tool to have better understanding of dynamic behavior of ^{137}Cs in natural water system, the K_d values in river waters, ranged from 2×10^4 to 7×10^6 L kg^{-1}, showed larger spatiotemporal variability. In this study, furthermore, very low K_d (20 L kg^{-1}) of ^{137}Cs was determined between Yugama crater water and sediment, Kusatsu-Shirane Volcano. It is important to elucidate factors controlling the partition coefficient of ^{137}Cs in natural water system. Previous study revealed that the logarithmic K_d of ^{137}Cs in river negatively correlated with logarithmic electro-conductivity and logarithmic suspended sediment (SS) concentrations, respectively. We, here, introduce a chemical model to explain variability of K_d of ^{137}Cs in natural water system. The chemical model contains complexation of stable cesium (^{133}Cs) with mineral and organic binding sites in SS, metal exchange reactions, and presence of colloidal species. The chemical model reveals that plots of the logarithmic K_d values versus logarithmic concentrations of $^{133}Cs^+$ are within a band of a slope of -1, which means that Cs is strongly associated with binding site in SS and a major chemical interaction between ^{137}Cs and binding site in SS is isotope exchange reaction between ^{133}Cs and ^{137}Cs rather than metal exchange reactions with other metal ions. The effect of the SS concentrations to K_d, may be explained by presence of colloidal ^{137}Cs, passing through filter, which is a potential dissolved species of ^{137}Cs in river water. The result suggests that better understanding of geochemical behaviors of stable Cs in natural water is important to know movement of ^{137}Cs in natural water systems.
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The distribution characteristics of Pu mass ratio in the marine environment around the Korean Peninsula

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Keywor ds: Pu mass ratio, Korea, Seawater, Sediment

The $^{240}Pu/^{239}Pu$ mass ratio has been used as a tool for understanding the biogeochemical characteristics of the marine environment, as well as the behavior of ocean currents and particle reactive elements, due to its variation in distribution and concentration based on various factors such as the source and inflow routes, and ocean currents. While various studies have been conducted on the distribution characteristics of $^{240}Pu/^{239}Pu$ in the northwest Pacific and the East China Sea, only a few studies have been conducted on the distribution of $^{240}Pu/^{239}Pu$ in the seas surrounding the Korean Peninsula, and as a result, it is not yet well known.

In this study, we measured the masses of ^{240}Pu and ^{239}Pu in seawater, sediment, and seafood in the seas in Korea and based on the reported results, we aimed to determine the distribution characteristics of Pu isotopes in the Yellow Sea, the East China Sea, and East Sea (the Sea of Japan).

In the Yellow Sea, the Pu isotopes originating from global fallout was dominant, whereas the impact of Pu isotopes from nuclear bomb tests conducted near the Pacific Proving Grounds was weak. On the other hand, in the East China Sea and the East Sea, the Pu isotopes from nuclear bomb tests conducted near the Pacific Proving Grounds was found to be significant source as they are being introduced through the Kuroshio Current.

Additionally, we will be reported on the characteristics of Pu mass ratio in seafood collected from the seas surrounding the Korean Peninsula, .

The effects of climate change on sources of radionuclides to and within the marine environment.

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Keywords: Climate change, sources, human activities, man-made radionuclides, naturally occurring radionuclides

The effects of climate change (CC) on contaminants and their potential consequences to the marine environment are increasingly important, as they pose overlapping risks. The Group of Experts on the Scientific Aspects of Marine Environmental Protection - Working Group 45 (GESAMP WG45) has been tasked to understand better the interactions of observed and predicted CC impacts and contaminants in the marine environment. Climate impacts on the land, cryosphere, and oceans will ultimately have consequences for the sources, fate, behaviour, uptake and toxic effects of contaminants for marine ecosystems and humans. Climate impacts, such as changes in ocean warming, ocean deoxygenation and circulation, sea-level rise, precipitation and run-off, intensification of extreme events, and ocean acidification impacts, will interact with contaminants in a complex manner that is currently poorly understood.

The radionuclide sub-group of GESAMP WG45 has focussed its initial efforts on the implications of relevant climate change impacts on existing sources of radionuclides to and within the marine environment from past and present, planned and accidental human activities and on further potential sources of radionuclides to the marine environment. Increased awareness of the scope of climate change impacts on the range of existing and potential sources of radionuclides is essential for national authorities, commercial and environmental stakeholders and the wider public alike to better understand future risks to changes of current levels of radionuclides in the marine environment. In addition, through such understanding the need for mitigation or adaptation can be identified and addressed where and as appropriate.

Monitoring of radioactivity along the French Mediterranean coast

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Keywords: Monitoring, marine environment, man-made and natural radionuclides

Since the beginning of the 90's, IRSN realised sampling of bioindicators (mullet fishes and mussels) along the French Mediterranean coastline in order to (1) establish reference levels and (2) highlight the possible influence of nuclear installation/activities on the marine environment. Gamma analyses, conducted since the beginning, are now completed by measurements of ^{3}H(OBT), ^{14}C, ^{241}Am, ^{238}Pu, $^{239+240}$Pu and allow toobtain a new overview of the radiological influence of human activities on this environment. Additional measurements of ^{210}Po in fishes and mussels also used to best estimated the dose by ingestion for seafood consumers.

Historical and spatial analyses are presented, and the influence of the different nuclear site/activities is investigated.

Transport and accumulation of artificial radionuclides in a marine core from the Celtic Sea

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Keywords: ^{236}U, ^{129}I, Sediments, Sellafield

The Celtic Sea is affected by the Sellafield nuclear fuel reprocessing plant (NFRP). Sellafield NFRP worked from 1952 to 2021 releasing liquids from spent fuel reprocessing and purge waters from fuel storage ponds. The discharges wastes contain a large range of radionuclides (e.g. isotopes of I, Cs, U, Np, Pu) which spread along the North Atlantic and Arctic Oceans and could be used as different environmental processes tracers. Sediments act as sink of some of those radionuclides and could be used to estimate the NFRP discharges.

In this work ^{129}I, ^{137}Cs, ^{236}U, ^{237}Np, Pu isotopes and ^{241}Am deep profiles of two sediment cores from the Celtic Sea are presented. Both cores (Core-A and Core-I) were collected in 2015 March in the new RRS Discovery in the DY030 sampling campaign (Shelf Sea Biogeochemistry, UK).

The results show the influence of Sellafield NFRP, principally in ^{129}I and ^{236}U concentrations and inventories, $2.03 \cdot 10^{15}$ at·m^{-2} and $4.09 \cdot 10^{12}$ at·m^{-2} respectively for Core-A and $5.20 \cdot 10^{14}$ at·m^{-2} and $5.96 \cdot 10^{11}$ at·m^{-2} for Core-I. Those values are considerably higher than the reported for soils from the Northern Hemisphere indicating the high influence of Sellafield NFRP discharges. The obtained results suggest that the ^{236}U behaves less conservative than is reported in the literature, on top of that, the ^{236}U trapped in sediments might act, in oxic conditions, as a secondary source of this radionuclide by redissolution from the sediments to the water column.

19 PARALLEL SESSION 7B

Radioanalytics I

Fast radiochemistry for the measurement of airborne radioactivity in emergency situations

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Keywords: Emergency preparedness, airborne radioactivity, radiochemical analysis, solid fusion, extraction chromatography

A key aspect of the radiological protection of the population and the environment is the fast detection of possible radiological events. For this purpose, diverse monitoring networks continuously search for any anomalous presence of radioactivity in the environment. In the event of a nuclear or other radiologically relevant emergency, also a timely response from the radiological protection authorities to organise adequate countermeasures is a crucial aspect, which may affect thousands of people. Decision-making in this context will be based upon the data provided by these networks, which need to be generated and exchanged as fast as possible, but also assuring their reliability. To make all these requirements possible, monitoring networks need improvement focused on the development of fast response protocols and the harmonisation of measurement results.

In the event of a nuclear or radiological incident, the direct measurement of the radioactivity on-site is the preferred option. However, there are possible scenarios where alpha and beta-particle emitting isotopes might be the predominant dispersed agent and, therefore, more complex determinations including radiochemical separation of these radionuclides would be necessary.

The present work deals with the development of a fast analytical method for the measurement of alpha- and beta-particle-emitting radionuclides in aerosol samples. Using solid fusion for the treatment of samples followed by a radiochemical tandem scheme based on extraction chromatography for the simultaneous separation of up to four radionuclides, the presentation will highlight the most significant results and point out the problems arisen along the process.

Monitoring heavy metal pollution by using sediment collector along a river catchment: Ker-Ya River in north western Taiwan

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Keywords: Heavy metal pollution, sediment collector, Hsinchu Science-based Industrial Park, Ker-Ya River

We designed a sediment collector to collect sediments in river water for monitoring heavy metal pollution in the catchment of Ker-Ya River which contains industrial manufactories and Hsinchu Science-based Industrial Park (HSIP). The sediments were collected about every two weeks from July 2021 to January 2022 in two sites: one is at the waste water outlet from Hsinchu Science Park (Site 3), and the other one is close to the river mouth of Ker-Ya River into the ocean (Site 1). Elements dissolved by 0.5N HCl (acid- leach, AL) and by Aqua Regia (Concentrated HNO3 : HCl = 1:3, AR) at 95 ºC on a hot plat from the 24 sediment samples were analyzed by using an ICP-OES, respectively. According to the regulation of Environmental Protection Administration of Taiwan (EPAT), the upper (must evaluate risk) and lower limits Cu, Zn and Ni in the sediments are 157 and 50 (mg/Kg), 384 and 140 (mg/Kg), 80 and 24 (mg/Kg), respectively (https://sed.epa.gov.tw/Sediments_Public/discoverC_quality). Our results show that (1) Cu and Zn concentrations in all samples from Site 3 are greater than the upper limits whereas their concentrations in Site 1 are lower than the upper limits except for the sample collected during 20210920~1006 when a typhoon appeared, reflecting pollution resource from the Hsinchu Science Park. (2) The AL/AR (%) of Zn and Cu are 100% respectively in Site 3, whereas the AL/AR (%) of Zn and Cu in Site 1 are 75% and 88%, respectively, indicating Zn and Cu from the industrial source are much more active. (3) The major elemental contents from the two sites are quite different: Ca>Al>Fe>Na>Mg>K in both AR and AL phases at Site 3, whereas Fe>Al>Na>Ca>Mg>K in AR phase at Site 1. The high Zn, Cu, Ni and Ga concentrations in Site 3 correspond to high Ca, Na and Sr contents, probably indicating the waste water was treated by large amount of salts for decomposing the pollutants. (4) Heavy metal elements can be effectively captured by suspended sediments in river water, which is the base for monitoring pollution event. With our sediment collector, one can continuously collect samples under all weather conditions.

20 PARALLEL SESSION 8A

Marine sediments

On the use of time-markers in ^{210}Pb sediment dating model validation

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Keywords: 210Pb dating models, assumptions, limitations, uncertainties, time-markers

Radiometric dating is widely used, and several models have been applied, especially in sediment studies. Unfortunately, model limitations, assumptions and uncertainties are seldom shown and discussed in published reports, which may lead to biased conclusions of the presented results. Limitations and assumptions that can results in bias in age and sedimentation rate calculations are e.g., that settled sediment particles are not changed after settling on the seafloor (mass conservation), radionuclides are immobile and daughter products in the decay chain will remain in secular equilibrium (^{226}Ra + daughters). One challenge is also to acquire undisturbed sediment cores that are not affected by sample handling. Tilted sediment corer during sampling, vessel movement/shaking on the sea are both sources of mixing introduced in the core. On the analytical side, challenges to measure and acquire traceable, precise, and accurate results can also result in a bias of the outcome model results. The supported activity seriously influences the dating model results. Once challenge is to determine the supported activity as it must be based on some assumptions on the relationship between ^{226}Ra and its granddaughter ^{210}Pb. It is vital to validate the dating results, and the use of time-markers is a powerful way doing this work. The presentation will discuss ^{210}Pb dating models in general, the assumptions, limitations and uncertainties, but with focus on the validation and tuning of the model using time-markers.

Radioactivity in the Irish coastal environment

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Keywords: Natural Radioactivity, Sellafield, Irish Sea, Oysters, Seaweed, Sediment

Radionuclide discharges to the Irish Sea from the Sellafield reprocessing complex in Cumbria (UK) since the early 1950s have led to the widespread contamination of North Western European Continental Shelf waters by a wide range of artificial radionuclides. Concerns about the potential radiological significance of these discharges to the Irish population prompted a number of studies to be carried out from the early-1980s, and to the establishment of regular monitoring programmes. As a result, a considerable body of data has been gathered on the geographical distribution and temporal evolution of artificial radionuclide levels in the Irish coastal environment, and on their accumulation and uptake in different environmental compartments. In contrast, comparatively few data exist on the distribution and behaviour of natural radionuclides, perhaps reflecting the fact that, for many decades, the impact of radionuclide discharges from Sellafield remained the main issue of public concern. However, natural radioactivity and, in particular, practices involving naturally occurring radioactive material (NORM), have become of renewed regulatory interest in recent years.

In this study, we report the results of a survey carried out by our laboratories during July-September 2021. The aim of the survey was to provide a status update on artificial radioactivity levels in the Irish coastal environment by revisiting some the sites from previous surveys carried out in the 1980s and 1990s, and to extend the analysis to include a range of natural radionuclides with a view to establishing a baseline with which to assess future concentrations and the potential impact of NORM activities. Samples of coastal sediment and seaweed (*Ascophyllum nodosum*) were collected from 19 sites around the Irish coastline, and oysters (*Crassostrea gigas*) were sourced from seven commercial farms located along the east and west coasts of Ireland. The samples were analysed using gamma spectrometry for the determination of natural and artificial radionuclides (^{40}K, ^{210}Pb, ^{137}Cs, ^{226}Ra, ^{228}Ra, ^{238}U and ^{241}Am). Additionally, the ^{210}Po content in the oyster samples was assayed by alpha spectrometry following radiochemical separation. The geographical distribution of artificial radionuclides was found to be similar to that in previous surveys, with the highest concentrations occurring along the North Eastern coast, reflecting the circulation pattern of waters in the Irish Sea. However, in line with the significant reduction of radionuclide discharges from Sellafield since the mid-1970s, ^{137}Cs levels are shown to have diminished by two orders of magnitude since the 1980s. Although artificial radionuclides remain present in all environmental compartments for samples located along the North Eastern Irish coast, measured concentrations are much lower than those for the natural radionuclides, which dominate the total activity of the samples and show no clear geographical pattern. For oysters, the highest measured ^{137}Cs concentration, at 0.04 ± 0.02 Bq kg^{-1} (fresh wt.), is three orders of magnitude lower than the measured mean for ^{210}Po and ^{40}K, and one order of magnitude lower than the measured mean for ^{210}Pb, ^{226}Ra and ^{238}U.

Tracing sediment dynamics in El Confital bay (Spain): natural radionuclides distribution and their relationships with sediment characteristics

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Keywords: Natural radionuclides, Tracers, Coastal sediments, Sediment dynamics

In this study, the spatial distribution of different natural radionuclides was compared for two periods of time in El Confital Bay (Spain). For this, the activity concentration values of ^{226}Ra, ^{228}Ra and ^{40}K were determined by gamma spectrometry for 37 submarine samples collected in 2005/2006 and 39 samples that were gathered in 2022. This comparison showed that ^{226}Ra, ^{228}Ra and ^{40}K trace the sediment erosion, transport and accumulation that can be found in diverse parts of the bay. Additionally, the spatial distribution of unsupported ^{210}Pb ($^{210}Pb_{ex}$) was analysed for the 2022 samples. This showed that $^{210}Pb_{ex}$ is a useful tracer of areas of the bay that present lower erosion of the seabed and thus, where accumulation by sedimentation is favoured. Besides this, an assessment of the influences of the grain size and mineral composition of the samples in their activity concentration values of ^{226}Ra, ^{228}Ra and ^{40}K and $^{210}Pb_{ex}$ was also carried out. The result showed that the variations in activity concentration values of these radionuclides in the different samples are more related to their mineral composition than to their grain size.

Plutonium isotopes dating for the recent sediments in shallow lakes in Eastern China

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Keywords: Plutonium isotopes, ^{137}Cs, sediment dating, shallow lakes,

Plutonium isotopes have been regarded as a promising substitute of ^{137}Cs for dating modern sedimentation process because of the increasingly sensitive, effective and ecnomic plutonium isotopes measurement technologies. In this study, sediment cores were collected in several typical shallow lakes in the middle and lower reaches of the Yangtze River in Eastern China, and analyzed for ^{239}Pu, ^{240}Pu, ^{137}Cs and ^{210}Pb. Sources and vertical distribution patterns of plutonium isotopes in sediments of different lakes were investigated and compared with ^{137}Cs. Factors influencing the distribution of radionuclides in the shallow lakes were discussed. According to the time markers of Pu isotopes in the sediment profiles, sedimentation rates were estimated for the lakes and the results were compared with those obtained from both the dating methods using ^{137}Cs and ^{210}Pb$_{ex}$. The comaprsion results indicated that plutonium isotopes dating method is a very sensitive and effiective geological tool for studing modern sedimentation process in shallow lakes. The total Pu inventories in different lakes were calculated and compared, as to deduce the response of the modern sedimentation process of the lakes to the regional environmental changes and human activities.

Sources of organic carbon in sediments from Kongsfjorden, Arctic

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Keywords: $\delta^{13}C$, $\delta^{15}N$, C/N, ^{14}C, TOC Source, Arctic

Since industrialization, the burning of fossil fuels and the clearing of land have increased the concentration of carbon dioxide in the atmosphere by 40 %. The role of the global carbon cycle and the impact of human activities on it are not only the focus of the scientific community, but also become the main basis for governments to formulate climate change mitigation policies. Global burial of carbon (especially organic carbon) in sediments has recently generated a great deal of interest in fjords, especially those in high latitudes, due to their high vulnerability to climate change and the significant carbon burial that exists there. In this research, the 210Pb and 137Cs dating methods were used to calculate the chronology of column samples collected in the Kongsfjorden, Arctic in 2017, and the organic carbon sources of sediments including surface sediments in this area were studied by means of $\delta^{13}C$, $\delta^{15}N$, C/N, ^{14}C and magnetism. By quantifying $\delta^{13}C$, $\delta^{15}N$, C/N, ^{14}C and magnetic data, the results show that with the increase of offshore distance, the organic carbon source in surface sediments gradually changes from terrestrial to Marine sources, and there are three obvious sources of organic carbon in the sediments in this fjord, namely, glaciated permafrost source, fossil fuel source and marine source. Based on this, a three-end-member mixed model was established to study the organic carbon in the sedimentary columns in this area. The results show that after global warming, the source of organic carbon in the sedimentary columns in this area is obviously transformed, which may be caused by the glacier dissolves and brings a lot of organic matter.

Plutonium isotopes as tracers of sediment transport processes in the southern Gulf of Mexico

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Keywords: $^{240}Pu/^{239}Pu$ ratio, deep-sea sediments, Nevada test site fallout, global fallout

We present a study on the source and distribution of plutonium (Pu) in deep sediments (depth: 257 to 3739 m) of the southern Gulf of Mexico. Sediment cores collected from the continental shelf and upper slope region showed $^{240}Pu/^{239}Pu$ ratios of 0.15 to 0.26, and $^{239+240}Pu$-inventories ranging from 14.7 to 33.0 Bq m^{-2}, which are consistent with those expected for global fallout Pu for this tropical region [1]. In contrast, sediment cores collected from the lower slope region and abyssal plain showed low $^{240}Pu/^{239}Pu$ ratios of 0.07 to 0.13 and much lower $^{239+240}Pu$ inventories below 6.8 Bq m^{-2}. Low $^{240}Pu/^{239}Pu$ ratios indicate that fallout from the Nevada testing site (USA, $^{240}Pu/^{239}Pu \sim 0.035$) was an important source of Pu in deep-sea sediments [2-5], and that this Pu was likely more efficiently scavenged from the water column than Pu from global fallout [2-5]. We estimate that up to 44% of the total inventory of $^{239+240}Pu$ in deep-sea sediments is due to the Nevada source. Analysis of Pu isotopes in two sediment traps from the upper slope regions shows $^{240}Pu/^{239}Pu$ ratios comparable to those observed in global fallout. These results indicate that global fallout Pu is currently the main source of Pu in sinking particles in the water column. Therefore, a significant fraction of global fallout Pu must still be present, either in a dissolved phase, or as biologically recycled material in the water column, or scavenged on the shelf and shelf break. We use an advection-diffusion model to simulate the Pu profiles in deep-sea

sediments of the Gulf of Mexico and to obtain bioturbation and sedimentation parameters. We show that Pu radionuclides in deep-sea sediments are tracers of bioturbation rather than accumulation processes [5]. Our results open up important questions on the application of Pu isotopes to support sediment chronologies.

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Temporal investigation of radionuclides and metals in Gera Gulf, Lesvos, Greece

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Keywords: NORM, hydrothermal vent, organic garbon (OC), major elements

The study of semi-enclosed gulfs is of great importance due to the biochemical and radiological load they receive. The gulf of Gera is a semi-enclosed water body located in the island of Lesvos characterized by coastal hydrothermal vents and igneous geological substrate. It is an area connected with the agricultural watersheds - mainly olive tree groves. The gulf also received tannery waste waters for many years. In this work a multidisciplinary study in the gulf of Gera was attempted in a temporal manner. Natural radioactivity, major elements, grain size analysis and organic carbon analysis were performed. The temporal investigation was achieved via applying radio-dating methods in the two sediment cores, one located near the coastal thermal vent and the other in the centre of the gulf. The coastal sediment core was more sandy (98%) and was characterised by higher sedimentation rates (0.61 cm y^{-1}) compared to the muddy (85- 95%) sediment core in the centre of the gulf (0.37 cm y^{-1}). The radioactivity concentrations were higher than the mean values in Greece, probably due to the igneous geological background. The anthropogenic impact in the gulf was found to be negligible.

21 PARALLEL SESSION 8B

Radionuclides in biota

Seafood ingestion dose following the Fukushima accident using probabilistic and deterministic approaches

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Keywords: Dose assessment, Probabilistic method, Deterministic method, Ingestion, Seafood

Radionuclides released from the Fukushima Daiichi Nuclear Power Plant (FDNPP) spread into the environment by various pathways, including the marine ecosystem and eventually into some marine organisms that could be consumed as seafood. Assessing this pathway is important from the perspective of public radiation protection. The ICRP presents two assessment methods (probabilistic and deterministic methods) for determining the dose for persons who are exposed to radiation. Which method to use and which specific values to select for each method depends on the characteristics of the assessment and available data, and it is left to the interpretation of the assessors.

In this study, internal dose from seafood ingestion was assessed using an extensive compilation of activity concentrations in seafood that considers 22 radionuclides. The assessment receptor represents the residents in the Tohoku region which includes the Fukushima Prefecture. Representative consumption rates were obtained from a national nutritional survey. From the probabilistic calculation, the 95th percentile dose from the FDNPP accident-derived radionuclides was 22 μSv from seafood consumption during the first year after the accident and 1.6 μSv during the second and third year. Overall, the ingestion dose for typical seafood consumers of the Tohoku region returned to near background levels within 3 years. The differences in results between probabilistic and deterministic methods will be discussed in the presentation.

Assessment of radio cesium and natural radionuclides in mosses and study of their distribution in a mountainous region in Central Portugal using GIS.

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Keywords: Portugal, radio cesium, lithogenic isotopes, mosses

Airborne transport is responsible for long-range spreading of pollutants via atmospheric routes. A fission product such as ^{137}Cs, is a good tracer to study the distribution of pollutants and its mechanisms through the atmosphere. It has great ability to be airborne transported on aerosols and its half-life of 30 years allows assessment in a time scale covering several decades. Moreover, lithogenic radioisotopes are also good indicators of transfer, especially in a region as Central Portugal, where the soil is naturally rich in those isotopes and their progeny.

Measurements for these radioisotopes were performed in mosses. Those nonvascular and non-root plants are relevant for the study of atmospheric contamination because of their capability to collect nutrients from precipitation or dry deposition. We collected samples in the Serra da Estrela and Beira Interior region in Portugal (400 to 1500m altitude). ^{137}Cs,^{7}Be, and lithogenic isotopes as ^{226}Ra, ^{228}Ra and ^{40}K are assessed using gamma spectrometry.

The samples are geolocated using a dual frequency handheld GNSS receiver for G.I.S. processing of data. The results are mapped to analyze the local distribution of the radioactivity and evaluate for a possible correlation with proxies such as geology, U content of the bedrock, but also morphology.

Results suggest that artificial and local radioisotopes are distributed following different mechanisms.

Dose rates to reference organisms due to regional radionuclide background levels in France

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Keywords : Radionuclides, background levels, dose rates, biota

The methodology of the radiological risk assessment to the biota follows a graded approach which is proportionate to the stakes. This methodology is based on the principle of the difference between the exposure concentration or exposure dose rate and a benchmark. Its nature can change depending on the assessment. At the second step the absorbed dose rates to reference animals and plants are compared with a limit dose rate which is evaluated from the ecotoxicity tests results (for example the screening dose rate of ERICA[1] tool: 10 $\mu Gy.h^{-1}$). The radiological risk for animals and plants can also be based on a comparison with the usual exposure level of organisms. This is an anthropogenic background level outside the influence of radionuclides releases from a given nuclear site.

The IRSN study involves operating the monitoring data which are on RNM[2] website in order to define regional radionuclide background levels. Then, these data on the regional environmental radioactivity are used to quantify the average absorbed dose rates to reference organisms and to know the levels to which animals and plants are usually exposed. They also represent a benchmark to interpret the risk assessment's results.

Regional background levels in France will be presented. They allow comparison with activity levels added by nuclear facility discharges into the environment and to evaluate the net contribution from those facilities. This is of particular significance since the added contribution may be similar or sometimes lower that from the background levels for some radionuclides. Then, dose rates to reference animals and plants calculated by the ERICA tool from regional radionuclide background levels will be presented. The assessor will also know the dose rate level to which reference organisms are exposed in a specific regional area outside the influence of radionuclides releases from a given nuclear site.

[1] ERICA : Environmental risk from ionising contaminants assessment

[2] RNM : https://www.mesure-radioactivite.fr/

Distribution of anthropogenic radionuclides in King George Island (South Shetland Archipelago, Antarctic Peninsula)

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Keywords: ^{90}Sr, ^{137}Cs, Antarctic, Cryptogamic species, zoobenthos, macrophytobenthos

For many years Antarctic ecosystems have been considered pristine, however recent studies, including our results, contradict this assumption. Activity of anthropogenic radioisotopes (^{137}Cs and ^{90}Sr) in the most common species, zoobenthos, macrophytobenthos, bryophytes, lichens, and vascular plants, as well as soil, sediment, seawater and guano samples collected over a large area on King George Island (South Shetland Archipelago) in the austral summer 2018/2019 clearly indicate the importance of large-scale transport in shaping the level of pollution in areas very distant from potential sources of contamination. Additionally, radioisotope pollution can be measured even after a very long period (>60 years) since their occurrence. The mean activity of ^{137}Cs measured in lichens, bryophytes, vascular plants and soil was, respectively: 3.72 Bq kg$^{-1}_{dw}$, 3.70 Bq kg$^{-1}_{dw}$, 2.62 Bq kg$^{-1}_{dw}$, 4.07 Bq kg$^{-1}_{dw}$. The highest activities of ^{137}Cs in lichen and soil were reported in the vicinity of other glaciers, where some lichen species have activity of ^{137}Cs from 16.5 Bq kg$^{-1}_{dw}$ to 25.7 Bq kg$^{-1}_{dw}$ and in soil 9.36 Bq kg$^{-1}_{dw}$. In marine species the lowest average activity of ^{137}Cs were in Gastropoda (0.52 Bq kg$^{-1}_{dw}$) and highest in Bryozoa (5.35 Bq kg$^{-1}_{dw}$) and Porifera (24.2 Bq kg$^{-1}_{dw}$) and could reflect differences in feeding strategies of these species.

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Removal of the radioactive micropollutants from environmental water by the activated carbon from alternative sources

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Keywords: fruit kernel, activated carbon, environmental water, adsorption, gross alpha and beta emitters (GAB), Liquid scintillation spectrometry (LSC), high resolution gamma spectrometry

Activated carbon is one of the most common adsorbent involved in water treatment due to its high specific surface area and high degree of surface reactivity. The alternative activated carbons derived from apricot (*Prunus armeniaca*), plum (*Prunus domestica*) and cherry/sour cherry (*Prunus avium/Prunus cerasus*) kernels were produced by thermo-chemical activation using phosphorous acid. The materials were already tested on wastewater polluted by heavy metals and pharmaceuticals. The study was extended to radioactive inorganic micropollutants. Environmental water obtained in the vicinity of former uranium mine at Žirovski Vrh was chosen due to its rather high content of radionuclides. Activities of total radionuclides were firstly obtained by screening method of gross alpha / beta activity determination for water before and after usage. Activated carbon from plum showed remarkable results, lowering alpha and beta activity for 95.1% and 95.9% respectively at certain treatment conditions. High resolution gamma spectrometry was second analytical technique for activated carbon and water characterization before and after the treatment. Results of both methods were comparable what confirmed the efficiency of the activated carbon produced from fruit kernels and usefulness of the rapid and simple screening method (GAB) for evaluation of different adsorption tests as well as for further routine monitoring of treated waters after economic removal of radioactive micropollutants on large scale.

Predicting radiocesium soil-plant transfer on a global scale: a meta-analysis study

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Keywords: Radiocesium Concentration Ratio (CR), Absalom model, random forest model, database.

Soil-to-plant models can guide decisions concerning agricultural countermeasures for radiocesium (^{134}Cs and ^{137}Cs, 'RCs' hereafter). However, the models are developed for temperate conditions in the aftermath of the Chernobyl and Fukushima accidents and are unlikely able to make worldwide predictions. The reason is that they were created with limited datasets of certain temperate regions and thus cannot be extrapolated to other climates and their typical soils. Therefore, a database was built of soil to plant RCs concentration ratio (CR) values of various combinations to verify the current process-based models and develop new data- driven models. First, data were obtained via meta-analysis (>3000 articles for the time period 1954-2022) and compared with the >6200 datapoints (>120 articles) of CR values (0.000052–370 kg kg^{-1}) summarized in IAEA reports (TRS-472 (2010), TE-1927 (2020), TE-1979 (2021)) and >1700 datapoints of CR values (0.00011–23 kg kg^{-1}) reported after the Fukushima accident. Second, datapoints from the reports were used to compare model performance. Using the same model variables, the machine learning (random forest) models consistently outperformed the process- based models (Table 1). The multiple (linear) regression models were not much worse than advanced machine learning models. A machine learning model solely based on the exchangeable K content in soils only poorly predicted RCs transfer (R^2 = 0.21, N = 815). Data quality and coverage of soil and plant species are of

utmost importance to create data-driven models to effectively predict the risk of ^{137}Cs entering our food chain in case of nuclear incidents worldwide.

Table 1. Comparison of RCs soil-plant transfer model performances evaluated on log CR values.

Process-based model name	*Data-points*	*Model variables*	*Multiple regression model R^2*	*Process-based model R^2*	*Machine learning model R^2*
Absalom1999	805	3	0.47	0.02	0.69
Absalom2001	175	6	0.64	0.23	0.68
Tarsitano2011	183	5	0.59	0.42	0.58

Soil erosion and sedimentation rate using Cesium-137 in the Sembrong catchment

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Keywords : Soil erosion; Sedimentation;, Cesium-137; Gamma Spectrometry; Catchment

The use of Fallout Radionuclides (FRNs) as tracers for the study of soil erosion and sedimentation in catchment areas is still not very popular when compared to conventional methods in Peninsular Malaysia. However, this approach is gaining ground among researchers because various factors have been identified especially in small study areas in parallel with the time period of the study. In this study, Cesium-137 is used as a medium-term tracer to measure the rate of soil erosion in the Sembrong catchment area, Kluang as a study site for two different study seasons. The Sembrong catchment area is the main choice for this study and the area is not very large and is among the catchment areas that have the most important ecosystems in Peninsular Malaysia. It has a fresh water reservoir of 7.76 km^2, with an estimated storage capacity of 24.84 million m^3 and covers an entire catchment area of approximately 130 km^2. Sediment core sampling is carried out in two different seasons, namely the rainy and dry seasons, using standard metal corers, involving sampling at several sampling stations that involve a variety of land uses. All the sediment samples taken were pre-sliced by 2cm and brought to the Radiochemistry and Environment Group (RAS), Nuclear Malaysia to undergo the sample preparation process such as drying, sieving and finally for analysis using a Gamma Spectrometry. The results of the analysis show that the rate of soil erosion and sedimentation for both seasons is variable where the dry season only gives the value of the soil erosion rate. Meanwhile, the rainy season has provided

both soil erosion values and sedimentation rates for the overall results. This situation is shown in the dry season which has given the value of the soil erosion rate between 5.09 t/ha/y to 65.2 t/ha/y. Meanwhile, the value of soil erosion and sedimentation during the rainy season ranges from 8.02 t/ha/y to 39.78 t/ha/y and 4.81 t/ha/y to -50.81 t/ha/y, respectively. Rubber and oil palm plantations refer to Station 17 and station 4/6 which are located near Lake Semberong and Sungai Sembrong have the highest soil erosion and sedimentation rates at 51.03 t/ha/y and -50.81 t/ha/y respectively. In conclusion, ^{137}Cs as a medium-term tracer has been successfully used to determine the rate of soil erosion and sedimentation in two different seasons for the Sembrong catchment area.

22 PLENARY SESSION VI

Current state of Zaporizhzhia NPP and other nuclear risks in Ukraine

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With the blasting of the Kakhovka dam in June 2023, the situation has once again escalated around the Zaporizhzhia NPP in Ukraine. Similarly, the stationing of Russian nuclear weapons in Belarus has reminded the globe of the risks of a nuclear confrontation in Eastern Europe. In this flash talk, I will give a brief overview of current nuclear risks resulting from the Russo-Ukrainian war. Rather than a tactical assessment, I will deliver a radioecologist's assessment. I will try to compile information from Ukrainian, Russian, European, and American sources for a comprehensive risk assessment including an outlook of how the situation might evolve in the future. A major point of this flash talk is sparking a discussion with the audience to compile the viewpoints of the radioecological community.

Distribution of carbon isotopes in different soil fractions, including soil CO_2 gas on the example of Ultisols, South Carolina, USA.

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Keywords: Soil fraction, Land use, Distribution of Radiocarbon and Stable isotopes

The Critical Zone is a thin layer between the rock and the sky, from the top canopy down to the bedrock-soil interface. This is the fragile zone on which natural ecosystems relies because this is where nutrients are being released from the rocks. Calhoun Critical Zone Observatory is one of the ten USA observatories that were studied with the accent on the restoration of soil after intense cotton agriculture and following erosion. We have studied three Ultisols: one believed to have been never used for cultivation, another was used for growing cotton since the beginning of 19th century through 1920s, with the forest regeneration after cultivation, and third is cultivated until now. We have analysed the bulk soil organic matter (SOM), humic acid extracted from the bulk soil and insoluble fraction. We have also analysed the carbon dioxide from soil gas collected at the different depths to estimate the intensity of SOM decomposition.

The results shown that its distinctive ^{14}C signature tracks SOM accumulated in the top 50-60 cm, acquired after massive atmospheric nuclear tests in the beginning of 1960's. Our data combined with model simulations indicate that not only a few decade old mostly conifer forest but also wide broad leaf reference forest rapidly incorporate "bomb" carbon in SOM and all its fractions. The maximum of $\Delta^{14}C$ =200‰ was in HA from the surface horizons of the reforested soil. The analyses of the soil CO_2 show the differentiation of ^{14}C concentration with the depth, the deep samples collected at 3 and 5 m cultivated soil CO2 exhibited a prevalence of the "bomb" carbon compare to both forest soils, and uncultivated soil under forest exhibited lowest ^{14}C concentration.

Development of population level biomarkers for low dose radiation: the importance of non-targeted effects.

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Keywords: ecosystem approach, radiation protection , low dose, non-targeted effects, radiation effects

Recent moves within ICRP to develop an integrated approach to radiation protection of both humans and non-human biota are focused on regulating dose to exposed populations based on behaviour, size, lifestyle and "radiosensitivity". Currently man and 12 reference organisms are used covering various taxonomic groups, behaviours, and exposure scenarios - e.g. marine, terrestrial, sediment or airborne. However, most biologists agree that particularly in low dose exposure legacy sites, the factors determining effects and outcomes are far more complex that this simple framework suggests. The issue is developing reliable predictors of system or ecosystem health rather than relying on biomarkers that give information about effects on individual cells, organs or organisms. Approaches to this include the Adverse Outcome Pathway (AOP) which looks at multiple levels of organisation from gene to ecosystem Another approach used by our group is to look at the role of non-targeted effects such as genomic instability (GI) and bystander effects (BE). These mechanisms involve transmission of information between different levels of organisation. In the case of BE signals from exposed to unexposed cells or organisms coordinate response at higher levels of organisation permitting population responses to radiation to be optimised. GI is more complex as it involves not only signalling but also trans-generational transmission of genetic or epigenetic changes and may lead to long-term adaptive evolution. GI may also be involved in memory or legacy effects, which contribute a further component to the dose effect measured in legacy sites. Our recent analysis of the contributions of memory and legacy effects to the total effect using data sets from Chernobyl and Fukushima (voles, birds and butterflies) suggest this type of analysis may help reduce uncertainties over lab to field extrapolations. Given the clear discrepancy between actual data measured in the field and dose effects generated using databases populated mainly with acute lab based experimental data, it is imperative that we strive to develop meaningful holistic systems for protection of those living in contaminated ecosystems.

Mean soil contaminant concentration does not provide a conservative indicator of external exposure to wildlife – reindeer in Jotunheimen, Norway as a case study

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Keywords: Wildlife dosimetry, Exposure characterization, Chernobyl fallout

Adequate information on external exposure is often a limiting factor in risk assessments due to a lack of dosimetry data for free-ranging animals in areas contaminated with a heterogeneous distribution of contaminants including radionuclides such as ^{137}Cs. Most wildlife exposure data are therefore estimated from model simulations which are rarely validated by empirical dosimetry data. An additional short-coming to ecological risk assessments are that fundamental assumptions inherent in exposure assessments most often are not tested. In the present work, we quantified the temporally and spatially resolved external exposure of reindeer (*Rangifer tarandus)* over a five months period in a Chernobyl fallout affected mountainous area of Norway using GPS-coupled radiation dosimeters. These data were then compared to ERICA Tool model simulations of exposure based on airborne surveys of ^{137}Cs soil contamination in order to test a fundamental assumption in screening-level risk assessments: *Mean soil contaminant concentrations can be used to conservatively estimate chronic external exposures to representative animals*.

Our results show that external exposure modelled from mean soil contaminant concentrations underestimated exposure by 70% compared to empirical measurements based on GPS-dosimeter collars on individual animals. Using area-weighted mean contaminant levels to account for spatial-temporal heterogeneity improved the model estimates somewhat, but still underestimated the field dosimeter data (46-53%). A comparison of our external dosimetry work on reindeer to similar work performed on Chernobyl wolves found the two studies concur that risk assessors should be cautious in using averaged soil contaminant levels to provide conservative estimates of external exposure to representative individuals as this could misguide assessors and cause inappropriate management decisions.

23 PARALLEL SESSION 9A

Radioecology

Environmental and Nutritional Chemistry of Wild Harvested Berries vs. Commercial Berries: Depositional and Uptake Chemistry and Human Health Assessment

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Keywords: Radionuclide and trace element uptake, Environmental cycling, Indigenous traditional foods

In northern Saskatchewan, Canada, there are several active and decommissioned uranium mines and mills licensed by Canada's nuclear regulator, the Canadian Nuclear Safety Commission (CNSC). In these areas, Indigenous communities harvest traditional foods and Canadian diet studies have identified wild berries as an important part of their diet. Food ingestion is recognized as an exposure pathway of anthropogenic and naturally occurring radioactive materials and trace metals. Accurately communicating potential human health risks from environmental radionuclides and trace metals in traditional foods is of vital importance since the information may affect the Indigenous community's mental and physical well-being. Uninformed concerns and miscommunication may drive dietary changes to replace traditional foods with less nutritionally dense market foods that can increase the risk of chronic diseases such as cardiovascular disease and diabetes. Wild blueberries and the soil the plant roots grew in were sampled approximately 10-25 kms away from CNSC-licensed facilities in northern Saskatchewan. Samples were analyzed by Inductively Coupled Plasma Mass Spectrometry (ICP-MS) in a metal-free, ultraclean laboratory to obtain trace metal concentrations and radionuclide concentration. Sample results and data were obtained for important dose contributors to calculate ingestion dose. As a comparison with the Saskatchewan blueberry and soil results, commercially-available blueberries were also collected from Ontario farms and grocery stores. This research project builds on the CNSC's ongoing, independent analysis of trace metals and radionuclides in foods and environmental samples near CNSC-licensed facilities, identifies geochemical relationships between radionuclides and trace elements in blueberries, examines the uptake chemistry and environmental cycling of radionuclides and trace elements, helps inform CNSC's regulatory decision-making process, and supports future human health risk communication with Indigenous communities.

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A New Global Seafood Dose Assessment

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Keywords: Seafood, global dose assessment, Polonium-210, Monte Carlo dose distributions

Artificial and natural radionuclides are known to accumulate in seafood worldwide and, when ingested, cause internal dose to seafood consumers. It has been nearly 30 years since the IAEA MARDOS global seafood dose assessment was published. Since then, world seafood consumption has increased, diet patterns have changed, and new inputs of radionuclides into marine systems have occurred (e.g., Fukushima accident).

A new global assessment of seafood dose is being conducted that uses a much-expanded global database on radionuclides in seafood (Marine Radioactivity Information System -MARIS) as well as global diet data and updated parameters for dose calculation. The new assessment:

- Evaluates 16 natural and anthropogenic radionuclides.
- Draws from more than 84,856 global data for biota in MARIS, from which 31,665 final activity concentration data passed quality assurance screening.
- Uses seafood consumption data from national and sub-national diet studies representing approximately 35% of the world population.
- Develops new correction factors for the loss of Po-210 from cooking and radiological decay as well as the decreases in Po-210 in maricultured seafood.
- Implements a bespoke Monte Carlo application for calculating seafood dose distributions.
- Compiles and evaluates + 150 seafood ingestion dose estimates published in the past 30 years.

The results provide well-supported estimates on the mean and distribution of background seafood dose for world consumers. This important new result provides a comparative reference for local, regional and national dose assessments; for the dose rates resulting from facility and accident releases, and for quantifying the global changes in ingestion dose from seafood over time.

Numerous researchers and aligned organisations from around the world have provided input into the project. The assessment is being conducted within the IAEA Coordinated Research Project “Behaviour and Effects of Natural and Anthropogenic Radionuclides in the Marine Environment and their Use as Tracers for Oceanography Studies.”

Influence of Eu(III) and U(VI) on rat and human kidney cells

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Keywords: Cytotoxicity, Kidney cells, Uranium, Europium, EC_{50}, Speciation

Radionuclides (RNs) that enter the human body, for example through ingestion or inhalation, pose a potential health risk due to their radio- and chemotoxicity. The kidneys are especially exposed to the incorporated RNs, as they are mainly responsible for the excretion of toxic substances from the blood stream. Therefore, the effect of uranium(VI) and europium(III), an analogue for trivalent actinides such as Am or Cm, on rat (NRK-52E) and human (HEK-293) kidney cells was studied in vitro at the cellular and molecular levels.

Exposure experiments were carried out in which cells were incubated with these metal ions (10^{-9} – 10^{-3} M) for 7, 24 and 48 hours. The cell viability after exposure to the metal ions was measured using the XTT-assay. The half-maximum effective concentration (EC_{50}) was calculated on the basis of the dose-response curves. In addition, morphological changes due to metal ion exposure were investigated by staining selected cell compartments and intracellular uptake was determined by ICP-MS. The speciation of a metal determines its bioavailability, influencing both the effect on cells and its uptake into cells. Therefore, time resolved laser-induced fluorescence spectroscopy (TRLFS) was used to investigate the speciation of Eu(III) and U(VI) in the cell culture medium, in the cell-exposed medium and in cell suspension. The obtained results on the cellular and molecular level contribute to a better understanding of the toxic effects of RNs.

This work is funded in the frame of the RADEKOR project by the German Federal Ministry of Education and Research (BMBF, grant number: 02NUK057A and 02NUK057B).

Influence of EDTA and EGTA on the Eu(III)/Cm(III) speciation in the human digestive system

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Keywords: Speciation, Complexation, Decorporation, Europium, Curium

In mining and industrial areas involved in lanthanide (Ln) production, both environment and population show increased Ln concentrations. To lower the health risks of these heavy metal ions on the affected persons by decreasing the Ln concentration in the human body, chelation therapy is used as decorporation strategy. Chelation therapy is also an important tool for radiation protection. The aminopolycarboxylic acid diethylenetriaminepentaacetic acid (DTPA) is the only clinical approved decorporation agent against actinides (An). However, DTPA is not equally efficient for all An and can be also toxic at higher concentrations.

Therefore, we comprehensively studied the complexation behaviour of DTPA related compounds such as ethylenediaminetetraacetic acid (EDTA) and ethylene glycol-bis(β-aminoethyl ether)-*N*,*N*,*N'*,*N'*-tetraacetic acid (EGTA) with trivalent europium and curium by combining spectroscopy and isothermal titration calorimetry. The influence of these ligands on the speciation of Eu(III) in the simulated human digestive system has been determined on a molecular level using time-resolved laser-induced fluorescence spectroscopy (TRLFS). Furthermore, the ligands were successfully synthesised in their deuterated form to perform ^{2}H-NMR spectroscopy to overcome the large ^{1}H-NMR background occurring from organic molecules such as proteins and enzymes in the artificial digestive system. These investigations contribute to an advanced understanding of the molecular processes in chelation therapy and its further development in the future.

This work is funded by the German Federal Ministry of Education and Research (BMBF) under grant number 02NUK057A and is part of the joint project RADEKOR.

^{210}Po loss in Seafood due to Cooking and its dose implications

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Abstract

An experimental study was conducted to assess the loss of ^{210}Po due to cooking fresh seafood. Fresh fish and shrimp samples from Northern Gulf waters were cooked (grilled and cooked using local recipes) to simulate the effect of different cooking methods. Twenty-Five species of fish were compared and significant differences in ^{210}Po concentration in uncooked samples were observed between species. The effect of the treatment (uncooked, grilled, boiled and stock) was compared for each species and it was found that cooking led to a significant decrease in ^{210}Po concentration ranging from 14 to 58% compared to the uncooked samples, with no difference between grilled or boiled treatments. The effect of the cooking and shrimp led to a significant 38% reduction of ^{210}Po concentration as compared to uncooked treatments with no difference between grilled and boiled samples. The two treatments with deveined shrimp led to a 75% decrease in ^{210}Po concentration compared to all other treatments. Cooked deveined shrimp contained an 84% lower ^{210}Po concentration than whole uncooked shrimp. This significant loss of ^{210}Po due to cooking highlights the issue that since ^{210}Po is known to be the major contributor to radiation dose in humans consuming seafood, there is a need to re-examine the calculation of the committed effective doses (CEDs) for cooked seafood-consuming populations. This might be a more realistic and reliable dose estimate for human seafood consumers.

24 PARALLEL SESSION 9B

Radioanalytics II

Weather-dependent detection limits for gamma-ray spectrometry in environmental radioactivity monitoring

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Keywords: environmental radioactivity, gamma-ray spectrometry, analysis methods.

In environmental radioactivity detection networks, it is common practice to quote a fixed value for the Minimum Detectable Activity Concentration (MDAC) of the isotopes under monitoring. In principle, this value only depends on the devices used for the detection and the analysis method. However, it is well known that natural radon emanations depend on weather conditions. As a consequence, gamma-ray emitting radon descendants (mainly ^{214}Bi, ^{214}Pb, and ^{212}Pb) have a variable contribution to gamma-ray spectra, both in terms of the peak height and of the resulting Compton scattering. This variability alters the ability of gamma-ray spectrometers to measure other photopeaks, most notably those from artificial origin. Here, we present a method to compute a variable MDAC taking into account the current state of the natural emitters, thus resulting in increased statistical robustness for the detection or non-detection of artificial isotopes. Moreover, we extend the method to the case were repetitive short-duration measurements are performed. This allows to set strict limits on an artificial radioactivity source highly diluted in the environment. Using a 2”x2” SrI_2(Eu) direct-observation spectrometer, we achieve MDAC values in a range as low as 0.4/0.4/0.18 Bq/m³ in 24h for ^{131}I/^{137}Cs/^{60}Co, respectively.

Questioning the increase of population around the Laguna Verde Nuclear Power Plant- Mexico

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Keywords: External Radiological Emergency Plan, nuclear plant

A site to install a nuclear power plant must meet several basic criteria, including: a) Low potential for use in agriculture and livestock, b) Low potential for housing and industrial use, c) Geological stability. These conditions must prevail during the operation of the Laguna Verde Nuclear Power Plant (LVNPP), however, the following two projects that oppose these criteria are being proposed:

1. Authorization of the mining industry of the "Caballo Blanco Exploration Project" on the side of the LVNPP, which, due to detonations with explosives, may induce tremors that could affect the operation of the LVNPP. The aforementioned authorization was issued by the Ministry of the Environment and Natural Resources (SEMARNAT), according to Official Letter No. SGPARN.02.IRA.0395/17 dated January 23, 2017.
2. Installation of a real estate project that will concentrate a considerable population, located in the vicinity of the LVNPP, specifically at the Diada La Mancha, called "REAL ESTATE PROJECT OF THE URBAN HOUSING ROOM TYPE" and which is also being proposed to SEMARNAT. The authorizations have been signed by an official who does not have any type of training in Radiological Protection or Nuclear Safety.

The previous projects will complicate the good performance of the "External Radiological Emergency Plan", whose purpose is to guarantee the safety of the population in case of a nuclear contingency, as it would be necessary to evacuate a larger number of people and a greater amount of resources would be needed: means of transportation, shelters, etc. This paper was written at the Department of Physics at the Faculty of Sciences of the National Autonomous University of Mexico..

Novel approaches for measuring low radon levels in the environment by passive detectors

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Keywords: Radon, Thoron, Climatic changes, Radon priority areas

In the last years the interest in measuring low radon levels in the environment raised significantly. In particular, such measurements are needed for delineating the radon priority areas, as requested by the European Council directive 2013/59/EURATOM, and for research related to climatic changes. As the existing passive radon detectors lack of sufficient sensitivity to address these challenges, efforts were focused in new designs. In this report we compare the sensitivity of some novel designs to that of existing passive radon monitors. The novel designs include monitors in which the detector (alpha track detector) is coupled with an efficient radon adsorber/absorber, and such in which large area and low background track detectors are used. Recent innovative solutions to compensate the influence of the temperature and to reduce the influence of humidity on detectors that use ad/absorber are discussed. The background signal of the detectors scheduled for use in novel designs is discussed. It is demonstrated, that novel approaches have the potential to improve the sensitivity of long-term radon measurements by more than one order of magnitude compared to the existing, widely used nowadays detectors.

25 PLENARY SESSION VII

Natural reactor in Oklo – 50 years from discovery

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Keywords: Nuclear reactor, Oklo, Nuclear wastes, Uranium

In summer of 1972 the routine sample of uranium hexafluoride analyzed in mass spectrometry laboratory in Pierrelatte (France) revealed small depletion of U-235. Undertaken investigation soon lead to discovery of natural nuclear reactor which operated in uranium deposit in Oklo (Gabon) about 2 billion years ago. Further wide scale studies resulted in finding remains of extinguished next 16 reactors in two locations in Gabon within a 30 km distance. The isotopic ratios preserved in minerals on site in combination with nuclear reactor modelling allowed to reconstruct the operational mode of natural reactors. The cores were basically acting as homogenous reactors with water moderator, however some energy was also released in fast neutron breeder mode. The process was self-controlled and cyclic was discovered. It was characterized by about half an hour criticality state followed by more than two hour dormant period. The cycle was governed by changes of water content in uranium core. Besides finding many details of reactors operation, those studies were unique opportunity for getting knowledge of the nuclear wastes behavior in course of extreme long time scale of storing. This studies brought also a verification of some models regarding a possible changes in time of fundamental physical constants, namely their combination known as fine structure constant alpha. A general overview of above mentioned three main aspects of conducted studies will be presented during the Conference.

POSTER SESSIONS

9

POSTER SESSION I

02 Radiometrics

07 Radioanalytics

08 NORM

10 Radionuclides in biota

14 Radioecology

POSTER SESSION I

02 Radiometrics

1-02-01

Background radiation measurements in Kuwait

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Keywords: Background Radiation, Dosimeter, Dose rates, Kuwait

Background radiation parameters, e.g. ambient absorbed dose rate, activity concentration of radionuclides in environmental matrices, etc., are important inputs for radiological environmental impact assessment of human activities, such as mining and accidental or planned releases of radioactive materials into the environment. In many countries, these parameters are measured and monitored continuously to update the baseline database and as part of safety preparedness and impact assessment.

During the last two decades, outdoor background radiation measurements have been carried out in Kuwait through various projects and studies covering many locations within the country. Giger-Muller (GM) and scintillation dosimeters have been used for in-situ measurements of the gamma dose rates and soil/sand samples were collected for laboratory analysis to determine the radionuclide concentrations. Some of these studies were parts of scientific projects to establish the database for the country while others represent efforts to address public concerns about possible contaminations of the environment by depleted uranium following the Gulf War.

The results from 112 locations using a NaI dosimeter show that the dose rates vary in the range of 31-59 nSv/h with a mean value of 47 nSv/h, whereas the GM results for another set of 20 locations are with values in the range of 61-93 nSv/h and a mean value of 76 nSv/h. The GM dosimeter recorded slightly higher values than the scintillation dosimeter due to the contribution of the cosmic-rays component with such types of dosimeters. In another study, the results obtained with a car borne GM dosimeter along the asphalt roads of Kuwait (total 3117 data points) show that the dose rates are between 40 and 180 nSv/h with an average value of 103 nSv/h.

In general, all the results of the gamma dose rates obtained in the different studies reveal no anomalous levels throughout the country. All the values are within the range reported from different regions of the world with normal background radiation. In addition, the results of the laboratory analysis of soil samples showed that the primordial radionuclide concentrations are below the global averages.

1-02-02

High sensitivity measurement of ^{238}Pu with uranium tracer for interference correction by thermal ionization mass spectrometry

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Keywords: Plutonium-238, mass spectrometry, isotope dilution, total evaporation TIMS

Routine measurement of low-level ^{239,240,241,242,244}Pu and ^{236,237}Np using static collection on a multi-collector thermal ionization mass spectrometer (TIMS) is undertaken at Los Alamos National Laboratory in support of treaty monitoring, environmental monitoring, safeguards, and nuclear forensics. One instrument method used includes a Daly detector and eight Sjuts ion counters to simultaneously measure all the isotopes in a total evaporation routine from a single resin bead source. We have recently added the measurement of ^{238}Pu to the measurement routine, which is challenging due to the isobaric interference of ^{238}U. To accurately measure the minor isotopes of Pu the routine requires ramping the filament to high temperatures to ensure ionization of small quantities of those isotopes to detectable levels. This high temperature encourages the ingrowth of ^{238}U interference on the ^{238}Pu measurement. To characterize this interference, we have created a method of simultaneously measuring ^{235}U (instead of ^{236,237}Np) along with the 6 plutonium isotopes. Measuring ^{235}U allows us to discriminate between the ionization profile of U vs Pu, as the filament undergoes temperature ramping. After the Pu has completely ionized from a filament leaving behind only U, an accurate ^{238}U/^{235}U ratio can be determined for the sample, which can then be used to correct the Pu cycles offline for the ^{238}U interference on ^{238}Pu. We provide data for measurements of a solution of NBL CRM U970 "tracer," calibrated for concentration in our laboratory, which provides for accurate characterization of the ^{238}U background in purified Pu sample fractions. Additionally, we provide results for the measurement accuracy and precision of added NIST 4323B ^{238}Pu standard via the new routine, and preliminary measurements on matrix-containing standards. The ability to characterize ^{238}Pu simultaneously with the other Pu isotopes will provide valuable signature information that has so far been missing from many low-level (picogram and below) sample measurements.

A consideration of the measurement of ^{241}Am in the environmental samples using gamma spectrometry

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Keywords: Environmetal radioactivity measurement**,** ^{241}Am, Gamma spectrometry, Self-absorption effect, Chemical composition

The measurement of ^{241}Am released into the environment through atmospheric nuclear weapons testing, reprocessing operations, aircraft accident, and nuclear power plant accident is important for environmental monitoring and radiological risk assessment. In gamma spectrometry, the measurement of ^{241}Am emitting low energy photon is significant affected by the self-absorption effect. It is common to consider only the apparent density of the environmental samples to correct this effect. The chemical composition that cause this effect should also be considered strictly, however this is not well studied in the scientific literature. In this work, the self-absorption correction factors of ^{241}Am related to the chemical composition of concrete and soil samples were evaluated using Monte Carlo N-Particle code. High Purity Germanium (HPGe) detector with 30% efficiency was modeled for the simulation study. In the element analysis using ICP-OES, the concrete sample was composed of SiO_2 (75.1%), CaO (14.7%), and Al_2O_3 (3.0%). The chemical elements of the soil sample were analysed as SiO_2 (66.9%), CaO (19.9%), and Fe_2O_3 (1.5%). As a result, the relative bias of the self-absorption correction factors of ^{241}Am in the concrete sample when only the density was considered and both the density and the chemical elements were considered was 20.0%. Similarly, in the case of the soil, the relative bias was about 17%. The self-absorption correction factors evaluated in the simulation will be verify through alpha spectrometry. In conclusion, in order to correct the self-absorption effect in the ^{241}Am measurement using gamma spectrometry, the chemical composition should be considered important with the density.

Recent research on the real-time detection system for environmental radiation at Daedeok nuclear facility in Korea

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Keywords: Environmental radiation monitoring, underwater radiation monitors, GM counters, high-resolution dose rate

Environmental radiation monitoring at the Daedeok nuclear facility, which includes research reactors, fuel production facilities, radioactive waste storage facilities, and related research facilities, is critical for the safety and preservation of the surrounding population and environment. In addition to the existing methods of environmental radiation monitoring, this study introduces a new system using GM counters that have been recently developed and operated.

This is a new approach for radiation monitoring with a GM counter, which is relatively cheaper than an ion-chamber. It provides real-time radiation data; in particular, it does not need a power supply. The main feature of the GM counter is its low power consumption. The solar panel is enough for the operation of this small dose rate measurement tool. This high-resolution dose rate measurement provides more comprehensive information about the dose rate, and we can easily detect anomalies of dose rate and detect the source of the contamination as soon as possible. Based on the high-resolution modeling and dose rate measurement with the GM counter, we can track radio-contaminants more easily and precisely. And we are trying to apply an AI technique based on very high-resolution numerical weather prediction data to track the source using a dense radiation network in high resolution.

Method validation of ^{14}C in the environmental samples with LSC and AMS

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Keywords: ^{14}C, LSC, AMS, Method validation

Atmospheric ^{14}C activity has remained at its natural level of 0.2 Bq/g-C (100 pMC) since the 1960s bomb-pulse. However, the level of ^{14}C, the primary gaseous phase emission from nuclear facilities, are relatively higher than natural levels around nuclear facilities. Fouther, ^{14}C is a radionuclide with a relatively large dose impact. Therefore, tracking fluctuations in ^{14}C activity in environmental samples is one of the main tools for assessing the impact of gaseous emissions from nuclear facilities. In general, for ^{14}C determination, CO_2 collected in a molecular sieve is crystallized into calcium carbonate, and CO_2 is regenerated using hydrochloric acid to prepare a sample for LSC measurement.

In this study, NIST SRM 4990C (OXALIC ACID) was used to validate the analytical method for ^{14}C in the environmental samples, and the accuracy and precision of the analytical results were evaluated. Finally, the method was validated by comparative analysis by LSC and AMS.

1-02-06

Development of procedures to be applied by the laboratories belonging to the Spanish Environmental Radiological Surveillance Network in "special" situations

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Keywords: Environmental radiological surveillances, radionuclides in the environment,

The laboratories belonging to the Spanish environmental radiological surveillance network, called REVIRA, and coordinated by the Consejo de Seguridad Nuclear (CSN), have quite well defined their role and their actuation plan in situations that we can qualify as normal, i.e., in situations no affected by any punctual radiological incident or accident. For these normal situations the laboratories developed normalized procedures, published by CSN, that should be applied by all the members of the network following a well-defined protocol..

The actuation of the laboratories belonging to the Spanish network should be also extended to situations that we can qualify as "special" situations. These situations will be the ones characterized for provoking an increment of radioactivity in the environment, and in the doses received by the public, but no reaching the values that can be associated to the lowest level (Level 1) in the International Nuclear Event scale (INES). Or in other words, will be no normal situations provoking doses in the public lower than the annual limits. of 1 mSv for the public. A typical case of "special" situation in Spain was the arrival of a quite diluted plume of volatile radionuclides generated by the accident of Fukushima,

The University of Seville, with the collaboration, supervision and financial support of CSN is developing a 2-year project with a central objective: to elaborate and develop a defined protocol to be applied by the laboratories of the environmental Radiological Surveillance Network in the case of "special situations". With this end an extensive study about the distribution in the country of the technical facilities and the working force available was carried out and the possible different scenarios that could generate "special" situations were identified. For each one of these scenarios the possible radionuclides involved have been identified as well as the different environmental matrixes that can be used as monitors, and radionuclide&matrix specific procedures for the determination of the levels of the radionuclides of interest are proposed.

The main results of the project, which will be practically finished at the time of the conference, will be presented in this work.

1-02-07

Pushing the sensitivity limit of quadrupole mass spectrometry ICP MS/MS for plutonium isotopes

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Keywords:
plutonium, ICP MS/MS, desolvating nebulizer, sensitivity

As an important fingerprint, the $^{240}Pu/^{239}Pu$ atomic ratio is often used to identify the source of the plutonium and estimate the effect of nuclear activities on the environment. For this point, it is critical to accurately determine ^{239}Pu and ^{240}Pu by mass spectrometry. However, extremely low $^{239, 240}Pu$ concentrations as well as high content of matrix and interference elements (Pb, Hg, Tl, U, etc) in environmental samples entail serious difficulties and challenges in plutonium measurements. In our study combined radiochemical procedure and ICP MS/MS 8900 instrument (Agilent Technologies) supported by APEX IR technology (Elemental Scientific) were implemented for $^{240}Pu/^{239}Pu$ atomic ratio determination. Effectively removing matrix elements was achieved by multi-chromatography separations, including AmberChrom + TEVA resins, which resulted in decontamination factors of uranium up to 10^7. Further reduction of the interfering $^{238}UH^+$ and $^{238}UH_2^+$ ions on $^{239}Pu^+$ and $^{240}Pu^+$ was assured by the use of a collision/reaction cell (CRC). It is well known that O_2 would readily react with plutonium converting it to PuO_2^+, but decreasing the portion of UHO_2^+ and $UH_2O_2^+$ ions. Unfortunately, the sensitivity not exceeding 700 cps/ppt at m/z = 271, 272 in O_2 mode when using the default sample introduction system. A nice alternative ensuring a significant increase of sensitivity for $^{240}Pu/^{239}Pu$ determination could be the APEX IR desolating nebulizer, which cooperates well with the ICP MS/MS 8900 instrument. Using a specific setup we were able to reach sensitivity as high as 5000 cps/ppt at m/z = 271, 272 in O_2 mode, which proved to be sufficient enough for $^{240}Pu/^{239}Pu$ analysis in examined samples.

1-02-08

Detecting heavy metal pollution events recorded by a sediment core from Ker-Ya River in NW Taiwan: Scanning XRF and ICP-OES methods

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Keywords: Heavy metal pollution, sediment core, Ker-Ya River, Scanning XRF, ICP-OES

Localed in the upper stream of Ker-Ya River, Hsinchu Science-based Industrial Park (HSIP) was established in 1980. From 1985 to 2022, registered manufactories in the Park increased from 50 to more than 552. The product sales of the Park reached 1.7 trillion NTD in 2022. As the industrial activity strongly increased, the eniveronmental concern has been paid tremendous attention. In order to survey heavy metal pollution during the past, a 24-cm sediment core was retrieved from the Ker-Ya River bed in July 2020, which contained the sediment sequence after 1996. Since the core coverd only about 20-year deposition and had large change in the sedimentation rate, no radiomatric dating method can be applied except using AMS ^{14}C dating on nuclear bomd ^{14}C signal. The sediments of the core are black fine clay mud with higtly enriched in organic carbon. Using an iTRAX core scanner, we have obtained elemental contents (semi-quantitative variation) of Fe, K, Ti, Si, Mn, Ca, Sr, Zn, Cu and Ni with sampling resolution of 0.2 mm. Strongly positive correlations appear among Fe, K, Ti, Si and Ca variations, indicating that these elements are mainly from clay minerals. These elements show clearly sesonal variations, which account for 20-year deposition. Higher Fe, K, Ti, Si and Ca contents reflect more detrital concents from natural sediments during warm/rainy season, whereas lower contents perhaps indicate higher organic contents in the sediments. In addition, these elements reduced abundance since 2007 when the river drainadge system started to be remedied which caused less sediment input from upper stream. A very outstanding peak of Ca and Sr contents is displayed at 19-cm depth which marked a recorded pollution event (pH>11.5) on September 8th, 2018. The scanning XRF results help us to determine the chronology of the core. Although the scanning XRF results show several Zn and Cu spikes, the absolute concentrations of those peaks are not confirmed by the results of ICP-OES measurements. A total of 120 subsamples have been taken from the 24-cm core. Currently, we are in process of the elemental analyses by ICP-OES measurements on 0.5N HCl acid-leach (AL) and Aqua Regia total dissolution (ARTD). The results of the ICP-OES analyzed elements will provide us the heavy metal pollution history since 1999.

RaPCUBES: An open (free and friendly) software (interface) for solving radioactive series

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Keywords: Natural series, Bateman equations, Free software.

RaPCUBES (Radioactivity and Population Calculator Using Bateman Equation's Solutions) is an activities and populations calculator able to solve the Bateman equations for the radioactive series, considering closed systems and a one-isotope initial presence in the sample. It was developed to provide the scientific community an open and simple tool to perform such complex mathematical operations.

Via MATLAB software (v. 2021b), RaPCUBES strikes as a very agile and versatile program. It not only obtains results and its uncertainties at a given date, but it also includes a graphic interface to depict magnitudes (number of nuclei or activities) and ratios evolutions with time as well as the possibility to save the resulting data to an external text file. As a matter of fact, there is no need of a MATLAB subscription to execute RaPCUBES since only the corresponding version of the free Runtime program must be installed to properly run it.

Main radionuclides from natural (^{238}U, ^{235}U, ^{232}Th) and ^{237}Np series have been implemented in this application. In addition, RaPCUBES' academic purposes stand out due to its intuitive and visual interface.

In short term, this software will be expanded with dating tools for ^{210}Pb and U/Th methods.

From NaI to $CeBr_3$ detectors for internal contamination dosimetry research

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Keywords: $CeBr_3$; dose; internal contamination; minimum detection limit.

The in vivo methods to measure the amount of radioactive material deposited in organs, tissues, or the whole body using externally-placed detectors are preferable, as they facilitate the rapid screening for workers in the radiation environment. Thus, the estimation of the absorbed dose must be as accurate as possible. The accuracy depends on many factors among which the activity quantification methods and the available instrumentations are very important.

Among instruments used in internal dosimetry laboratory, the HPGe detectors are commonly used as these have high energy resolution. Other types, such as LaBr3(Ce) and $CeBr_3$ are also useful. $LaBr_3$(Ce) has superior energy resolution (approximately 3% at 662 keV) among scintillators as well as a short decay time (16–30 ns), however, it has a large amount of intrinsic radioactivity. $CeBr_3$ has good energy resolution (4% at 662 keV) and a short decay time (<20 ns). The intrinsic radioactivity of $CeBr_3$ is much smaller than that of $LaBr_3$(Ce). Therefore, despite the energy resolution of $LaBr_3$(Ce) is superior to that of $CeBr_3$, the minimum detection limit of $LaBr_3$(Ce) is inferior to that of CeBr3 in the spectral range of 50–3000 keV. However, all detectors have several advantages and disadvantages with respect to their applications.

This paper presents tests performed for the last two detectors, for an initial assessment as whole-body counters, in different sizes and geometrical configurations. The parameters evaluated were efficiency and minimum detection limit, in order to find the most proper configuration.

POSTER SESSION I

07 Radioanalytics

1-07-01

Rapid measurement of cesium-137 (^{137}Cs) in seawater using an ion-exchange resin (AMP-PAN resin, KNiFC-PAN resin)

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Keywords: Cesium, Radioactive, AMP-PAN resin, KNiFC-PAN resin

In this study, we attempted to optimize a rapid preconcentration method by cesium- 137 (137Cs) in seawater (100L) based on a commercial ion-exchange resins (AMP- PAN resin (Ammonium MolybdoPhosphate- polyacrylonitrile) and KNiFC-PAN resin (Potassium-Nickel Hexacyanoferrate (II)- polyacrylonitrile)). The concentrated ^{137}Cs sample were measured using the High Purity Germanium (HPGe) Gamma-ray Spectroscopy System (Ortec Inc., USA) with relative detection efficiency of 100% (energy calibration error within ±1% range and within
±5% range). In this study, 137Cs preconcentration was conducted under various conditions. i) Time (1hour, 3hours, 4hours), ii) Amount of resin (5g, 19g, 25g) and
iii) Stirring type (stir, cross-stir, air bubble). First, the sample was reacted with resin for at least 3 hours, the best recovery rate was 74.6 ± 1.6% for AMP-PAN resin and 94.5 ± 2.6% for KNiFC-PAN resin. Therefore, all preconcentration experiments were performed for 3 hours. Second, the amount of ion-exchange resin (5g, 19g, 25g), when 25g used, AMP-PAN resin was 81.6 ± 2.4% and KNiFC- PAN resin was 93.8 ± 2.1%, which was 1- 4 times higher than that of 5 g and 19 g. Third, in the case of stirring type, AMP-PAN resin was 74.60 ± 1.6% and KNiFC-PAN resin was 93.8 ± 2.1% when cross-stirring, the recovery was more than twice as higher than other stirring-types. Regardless of the reaction experiment condition, when using KNiFC-PAN resin, it was consistently higher than (about
1.2 times) AMP-PAN resin. In comparison with AMP co-precipitation; it takes about >7 days after samples were moved to laboratory from the sea; our method ^{137}Cs was able to reduce the to 6 hours for per-treatment and 8 hours for detection. Our results suggest that this optimized rapid ^{137}Cs analysis in seawater can be used in the event of a radioactive accident requiring urgent monitoring in the ocean.

1-07-02

Radiochemical analysis and evaluation in radioactive samples for decommissioning of nuclear power plant

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This study presents optimum classification of decommissioning radioactive samples in KORI Reactor-1. Also, rapid and quantitative sequential radiochemical separation method for Pu, Am, Tc, Sr, Nb, Fe and Ni isotopes in radioactive samples from the nuclear power plant with extraction chromatographic resins. After radionuclides were leached from the radioactive samples with concentrated HCl and HNO_3, the radionuclides such as Pu, Am, Nb and Fe isotopes were coprecipitated with Fe after filtering the leaching solution with 0.45 micron HA filter, while the Sr, Tc and Ni isotopes were in the solution. Pu and Am isotopes coprecipitated with Fe were sequentially purified with anion exchange resin and TRU resin, respectively, on the other hand Tc and Sr isotopes in the solution were purified with the TEVA resin and the Sr resin, respectively. Also, Nb and Fe isotopes were separated through anion exchange resin column from Fe coprecipitation step, while Ni isotopes were purified with dimethylglyoxime (DMG) precipitation in the solution. After α source preparation for the purified Pu and Am isotopes with micro-coprecipitation method, Pu and Am isotopes were measured using alpha spectrometry. Also, Tc, Sr, Nb, Fe and Ni isotopes were measured using a low level liquid scintillation counter. The radiochemical procedure for Pu, Am, Tc, Sr, Nb, Fe and Ni isotopes investigated in this study has been applied to the samples for decommissioning main structure of nuclear power plant after method validation.

Keywords: Sequential Radiochemical Separation, Radioactive Samples, Pu, Am, Tc, Sr, Nb, Fe and Ni Isotopes, Decommissioning

1-07-03

Sequential extraction of actinides from sediment samples for the analytical determination of ^{237}Np by AMS

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Keywords: 237-Np, actinides, Accelerator Mass Spectrometry, sediment

^{237}Np ($T_{1/2}$=2.14 My) studies from environmental samples suppose an analytical challenge due to the lack of an appropriate long-lived isotopic tracer to control both laboratory procedures and Accelerator Mass Spectrometry (AMS) analysis. Additionally, the very scarce list of reference materials certified for ^{237}Np limits the development of new sample preparation methods. ^{237}Np analysis in environmental samples are usually performed using ^{242}Pu as a non-isotopic tracer. To this aim, robust chemical methods are necessary. The 1 MV AMS system at the *Centro Nacional de Aceleradore*s *(CNA)* has demonstrated its potential to analyse actinides radionuclides at ultra-trace levels. A radiochemical method to separate sequentially U and Np+Pu from seawater samples, and their subsequent isotopic analysis by AMS (^{236,238}U,^{239,240}Pu, ^{237}Np), has been recently setup. In this context, the aim of this work is the adaptation of this method to sediment samples. The challenge lies in the fact that sediments are much more complex matrixes than seawater samples, since the sample pre-treatment stage plays a key role in the whole process. Moreover, the method is also aimed at the extremely rare radionuclides ^{244}Pu and ^{233}U, for which the removal of ^{232}Th is critical. The radiochemical procedure consists of a leaching step followed by a $Fe(OH)_2$ co- precipitation of actinides and a sequential extraction of U and Pu+Np (including Th elimination) using TEVA® and UTEVA® extraction chromatography resins in tandem. Finally, the method is going to be applied systematically to measure ^{237}Np for the first time in sediment samples provided by the IAEA as reference materials.

1-07-04

Simultaneous determination of ^{210}Pb and ^{90}Sr and ^{210}Po isolation in sludge samples using a plastic scintillation resin and measuring by liquid scintillation counting

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Keywords: Secuential separation, plastic scintillation resin, lead, strontium, polonium

The drinking water treatment plant (DWTP) located in L'Ampolla (Tarragona) collects water from the Ebro River. This river, besides the influence of the terrain's lithology is influenced by the presence of a nuclear power plan. The sludge generated as a by-product of the different water treatment processes in the DWTP could be useful for assessing the presence of some radionuclides that would otherwise be very difficult to measure directly in water samples due to their low levels. Among all the radionuclides we determined in previous studies in sludge samples from the DWTP in L'Ampolla (Tarragona, Spain), the present study focuses on determining ^{210}Pb, ^{210}Po and ^{90}Sr due to their radiotoxicity.

This study describes a new and fast method for separating ^{210}Po from ^{210}Pb and ^{90}Sr, before simultaneously measuring the individual activities of the latter two radionuclides using a plastic scintillation resin (PSresin) in sludge samples taken from a drinking water treatment plant. This approach speeds up the analysis process significantly by combining separation and measurement in a single step thus reducing the amount of reagent used. The method is reproducible and has a relative standard deviation of less than 25% for ^{210}Pb, ^{210}Po and ^{90}Sr. Moreover, the method was satisfactorily validated with an intercomparison sample and applied to sludge samples from a DWTP.

.1-07-05

Improving the measurement of ^{210}Po in seawater samples

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Keywords: Radioactive, disequilibrium, carbon export, seawater, radiochemistry, polonium.

Disequilibrium between the radioactive pair ^{210}Pb-^{210}Po in the ocean provides POC flux estimations in seawater, which is a key parameter to evaluate local and global carbon inventories.

The most popular method to extract ^{210}Po from the sea water matrix is based on the co-precipitation of polonium using $Fe(OH)_3$. Previous studies suggest that this method is not robust for the extraction of ^{210}Po in seawater. Because, unlike the added internal tracer ^{209}Po, ^{210}Po is tightly associated to the sea water ions and in occasions it is only partially scavenged by the iron (III) hydroxide, in relation to ^{209}Po. This results in a systematic underestimation of the ^{210}Po activity measured in seawater samples. Other methods, such us that one based on Co-APDC, successfully works to extract equal concentration of ^{210}Po and ^{209}Po. However, Co- APDC is a long, difficult to apply method in cruises in open sea waters.

In this work, a new method based on coprecipitation using Fe^{2+}, instead of Fe^{3+}, based on the coprecipitation of $Fe(OH)_2$ has been developed and tested in three seawater profiles. Polonium and lead are pre-concentrated from the bulk sample with $Fe(OH)_2$. First $K_2S_2O_5$ is added to the samples, once dissolved, Fe(II) is added as iron sulphate ($FeSO_4$) and the $Fe(OH)_2$ is precipitated by in-creasing the pH to 9 through concentrated ammonia (NH_4OH).

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The results obtained in different matrices including mineral, well, ground and seawater, using both methods, Fe(II) and Fe(III) validate that i) Fe(II) co- precipitation successfully extracts polonium and lead isotopes from water matrices;
ii) Fe(III) systematically underestimates ^{210}Po concentrations, as reported in previous works; and finally iii) despite the fact that the extraction yield is usually slightly lower for Fe(II) than for Fe(III), Fe(II) provides reproducible and higher concentrations of ^{210}Po in relation to Fe(III).

We propose the co-precipitation of $Fe(OH)_2$ as a novel, robust, easy to perform, method to estimate ^{210}Po and ^{209}Po in seawater, in order to accurate evaluate ^{210}Po- derived POC fluxes in seawater.

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1-07-06

Challenges in measuring ^{22}Na in rainfall by gamma spectrometry in the city of São Paulo, Brazil

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Keywords: Cosmogenic radionuclides, gamma spectometry, 22Na, rainfall

Na-22 is a naturally occurring radionuclide of cosmogenic origin with half live of 2.6 years, being a beta and gamma emitter (541keV and 1274.5keV, respectively). This cosmogenic radionuclide is mainly formed when cosmic rays interact with argon nucleus, occurring a fragmentation of this nucleus. The process of production of ^{22}Na occur continually in upper atmosphere, lower stratosphere and rainfall is the predominantly process of deposition of cosmogenic radionuclides in terrestrial surface. Na-22 together with ^{7}Be ($T_{1/2}$) = 53.3 d, gamma ray 476.7keV) can be used as tracers in studies of aerosol transport between layers of the atmosphere. At the same time ^{22}Na is rarely used in these studies due to its extremely low abundance in rainfall. The objectives of this work were to present the first results ^{22}Na activity concentration measured in rainfall collected at the IPEN campus located in São Paulo, Brazil. Large volumes of rainfall samples were collected from October 2022 to April 2023, totaling 20 samples, and ^{22}Na activity concentration was measured by non-destructive gamma-ray spectrometry using a coaxial Be-layer HPGe detector with 46% relative efficiency and associated electronic devices and live counting time varying from 250,000 s to 500,000 s; the rainfall volumes ranged from 14 L to 164 L. The collection container was previously acidified with 1mol L^{-1} HNO_3 to avoid loss of radionuclide by absorption on the container walls. The first eight rainfall samples were collected in a catchment area of 1m^2, which was not enough to measure the radionuclide, since all the determined results were smaller than the detection limit of the methodology. After these results, it was decided to increase the catchment area by collecting rainfall samples from the roof of the laboratory building, in an area of 78 m^2; the container used to collect samples from this area was also acidified with 1 mol L^{-1} HNO_3. In this new area, 12 rainfall samples were collected, however, as the volume of rainfall was very large in the rains collected, only one sample was acidified, a rainfall of 2 mm and a volume of 98 L; in the other samples, the large volume of rain did not allow the water to become acidic because the collection container overflowed with water. In the acidified rainfall sample, the result of 0.725 ± 0.252 Bq L^{-1} was determined for the radionuclide ^{22}Na. With this result, it is possible to prove the importance of both the catchment area and the acidulation of the sample in the determination of trace radionuclides in rainfall samples

POSTER SESSION I

08 NORM

1-08-01

Natural radioactivity and radon emanation coefficient of various rocks used in building materials

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Keywords: NORM, activity concentration, radon emanation, building materials

Most building materials derived from rocks and soil contain some naturally occurring radionuclides (NORM) in the U and Th series, and ^{40}K-40. External exposure is caused by radionuclides that emit gamma rays, and internal exposure is caused by inhalation of radon (^{222}Rn) and its short-lived radionuclides. The radioactivity of ^{226}Ra, ^{232}Th, and ^{40}K in 30 rock samples were determined using γ- ray spectrometry.

Radon emanation coefficient of the samples were also determined using γ-ray spectrometry. The radioactivity of ^{226}Ra, ^{232}Th, and ^{40}K ranges from 2.71 to 492 Bq/kg, 1.06 to 275 Bq/kg and 22.1 to 1570 Bq/kg, respectively. The radon emanation coefficient varied from 0.045 to 0.35. The activity concentration index and radon exhalation rate could be estimated using the radioactivity and radon emanation coefficient.

^{40}K, ^{226}Ra, ^{232}Th, ^{238}U, and radiological risks in surface soil around the Plomin thermal power plant (Istria, Adriatic Sea, Croatia)

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Keywords: Coal combustion, Doses, Radioactivity, Radionuclides, TENORM, TPP

Plomin thermal power plant (TPP) is the only active coal-fired TPP in Croatia. Coal combustion produces bottom- and fly ash that are enriched with natural radionuclides and may represent TENORM (Technologically Enhanced Naturally Occurring Radioactive Material). Fly ash and coal piles stored in the open space may influence the surrounding area. Plomin TPP influence on the surface soil (0– 10 cm depth) has been studied depending on the distance from the plant and on the prevailing wind direction. Samples were taken radially around the plant at 1, 5, and 10 km distances. A profile in the prevailing wind direction was sampled each 100 m from the plant to 1 km distance. ^{40}K, ^{226}Ra, ^{232}Th, and ^{238}U distributions around the plant and their dependence on the distance from the plant were studied. Radiological risks were calculated: outdoor absorbed dose rate in air (D, in nGy/h), annual outdoor effective dose rate (D_{ef}, in mSv/yr), and external hazard index (H_{ex}). Their distribution and dependence on distance from the plant were studied as well. Relative contributions of ^{226}Ra, ^{232}Th, and ^{40}K to D and H_{ex} were determined. Radionuclides' massic activities and radiological risks were compared to control samples from uncontaminated areas. ^{226}Ra and ^{238}U distributions point to TPP's impact on the soil in the prevailing wind direction, the effect being the strongest at 1 km distance or less. The same pattern was observed for radiological risks. H_{ex} was higher than the recommended value at one station at 1 km distance from the TPP close to the prevailing wind direction.

Assessment of radioactivity content in raw and manufactured building materials in Morocco analysed by high resolution gamma-ray spectrometry

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Keywords: Building Materials, Morocco, HPGe gamma spectrometry, gamma index.

In addition to terrestrial and cosmic radiation, building construction materials are considered as the main source of natural radioactivity responsible for indoor gamma radiation. Building materials, such as cements, bricks, gypsums, gravels of different type and origin in Morocco, were analysed by HPGe spectrometry to determine naturally occurring radionuclide concentrations. Substantial variabilities in concentrations were found from one matrix to another and from site to site within the same material. ^{226}Ra, ^{238}U and ^{40}K specific activities were used in *Gamma Index* calculation, as indicator of gamma-ray external exposure. The obtained values for each analysed sample were all below the reference level suggested in the European Directive 59/2013.

The present work presents, to our knowledge, the first set of data regarding radiological contents in the most commonly used materials in building construction in Morocco.

1-08-04

Distribution of natural radionuclides in horticultural systems due to phosphate fertilization in Uruguay

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Keywords: Phosphate fertilizers, Naturally occurring radioactive material, Distribution coefficients

Uruguay is an agricultural country, where thousands of tons of fertilizers are applied every year. Although the international literature on this subject is vast, to the best of our knowledge, the radioecological impact of the use of phosphate fertilizers in Uruguay had not been studied prior to this work. We reported here the first results on natural radionuclides distribution in an horticultural system due to phosphate fertilizers marketed in the country. Fertilizer samples from different brands were acquired in the retail market. The activity concentrations of ^{238}U, ^{234}U and ^{210}Po, were determined by alpha spectrometry and the activity concentrations of ^{226}Ra^{232}Th, and ^{40}K by gamma spectrometry. The most representative fertilizers (phosphate rock, superphosphates, ammonium phosphate, and NPK) were used for spinach *(Spinacia Oleracea*) pots essays. Two representative soils of Uruguay (Canelones´s soil: mud and muddy sand, and Rocha´s soil: sandy mud) were used for the spinach cultivation with controlled irrigation during three months. The activity concentrations of natural radionuclides in soil, gravitational water with leachate and spinach crop were evaluated. The distribution coefficients of the mentioned radionuclides were also determined in the different matrices. In general, results obtained in the present study indicated that mobility of radionuclides was low but not negligible in both soils studied. Future work will be focused on the radiological and radioecological impact of phosphate fertilization in the most representative crop fields (rice, soy, wheat) in Uruguay and fertilized pastures for livestock.

1-08-05

In-situ measurement of radon and thoron exhalation rates from interior walls in a Japanese building

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Keywords: Radon, Thoron, In-situ exhalation measurement, Solid wall, Cavity wall

Building materials such as brick and concrete are known to be one of indoor radon (^{222}Rn) and thoron (^{220}Rn) sources. Most radon and thoron exhalation studies have been based on laboratory tests using pieces and blocks of such materials. To elucidate how laboratory findings can be used in a real-world environment, we conducted intensive in-situ radon and thoron exhalation tests on interior walls with different structure types (i.e., solid wall and cavity wall) for over a year.

In this work, exhalation rates were determined based on an accumulation method that employed a chamber for covering a wall and a monitor for continuously measuring radon or thoron. Better data analysis approaches were considered and validated to accurately quantify exhalation rates from readings of radon or thoron concentration. It was found that: for radon exhalation the interference of and variation in indoor radon should be considered due to air leakage and resulting air exchange between inside and outside the measurement system; and for thoron exhalation, the formulation has to be made considering the disintegration in the measurement system due to its short half- life (55.6 s).

For solid walls, our in-situ tests revealed insignificant influences of environmental parameters, i.e., temperature and absolute humidity, on radon and thoron exhalation rates from the walls. This finding was not contradictory to previous works tested in laboratories, where concrete block samples were subjected to various temperature and water content conditions. Meanwhile, a significant linear correlation between the exhalation rates of radon and thoron was obtained for only one of the two walls tested, suggesting a difference in wall characteristics associated with their generation, emanation, or migration processes. For cavity walls, some distinct characteristics were observed, which will be presented and argued. This study provides an insight into parameterizing radon and thoron source inputs in modeling the spatial and temporal dynamics of indoor radon and thoron air concentrations.

Analysis of Naturally Occurring Radioactive Materials NORM (Uranium (U-238 & U-235), Thorium (Th-232) And Potassium (K-40)) In Soil Sample Using Gamma Ray Spectroscopy

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Industrial materials that absorb or emit radionuclides of natural origin would threaten the environment, the community at large, or workers. These naturally occurring radioactive materials, which can be found in minerals and ores that were first discovered in the environment, are frequently referred to as NORM. Radiation management and regulation are necessary for several NORM materials. In general, radionuclide activity concentrations in soil and rocks found in the natural environment are minimal Many minerals contain significant concentrations of uranium, thorium, or potassium, including several that are exploited economically. The radionuclides may be unevenly distributed among the numerous components produced by the mining of minerals from the crust of the Earth and their physical or chemical processing. The amount of NORM radionuclides in our environment may considerably rise as a result of these human activities. These industrial activities can produce NORM in a variety of forms, including ore, process feedstock, intermediate products, end products, byproducts, and process residue. It can exist in the form of a solid, liquid, or gas. The variety and quantity of radioactive elements varies greatly from industrial process to industrial process. For the influencing factors mentioned above, potential radiation hazards must be located and controlled
. Gamma radiation has a high penetration and reacts with matter by ionization it using three processes: pair creation, Compton scatters, and the photoelectric effect. Because gamma radiation penetrates the body deeply, its effects can be felt throughout. All nuclear radiation contains energy that can remove electrons from the atoms and molecules with which it interacts (ionizing radiation). This electron ionizing property is causes harm to human. As a result, detecting gamma rays in areas where we spend the majority of our time is critical. In this experiment we have used the NaI(TI) detector in gamma ray spectroscopy in order to detect and analysis NORM radiations in a soil sample that collected from ARAMCO company of oil production wells area in Saudi Arabia. In this research, a thallium activated sodium iodide NaI (TI) scintillation detector has been calibrated as well. The detector energy and voltage calibrations were performed using two standard sources of Cs-137 and Co-60.

1-08-07

Studies on procedure for thorium determination in NPK and micronutrient fertilizers

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Keywords: Phosphate fertilizers, Thorium, NORM, Alpha spectrometry

Observed increase in fertilizer use can be attributed to a combination of factors, including population growth, changes in farming practises (increase in intensive farming), decline in soil fertility and economic pressure to increase crop yield. Mineral fertilizers are typically classified into three groups based on their primary nutrient content: nitrogen (N), phosphorus (P) and potassium (K). These are commonly referred as NPK fertilizers. In addition there are also micronutrient fertilizers that contain trace elements such as iron, zinc, copper and manganese, which are essential for plant growth but required in smaller amounts. The NPK fertilizers are commonly used in large quantities for both agricultural and domestic applications, while micronutrient fertilizers are more often used in a smaller scale like flower cultivation. Fertilizers can be a source of an external and internal exposure to radiation through the presence of naturally occurring radioactive elements namely uranium, thorium and their decay products in some types of raw materials used for their production.

The goal of this research was to the elaborate analytical procedure for thorium determination in small samples of fertilizers by means of alpha spectrometry. The proposed methodology encompassed microwave digestion for sample decomposition, ion exchange chromatography for thorium separation. Thin and clear alpha sources of thorium were obtained by electrodeposition on stainless steel discs.

The obtained results were characterised by good counting parameters (FWHM below 18 keV for Th-232 and 16 keV for Th-230) and satisfactory chemical recovery (the lowest observed value was 35%). The preliminary studies of several commercially available fertilizers revealed strong connection between fertilizer type and Th-232 concentration.

Relationship between indoor radon concentration and soil radon concentration and soil uranium and radium content in Urumqi City

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Keywords: Indoor radon, Soil radon, Uranium, Urumqi City

Urumqi City is located in the northwesten China, Xinjiang Uygur Autonomous Region of China. The climate is cold and dry. Every year, the temperature is lower than minus 10 degrees Celsius for more than 150 days in winter. In order to find out the cause of the high indoor radon concentration in the city, a survey of indoor radon concentration, soil radon concentration and distribution characteristics of radionuclides in soil was carried out in the district with typical geological characteristics in the city from 2020 to 2021. The results showed that the distribution of uranium, radium, thorium and potassium-40 in surface soil layer was basically uniform, and it is consistent with to the data of 1:200000 geochemical databases. The specific activity of uranium and radium in surface soils of Yamarik Mountains and the Black Hill is a little higher. The sites, about 38.1% sites of a total of 63 soil radon measuring points, are with concentration of radon in soil higher than 24 kBq/m3. There was no significant correlation between soil radon concentration and soil radium specific activity. The indoor radon anomaly sites were located near Yamarik Mountain in Urumqi City, and the observed instantaneous radon concentration was higher than 800Bq/m^3, and the rooms with indoor radon concentration higher than 100Bq/m^3 is about 31.2% of the whole rooms. Most radon concentrations in basements are higher than 100Bq/m^3, and the maximum measured radon concentration in basements is 2138 Bq/m^3. In addition to the high indoor radon concentration in the residential houses near Yamarik Mountain and the Black Hill, indoor radon concentration anomalies were also

found in other areas. Therefore, the influencing factors of high indoor radon in Urumqi City should be further studied.

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Definition and assessment of the pollution indexes for radionuclides in the Biosphere Reserves of the Odiel Saltmarshes (Southwestern Iberian Peninsula)

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Keywords: Phosphogypsum, Acid Mine Drainage (AMD), Natural Radionuclides Pollution, Radioactive Background, Huelva Estuary

The Huelva estuary is formed by the common mouths of the Odiel and Tinto Rivers, and inside of this ecosystem is the Biosphere Reserves of the Odiel Saltmarshes which cover an extension of about 7800 ha. This ecosystem has been historically affected by acid mine drainage which is present in the Odiel River, and the releases coming from a big chemical industrial complex located at its surroundings, which started in 1965, and especially by for those from phosphoric acid industrial plants and the phosphogypsum waste stacks (PG). The waters of the Odiel River present ^{238}U concentrations that are one order of magnitude higher than unperturbed surface waters, while the liquid releases from PG piles have ^{238}U and ^{210}Pb concentrations that are 3-4 orders of magnitude higher than natural waters. Until 1998 the 20% of the PG generated (about $5 \cdot 10^5$ t/year) was discharged directly into the channels of Odiel Natural Reserves.

The estuary of the Piedras River was chosen as reference of a non-impacted system to assess the background values, and the environmental impact in Huelva estuary was accomplished by using mainly the enrichment factor as pollution index. It has been demonstrated that the deepest samples of the sediment core taken at Huelva estuary had similar radionuclide concentrations (depths > 40 cm) than the background, but surface samples (depths from 0 to 40 cm), were very affected by ^{238}U-series radionuclides present in releases that come from the phosphoric acid production.

Activity concentration of natural radionuclides (^{238}U, ^{226}Ra, ^{232}Th, ^{228}Ra, ^{210}Pb and ^{40}K) in soil amended with niobium tailings

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Keywords: Environmental radionuclides, NORM, gamma spectrometry, soil analysis

The storage of tailing from anthropic activities like mining, which may contain radionuclide traces, is a problematic situation consequent from NORM industries activities and for which they seek alternatives. The study presented in this paper is related to carbonate deriving from niobium extraction. This carbonate is stored in dams, which can cause an increase in radionuclides and metals concentration, imposing restrictions on its use. To ensure the safe usage of the residue, it is assessed the activity concentration of ^{238}U, ^{226}Ra, ^{232}Th, ^{228}Ra, ^{210}Pb and ^{40}K in soil samples as well as mixture soil + carbonate, soil + carbonate + lime, soil + lime and soil. The techniques used were *gamma spectrometry* and *instrumental neutron activation analysis*. Activity concentration evaluation was performed before and after the tillage of lettuce (*Lactuca sativa*) and bean (*Phaseolus vulgaris*), and the soil-plant transfer factor was determined for lettuce. The study of radionuclides and metals availability in the soil solution is important for a better understanding of the mobility of contaminants in water/soil systems, in order to estimate the real environmental impact. Preliminary results show samples with niobium traces presented values within the recommended world values.

Assessment of environmental radiological impact of naturally occurring radionuclides in former metallic mining sites in Extremadura (Spain)

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Keywords: radiological impact, mining, naturally occurring radionuclides

Metallic mining had a considerable boom in Extremadura until the middle of the 20th century, with a large number of mines dedicated to the extraction of Cu, Ni, Zn, Pb, Ag, Fe, Sn, W, etc. However, due among other reasons to the impoverishment of the mineral veins or fluctuations in the price of metals, they have caused the vast majority of these metal mines to be abandoned, leaving as a legacy tailings with a large collection of waste. Even though they are not exactly facilities in which radioactive material is extracted, the waste generated can cause a significant increase in the content of natural radionuclides on the surroundings, becoming considered NORM (Naturally Naturally Occurring Radioactive Material). This paper assess the environmental radiological impact of different former metal mining sites in Extremadura, evaluating the radiological impact both on the population and on the environment, estimating the exposure of the different RAPs (Reference Animal and Plants) contemplated for terrestrial ecosystems.

Acknowledgments: This work has been financed by the Junta de Extremadura through the project " Evaluación del impacto radiológico ambiental de la minería metálica en Extremadura " (IB20060).

POSTER SESSION I

13 Radionuclides in biota

1-13-01

Distribution of tritium within different tissues of freshwater carps from a cooling reservoir of a Nuclear Power Plant in a Mediterrranean ecosystem

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Keywords: Tritium, OBT, fish, tissue

In the routine operation of Nuclear Power Plants (NPPs), tritium is released into the environment, and it may associate to water molecules or organic molecules, which later may be incorporated by non-human biota. In order to assess the tritium distribution in freshwater biota, carps (a representant of freshwater Reference Animal and Plants) from a cooling reservoir used by a NPP were sampled monthly, and different tissues were separated (muscle, skin and head and bones). Organic Bound Tritium (OBT) and free tritium were evaluated separately by free-drying the tissues and collecting their extracted water. OBT was determined by a combustion method and later collection of the water vapour formed in the process. Thus, the distribution of OBT and free tritium can be assessed within the selected tissues, and the whole organism.

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Recent trends on bioaccumulation of artificial radionuclides (^{137}Cs, $^{239+240}$Pu and ^{90}Sr) in marine organisms from Korea seas: A comprehensie review

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Keywords: Artificial radionuclides, Marine organism, Bioaccumulation

Radionuclides are known to accumulate in marine organisms of various types, which can potentially affect humans according to food chain. In South Korea and surrounding East Asian countries (Japan, China, and Russia), large numbers of nuclear facilities are currently operating, and new facilities are continuously being constructed. Especially, nuclear power plants(NPPs) are currently one of the significant sources of electricity production in South Korea. After the Chernobyl- and Fukushima NPP accidents, concens about the bioaccumulation of radionuclides in domestic and foreign marine products have been raised. In addition, the South Korea and East Asian countries have shown the highest consumption of marine products in the world. In this study, we investigate the levels of artificial nuclides in various marine products (>40 species) from Korea seas from 2015 to present (2023). We also evaluate the potential dose rates, concentration factoer(CF), and annual effective dose(AED) of artificial radionuclides. Several studies have revealed the following major facts: i) the artificial radionuclide Cs can be bioaccumulated in fish according to their growth stage ii) anchovies, a coastal migratory fish with a relatively short lifepan, showed a particularly high bioaccumulation rate of radionuclides compared to other species iii) the internal organs of fish had a higher level of $^{239+240}$Pu activity than the muscle or skin. In this presentation, we will introduce these results and other summarized discussion based on latest works.

1-13-03

Anthropogenic and natural radionuclides in moss samples from Sweden 30 years after the Chernobyl accident

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Keywords: Moss samples, 137Cs, natural series radionuclides, Chernobyl

The impact of the Chernobyl accident over Sweden has been widely studied in the literature. In this work, carried out 30 years (one half-life of ^{137}Cs) after the accident, moss samples were used to crosscheck the present values of ^{137}Cs (plus natural series radionuclides from ^{238}U and ^{232}Th series) activity concentrations in the swedish environment.

To that aim, during several sampling campaigns in 2016 throughout Sweden, more than 30 samples of moss samples were collected covering from Southern to Northern areas of Sweden. Once in the laboratory, samples were dried and grinded to be later stored in Marinelly beakers that finally were measured via gamma spectrometry with HpGe detectors.

Quality controls are regularly applied and as a preliminary results, ^{137}Cs activity concentration (dry weight) were found in the range 9 to 20100 Bq/kg while ^{210}Pb was found in the range 500 to 2000 Bq/kg. Additionally, while secular equilibrium was found in the vast majority of samples concerning ^{232}Th series radionuclides, disequilibrium was found for ^{238}U series radionuclides. All these results will be expressed in Bq/m^2 to correlate with values from the existing literature.

Are the accumulated ^{210}Po and ^{210}Pb in Polish wild herbs safe for consumers?

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Keywords: Polonium ^{210}Po, Lead ^{210}Pb, herbs, radiological safety

Botanic materials accumulate chemical elements to a different extent and reflect the area in which they grow. Due to the growing pollution of the natural environment, there is also an increase in the amount of accumulated toxic compounds, mainly heavy metals, which may expose patients to the dangerous concentration of these compounds to their health. Since 70-80% of the world's population uses unconventional medicine and treats it as primary health care, it is worth determining whether the consumption of herbal preparations is safe from a radiological point of view.

Among naturally occurring radioisotopes, highly toxic emitters, namely polonium ^{210}Po and its precursor, radiolead ^{210}Pb, are particularly important. Knowledge of the content of both radionuclides in the tested herbs allows for assessing radiotoxicity and the safety associated with the consumption of medicinal plants growing in Poland. The results of ^{210}Po and ^{210}Pb activities measured in herbal raw material: flowers, leaves, shoots, fruits, herbs, cones and roots were from 0.12±0.01 Bq·kg^{-1} dw in the fruit of horse chestnut (*Aesculus hippocastanum*) collected in Gdańsk to 19.6±1.46 Bq·kg^{-1} dw in leaves of common tansy (*Tanacetum vulgare*) from Kętrzyn for ^{210}Po, while for ^{210}Pb activity concentrations ranged from 0.16±0.08 to 38.5±0.76 Bq·kg^{-1} dw. The studies indicated that the estimated annual effective radiation dose from Polish herbs consumption was low, ranging 0.14-23.5 μSv from ^{210}Po and 0.11-26.5 μSv from ^{210}Pb. There is no radiological risk connected to the use of herbal plants.

On the occurrence and related dose assessment from ^{210}Po and ^{210}Pb in Ukrainian wild medicinal plants

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Keywords: Polonium ^{210}Po, Lead ^{210}Pb, herbal material, radiation risk assessment

The 13 most popular wild herbaceous and woody plant species included in the European Pharmacopoeia collected across Ukraine were analysed, and ^{210}Po and ^{210}Pb activity concentrations were calculated. The results of ^{210}Po and ^{210}Pb activities measured in herbal raw material: flowers, leaves, and aerial parts were from 2.28±0.17 Bq·kg^{-1} dry weight in herb of common horsetail (*Equisetum arvense*) collected near Lviv to 37.7±2.02 Bq·kg^{-1} dw in leaves of common birch (*Betula pendula*) from Rava Ruska for ^{210}Po, while for ^{210}Pb from 1.19±0.08 Bq·kg^{-1} dw in herb of common horsetail from Lviv to 28.4±0.76 Bq·kg^{-1} dw in leaves of common birch from Mizhhirya. There were statistically significant differences between ^{210}Po and ^{210}Pb content in flowers, leaves, and aerial portions. The studies indicated that the estimated annual effective radiation dose from Ukrainian herbs consumption was low, ranging 5.00-82.6 μSv from ^{210}Po and 0.56-
35.8 μSv from ^{210}Pb.

1-13-06

Measurements of ^{90}Sr, $^{239+240}$Pu and ^{241}Am in white-tailed eagles in Sweden and Poland

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Keywords: White-tailed Sea Eagle, bones, ^{90}Sr, $^{239+240}$Pu, Studsvik, Sweden, Poland

White-tailed Sea Eagles (Haliaeetus albicilla) are top predators in the ecosystem and can potentially accumulate contaminants, including radionuclides, like ^{90}Sr, $^{239+240}$Pu or ^{241}Am, in their bones. In this work, bone samples from three Swedish eagles that were gathered at various places in Sweden were examined for ^{90}Sr, $^{239+240}$Pu and ^{241}Am, and the results were compared with analogous data from Polish eagles examined in 2005. Two of the Swedish eagles were found dead 100 km south of Stockholm, close to the nuclear research facility Studsvik, which has been releasing anthropogenic nuclides into the environment since 1959. The third Swedish eagle was found dead in 2006 in Gällivare, about 950 km northwest of Stockholm. The bones were collected by The Swedish Museum of Natural History. Despite Studsvik being the largest source of ^{90}Sr emissions in the Baltic Sea region, the highest concentrations of ^{90}Sr in bones are not found in eagles from the vicinity of Studsvik, but rather in the eagle from Gällivare. The levels of $^{239+240}$Pu, however, are the greatest in the bones of eagles raised near the nuclear research facility. Regardless, levels of both ^{90}Sr and $^{239+240}$Pu are the lowest in the Polish eagles. In Poland and Gällivare, the activity ratio of ^{90}Sr to ^{239,240}Pu is the greatest, reaching 1700-1900. Eagles in the Studsvik area have a corresponding activity ratio of 170 to 480. The different ratios might be attributed to the different meals that the eagles in each region consumed and to variations in the mechanisms by which Pu and Sr were incorporated into bones through nutrition and inhalation. Different fallout rates from both worldwide nuclear weapons testing and the disaster at the Chornobyl nuclear power facility are other crucial factors. The levels of ^{241}Am were below MDA (22 mBq/kg) for all of the Swedish eagles, but not for all of the Polish eagles. Our findings emphasize the importance of monitoring radionuclide releases into the environment and their potential impacts on top predators.

1-13-07

URANIUM CLEARANCE KINETICS IN HAIR AFTER THE CESSATION OF CHRONIC WORKPLACE EXPOSURE

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Keywords: uranium, excretion, hair, nuclear fuel cycle

Preferred: Poster

Human hair is seen as a potential biomarker for retrospective assessment of uranium exposure due to advantages such as robustness, easy handling and the possibility to obtain information of internal dosimetry even long after exposure. Workers retiring from a nuclear fuel fabrication plant were recruited to this study. The workers provided hair samples regularly for up to 6 years. The hair samples were analyzed with alpha spectrometry and inductively coupled plasma mass spectrometry (ICP-MS) to quantify the ^{234}U, ^{235}U and ^{238}U content in the hair. The excretion in hair was evaluated in relation to urinary data from a connected study of long-term excretion to urine for the same workers. A major advantage in the present study is the possibility to discern the endogenous uranium component from the exogenous component, a factor that has been difficult to assess in previous studies of uranium in hair where exogenous hair exposure could not be avoided. The aim is to determine the long-term excretion of uranium to hair after long-term chronic workplace exposure, evaluate the endogenous component and investigate the relationship between excretion to hair and to urine.

POSTER SESSION I

14 Radioecology

1-14-01

Identification and characterization of the radioactive fraction in black sands

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Keywords: Black sand, Uranium, Thorium, Monazite.

Black sands are sedimentary accumulations formed by high concentrations of heavy minerals such as ilmenite, magnetite, rutile, zircon, and monazite, present in different parts of the world.

These black sand deposits (or placer deposits) are formed because of processes of mechanical erosion, transport and hydrodynamic or wind classification, generating the preferential concentration of minerals of greater density in longitudinal sheets. In general, heavy minerals have common characteristics such as high physical resistance, great chemical stability, and high specific gravity.

Depending on the characteristics of the parent rock (provenance), black sand deposits can be enriched in rare earths and contain significant amounts of radionuclides of the uranium and thorium natural series. Placer deposits constitute a challenge in radioecology because the behavior of natural radionuclides and their transfer to different environmental compartments can be affected by the presence of radionuclides in a mineral fraction associated with individual inert particles.

This work focuses on the study of a black sand deposit present on the east coast of Uruguay, where an average content of 5% of heavy minerals was determined. Once the heavy minerals were separated by gravimetric and magnetic procedures, each mineral fraction was characterized to determine the fraction responsible for the activity.

In a first stage, the radioactive content in the different minerals was screened by autoradiography and continued with the determination of their elemental composition by SEM-EDX.

Based on these results, we can affirm that the fraction responsible for the radioactivity of the black sands is monazite, mainly due to the thorium content and to a lesser extent to the uranium content. The presence of monazite inclusions detected with EDX in ilmenite samples can contribute to the total activity, especially considering that ilmenite is the most abundant mineral in heavy minerals.

1-14-02

Radioecological investigation of a contaminated site in southern Germany

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Keywords: contamination, Cs-137, Am-241, Plutonium

In spring 2021, an internet blog reported on elevated local dose rate along the Hirschgraben, which runs as a receiving watercourse of the Karlsruhe Institute of Technology (KIT) and drains the rainwater network of the campus via six sand traps. KIT campus north, formerly known as research center Karlsruhe was one of the largest federal nuclear research laboratories in Germany. For verification purposes, the KIT Safety and Environment Department carried out measurements and sampling at the Hirschgraben, which revealed increased dose rates of up to 300 nSv/h, especially at Sand Trap V. However, the final result of the KIT report to the supervisory authority, the Baden-Württemberg Ministry of the Environment, completely ruled out risk to humans and the environment due to the contamination. Nevertheless, there was interest in further investigating the causes of contamination. Therefore, in cooperation with the Institute of Radioecology and Radiation Protection (IRS) of the Leibniz University Hanover, soil samples were taken at Sand Trap V, which are analysed using radiometric methods. In particular, the nuclides Cs-137, Am-241 and the various plutonium isotopes are in the focus of attention. Based on the isotope signatures and decay equilibria, conclusions were drawn on the possible origin of the contamination.

1-14-03

Radiopharmaceutical waste and its impact on the environment

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Keywords: radiopharmaceutical waste, environment, radiation protection

Radiopharmaceuticals are radioisotopes produced in nuclear reactors or particle accelerators. These radioactive drugs, widely used in fight against cancer and others diseases, have shown a great success. In nuclear medicine the radionuclides used for diagnosis, produce an image of the organ or tissues, of interest, in the patient's body. The use of radiopharmaceutical associated to the recent advancements in imaging technology are promising in solving a wide range of clinical problems.

On the other hand, the number of patients administered radiopharmaceuticals is increasing rapidly, leading to an increase in radioactive waste. It should be noted that the treatment of radioactive waste is expensive and time- consuming.

In this study, we list the radioisotopes commonly used in medicine. We give their radioactive characteristics and specify the purpose and the medical field of their applications. We focus on the applied procedures for the treatment and storage of radiopharmaceutical waste, we are mainly interested in the assessment of the radioactive risk of environment contamination, essentially water contamination, if the waste treatment is not rigorously applied and this by respecting the radiation protection rules as recommended by the international organisations as the International Atomic Energy Agency (IAEA).

1-14-04

Anthropogenic and natural radionuclides in soil profiles of forest ecosystem in vicinity of the BelNPP

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Keywords : Vertical distribution, ^{137}Cs, ^{7}Be, ^{210}Pb, ^{214}Pb

To assess the radioecological situation in the area of the Belarusian NPP (BelNPP), moss and soil material from soil profiles in the forest ecosystem was collected in the Lithuanian part of the 30-km zone. Terrestrial mosses, forest soil organic and mineral soil samples collected from the pine forest ecosystem in the summer of 2022 were studied by gamma spectrometric method. As shown by our previous work on the analysis of samples collected in 2017, anthropogenic radionuclides (^{137}Cs and $^{239, 240}$Pu) in the 30-km zone of the BelNPP were mainly due to global fallout after nuclear tests. At some sampling points, radionuclides from the Chernobyl accident were present in a small proportion. Samples taken in 2022, with a more detailed resolution compared to 2017, made it possible to more accurately assess the vertical distribution of not only the anthropogenic radionuclide (^{137}Cs), but also some natural radionuclides (^{7}Be, ^{40}K, ^{210}Pb and ^{214}Pb). An analysis of these data and relationships between anthropogenic and natural radionuclides in eight soil profiles is presented in this study.

1-14-05

Characterization and assessment of ^{137}Cs, ^{90}Sr and ^{40}K radioactivity of five species of herbs collected in two regions of central Poland

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Keywords: radioactivity, herbs, K-40, Sr-90, Cs-137, mint, hypericum perforatum, tansy, horsetail, nettle

As the usage of various plants for health purposes is gaining popularity afresh the need for assessment of their radionuclide contamination is also growing in importance. Peppermint, hypericum perforatum, tansy, horsetail, and nettle were selected as research material. Chosen herbs species were obtained from plantations located in two regions of Poland - Podlasie and Kurpie.

The study describes the measurement of ^{90}Sr radioactivity by radiochemical method and the measurement of ^{137}Cs and ^{40}K radionuclides activity by gamma-ray spectrometry. Measurements in the radiochemical method were conducted with the use of a Low-Level Beta GM Multicounter System and in gamma-ray spectrometry – using Canberra spectrometric system with GENIE 2000 software and a Tennelec AL.30 HPGe detector.

The connection between the obtained results of radioactive concentration of said radionuclides in plant samples and the radioactive concentrations of radionuclides contained in soils from corresponding to them regions were also analyzed, as well as the influence of available in the literature, average concentrations of chemical analogs of strontium and caesium – calcium and potassium on radioactive concentrations of this radionuclides. The highest obtained value for ^{90}Sr was 8,91± 0,94 Bq/kg for nettle while the lowest result was 1,01 ± 0,18 Bq/kg for tansy. For ^{137}Cs highest and lowest results were: 7,37 ± 0,40 Bq/kg (nettle) and <0,5 Bq/kg (peppermint and tansy) respectively. Radioactive concentrations of ^{40}K were higher in the samples from Podlasie than from the Kurpie region. In the case of the radioactive concentration of ^{137}Cs, an inverse dependence is visible - higher values were found in samples from the Kurpie region.

The level of radioactivity of the tested herbs, which could pose a threat to people consuming them, was not found. However, significant gaps in the literature were noted, suggesting the need for more research.

1-14-06

Presentation of the CERES platform used to evaluate consequences on population of releases of pollutants

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Keywords: impact evaluation, radionuclides, atmospheric accidental releases, authorized releases

This presentation is relative to the CERES® platform developed by CEA and used to evaluate the impact on population of releases of radionuclides in the environment. In order to ensure that the part "Dosimetric impact on population" presented in safety reports submitted to authorities by CEA's installations follows regulations and same parameters when justified. French energy atomic commission has developed the CERES platform in the early 2000's. It is used by all CEA sites and other French nuclear operators for safety cases and for emergency assessment.

However, as this application is quite old, it has been decided to develop a new version, enlarging the capacities of calculations and incorporating new features new demands such as external dose coefficients function of age. In addition, for emergency situations, recommendations from CODIRPA has been implemented, helping users to determine counter-measures zones such as "*evacuation perimeter*".

The Graphical User Interface of this new tool is user friendly and the edition of results is very rapid. The RN database contains more than 900 radionuclides, in order to consider all RN used in CEA installations, reactors and laboratories. This database is regularly upgraded when new data are available, such as dose coefficients or transfer in food chain.

CERES: Code d'évaluations rapides environnementales et sanitaires (Environmental and Sanitary rapid assessment code)

1-14-07

Vertical distribution of Cs-137 in uncultivated soil at selected sites in the Czech Republic

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Keywords: Vertical distribution of Cs-137, in-situ gamaspectrometry, soil

Radioisotope Cs-137 released into the air in the Chernobyl nuclear power plant accident can still be detected in some places, not only in the Czech Republic, due to the fallout of radioactive air masses. It has a half-life of 30 years, so at present, 37 years after the accident, its activity should be about half that at the time of the fallout. However, this assumption is purely theoretical and not always valid under field conditions. The mobile group of SÚRO, v.v.i. has been taking soil samples for a long time and monitoring Cs-137 concentrations in soil by in-situ spectrometry at several sites in the Czech Republic. The sampling sites were selected on the basis of the assumption of higher Cs-137 occurrence according to data obtained from extensive ground monitoring in the period after the Chernobyl accident and other additional measurements. The physicochemical properties and processes of the soil, the composition or the purpose of human use of these soils also have a significant influence on the distribution of Cs-137.

Radio-caesium and Pu isotopes in the sediment cores in Yunnan plateau lakes, Southwest China: Distribution and source identification

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Keywords: Chernobyl accident, transport pathways, ^{137}Cs sedimentation model, 1986 time-marker

Anthropogenic radionuclides of ^{137}Cs and plutonium in lake deposition systems have been applied for tracing the environmental impact of nuclear events as well as for modern sediment dating. The source and transport pathways of these fallout radionuclides in the Yunnan Plateau are not clarified. In this work, ^{137}Cs and ^{239,240}Pu in undisturbed sediment cores from three lakes were investigated in order to elucidate their distribution and source terms in the Yunnan Plateau. All ^{137}Cs activity profiles generally show a maximum peak in the deep layer along with a small sub-peak in the upper layer. A ^{137}Cs sedimentation model was applied to validate that the maximum peak and sub-peak correspond to the global fallout maximum year in 1963 and the Chernobyl accident in 1986, respectively. Hysplit forward trajectory analyses suggest that the radionuclides released from Chernobyl accident were transported to the Yunnan Plateau by the southern branch of westerly. Unlike ^{137}Cs, only a maximum peak could be observed in $^{239+240}$Pu activity profiles but no sub- peak in the corresponding upper layers. This is due to the differential deposition of Chernobyl-derived Pu and Cs in sediments, which is determined by their host particles and atmospheric transport mechanisms. The ^{240}Pu/^{239}Pu atom ratios in the core sediment samples were much lower than the values for Chernobyl accident, suggesting that no obviously Chernobyl accident Pu signature was recorded in the studied lakes. Our work suggest that the undisturbed sediments can provide a favourable record for monitoring atmospheric fallout and identifying the source terms of radioactive pollutants in the Yunnan Plateau region.

1-14-09

^{137}Cs and Isotopic Pu "Zero Point" Screening for Potential Anthropogenic Radionuclide Fall-out in Eastern Lithuania

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Anthropogenic radionuclides can travel tens and hundreds of kilometres away from its emission source and under favourable meteorological conditions still be detected. In order to determine and assess new contributions to the anthropogenic radionuclide balance in the current environment and to firmly distinguish new contributions from previous global nuclear tests or earlier emissions from nuclear facilities, it is important to screen the "zero point" anthropogenic radionuclide isotopic composition and activity values, e.g. around new operating nuclear facilities. In this work the radiochemical separation, gamma-, alpha- and mass-spectrometry measurement techniques were combined to determine concentrations and compositions of anthropogenic radionuclide isotopic composition in soil samples collected in Lithuania within 70 km radius around the Belarussian nuclear power plant in Astravec. Spectrometric measurements were performed with the state-of-the-art alpha spectrometer and gamma spectra were recorded by gamma spectrometer with HPGe coaxial detector. Radionuclide isotopic ratios were measured by a sector field mass spectrometer combined with a high sensitivity APEX IR sample introduction system. In this work 137Cs/239,240Pu, 238Pu/239,240Pu, 240Pu/239Pu isotopic "finger print" values revealed that previous nuclear weapon tests in the Northern hemisphere are prevailing in the most of the sampling sites.

1-14-10

Questioning to disposal of spent fuel at the Laguna Verde Nuclear Power Plant- Mexico

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Keywords: Radioactive waste, nuclear plant, plutonium

The spent fuel from the two nuclear reactors of the Laguna Verde Nuclear Power Plant (LVNPP) in Mexico, which contains radionuclides such as Plutonium-239, Cesium-137, Krypton-85, Uranium-238 and Uranium-235, has remained for many years at highly secure sites such as the spent fuel pools of the Reactor's buildings, which are located within the double perimetral fence that has television cameras and intruder detectors, and is guarded by armed security personnel. These conditions have been modified due to the authorization to construct a "Spent Fuel Warehouse" located outside the double fence, without having previously made the "Environmental Impact Statement" necessary for this type of high risk facilities; the authorization was issued by the Ministry of Environment and Natural Resources (MENR) to the LVNPP, according to Official Letter No. SGPARN.02.IRA.3134 / 14 dated July 4, 2014. The projected site involves risks; the container will present problems due to the aging of the materials and the saline corrosion of the natural cooling system; the incidence of hurricanes might affect their integrity. We point out that Plutonium 239 is a material for the construction of nuclear weapons. The present paper analyzes the permit and installation questioned, and proposes an alternative solution to solve the problems cited, minimizing the risks to the population and the Environment. The authorizations have been signed by an official who does not have any type of training in Radiological Protection or Nuclear Safety. This paper was written at the Department of Physics at the Faculty of Sciences of the National Autonomous University of Mexico

Determination of biobased carbon content in Argentine industry products by AMS

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Keywords: Bioeconomy, Biobased products, Biobased carbon content, Carbon isotopes, AMS

Made from renewable raw materials, biobased products are proposed as an effective strategy for climate change mitigation and fossil origin products substitution for bioeconomy development. In order to encourage biobased products manufacturing and demand, Argentine State has released the Argentine Bioproduct label, which helps consumers recognize biobased products when shopping. An analytical method is needed by manufacturers to demonstrate their products to be biobased.

Biobased carbon content is the fraction of carbon in a product that comes from renewable sources. By measuring ^{14}C and the other carbon isotopes, AMS (Accelerator Mass Spectrometry) provides an excellent analytical method for biobased carbon content asessment. Only products showing enough biobased carbon content may get the label for exportation.

Sixteen samples from products made by Argentine industry were collected, turned to graphite, and assessed by AMS at CNA. Results of biobased carbon content are presented.

Effects of NH_4^+ Origin on ^{137}Cs desorption from Lake Sediments

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Keywords: Cesium-137, Sediment, Desorption, Ammonium

Many studies have found that ^{137}Cs is desorbed from lake sediments by exchange with NH_4^+. NH_4^+ in the lake bottom environment can be attributed to organic matter decomposition under anaerobic conditions (internally generated) or to loads from lake catchment due to such as farming activities (externally supplied), but the difference of the NH_4^+ origin on ^{137}Cs desorption from sediment has not been unveiled. In this study, we collected sediments from a dam lake contaminated with ^{137}Cs to evaluate how the concentration of desorbed ^{137}Cs differs due to the internal/external increase of NH_4^+ by static incubation tests and shaking tests.

Sediment incubation tests under constant temperature conditions revealed that the distribution coefficient of ^{137}Cs in the sediment was inversely proportional to the NH_4^+ concentration in the pore water (extracted by centrifugation), indicating that ion exchange between ^{137}Cs and NH_4^+ was in equilibrium. On the other hand, when water adjusted to several levels of NH_4^+ concentrations (10^{-2}-10^{1} mg L^{-1}) was added to the sediment, shaken in 150 rpm for 48 hours and the pore water was extracted by centrifugation, the decrease in the distribution coefficient of ^{137}Cs in response to increasing NH_4^+ concentration was slower than in the incubation test. This result suggests that the externally added NH_4^+ did not reach the adsorption site of ^{137}Cs on the mineral particles and did not reach the expected equilibrium with internally increased NH_4^+. Therefore, when modeling the ^{137}Cs behavior in lakes where NH_4^+ concentrations easily fluctuate, it is necessary to apply different calculations depending on whether the origin of NH_4^+ is internal or external.

Transuranic signals in rabbit feces collected at the contaminated terrestrial site of Palomares (Spain)

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Keywords: Radioactive particles, Palomares, actinides, rabbit feces.

On January 17, 1966, a B-52 bomber and a KC-135 tanker aircraft, both belonging to the United States Air Force, collided during mid-air refueling over Palomares (Spain). Both aircraft were destroyed, and the four thermonuclear bombs carried by the bomber fell to the ground. Two of the bombs remained intact due to their parachutes, while the other two impacted the ground, causing part of their chemical explosive to detonate and spreading a significant amount of nuclear fuel in the form of plutonium (Pu) and uranium (U) oxides. Despite cleaning efforts, today we continue to detect radioactive particles in the area of the accident.

Our work focuses on studying possible impacts of the accident on biological systems using rabbit feces as a marker. Feces are appropriate indicators of the accident's impact on the biological systems in the area, as they are the final result of the food chain.

Our goal is to search for radioactive particles formed by elements from the bombs in animal feces. Identifying these radioactive particles in rabbit feces allows us to determine the main route of contamination: the animals consumption of material that contains radioactive particles adhered to its surface.

We have used advanced techniques such as autoradiography, gamma spectrometry, computed tomography, scanning electron microscopy, and X-ray microfluorescence to find radioactive particles in feces and detect the presence of radioactive elements in numerous samples. The coincidence of the elements found in our samples with those that composed the bombs demonstrates the existence of contamination in the environment and its impact on some biological systems in the area.

Tritium Distribution of Groundwater near Geum River and Nakdong River Basin in Korea

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Keywords: Tritium Distribution, Keum river, Nakdong river, groundwater

Recent climate change caused low precipitation in some area but water demand rapidly increases due to industrialization and population growth, therefore, the available water resources are gradually decreasing. As water shortages become more severe, stable water resources are increasingly necessary and groundwater is being recognized as a valuable alternative. For the sustainable use and efficient water management in the midwestern part of South Korea, it is necessary to understand the regional distribution of surface water and groundwater quality. To overcome water demand, we studied groundwater near the Geum river and Nakdong river basin and large amount groundwater possible regions were selected and ^{3}H content distribution was analysed for knowing groundwater residence time. ^{3}H content distributions of Nakdong river basin ranged <0.3 ~ 4.15 TU at CN region and <0.3 ~ 3.63 TU at HC region. And average ^{3}H content of Geum river basin was 2.19 TU at KS region, 2.15 TU at KJ region, 2.38 TU at NS region and
2.88 TU at BO region.

Evaluation of the New Environmental Radiological Surveillance Network of the Basque Country

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Keywords: Dose Rate, Environmental, Surveillance, Network

Countries usually update/improve the performance of the radiation-monitoring networks for establishing response actions and assessing risk or damage. One of the task carried out is focused on the optimization of the present set of monitoring stations with the aim of detecting quite rapidly the release and delineating and tracking the plume. The use of atmospheric dispersion models is needed to address this evaluation. The autonomous community of the Basque Country has its own automated network, similar to that of the CSN (Consejo de Seguridad Nuclear). From 2001 to 2022 the Environmental radiological Surveillance Network of the Basque Country had 3 station located in the most populated areas of the Basque Country. Nowadays, a new design comprising 11 monitoring stations, has been implemented, considering the posibility of a radiological incident caused by the nearest Nuclear Power Plants, both in Spain and France. The present analysis has evaluated the response of this monitoring network to radioactivity plumes from different NPPs under meteorological conditions favouring the transport towards the Basque Country. Considering that transport, dispersion and ground deposition of radioactivity substances in air vary according to the change in time and space of meteorological conditions, the present methodology combines the calculation of air mass trajectories from each NPP by the HYSPLIT model and the RASCAL code to simulate the dispersion and transport of the plumes and the radiological dose associated. At this moment, there are 11 stations located in the autonomous community of the Basque Country, see figure, and the number of non-detection situations is decreasing.

Behaviour of transuranic (Np, Pu, Am) and fission products (^{99}Tc, ^{129}I) in the environment in the Northeast Asia

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Keywords: Japan Sea, bottom sediments, actinides, low level radioactivity, fission products, environment

Here, we report for the first time that the level and distribution of anthropogenic radionuclides in bottom sediments of a lake and sea in the northeast Asia and their radioecological impact.

A sediment sampler has been modernized, produced and tested, for sampling imarine and fresh water sediment. In total, 7 sediment cores from Lake Khanka (Xingkai) and 10 soil cores around it; 12 sediment cores from Japan Sea (Ussuri and Amur Bays) were taken. Water samples (200-300 L) were also collected. The sediment samples were analyzed by XRD (Advance D8 device (Bruker) with CuKα radiation), XRF (Shimadzu EDX-800HS), γ-spectrometry (ORTEC GEM-C5060P4-B). The concentration of ^{237}Np, $^{239, 240}$Pu, ^{241}Am, and ^{99}Tc was determined by chemical separation followed by ICP-MS/MS measurement, ^{129}I in water was separated by solvent extraction and measured by AMS in the Xi'an AMS center.

The sedimentation process was uniform over the investigated period. The sedimentation rate in the eastern part of Lake Khanka (Xingkai) was estimated to be 1.6 mm/year, and 0.43–0.5 mm/year in Amur Bay. This was confirmed both based on the content of Pb_{ex} and Cs, and Pu. The concentrations of ^{240}Pu, ^{241}Am, ^{99}Tc in sediment samples are below detection limits in Khanka sediment core. Actinides are mainly from the global fallout of atmospheric nuclear weapons testing during 1950s-1970s. In marine bottom sediments, ^{241}Am was determined in the amount of 0.05-0.55 mBq/g, depending on the depth of the horizon. The ^{129}I/^{127}I atomic ratios in the fresh water [$(0.87–1.13)\times10^{-8}$] are two orders of magnitude higher than those in the sea water [$(0.91–1.15)\times10^{-10}$]. ^{129}I deposited on the land and flowed into sea from the river was quickly diluted in the seawater, causing a declined ^{129}I concentration, the orders of magnitude higher stable ^{127}I concentration in seawater compared to the fresh water enlarged the difference on the ^{129}I/^{127}I atomic ratios. The actual content of ^{237}Np in bottom sediments varies from 4.43×10^{-5} to 1.06×10^{-6} mBq/g for the bottom sediments of Lake Khanka and $(1.05\text{-}25.17)\times10^{-4}$ for the Amur Bay.

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Gross alpha and gross beta radionuclides contamination of surface waters in heavily industrialized areas near Warsaw (central Poland)

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Keywords: surface waters, gross alpha, gross beta

Water is a chemical substance that is necessary for living organisms to function, but its daily intake is associated with the possibility of long-term exposure to increased activity of radionuclides in the case of consumption of water contaminated with them. Measurements of surface water radiation activity are also an important element of environmental radiation monitoring [1].

Warsaw, being capital city of Poland, which is placed near numerous transit routes has plenty of heavily industrialized areas. The aim of the study was to examine the level of gross alpha and beta radioactive contaminations in water reservoirs located in such places (e.g., near highways).

Eight samples were obtained from ponds in and around the area od Warsaw with reference sample, being municipal tap water.

Gross alpha and beta radioactivity were measured using an Alpha Beta iSolo Spectrometer with a silicon PIPS detector and a Low-Level Beta GM Multicounter System respectively.

The highest obtained value for gross alpha radioactivity was 0,016 ± 0,004 Bq/l while most results were <0,015 Bq/l. For gross beta radioactivity the highest result was 0,91 ± 0,10 Bq/l while the lowest was 0,10 ± 0,01 Bq/l. Arithmetical mean value for this samples was 0,58 Bq/l.

The results obtained were no greater than than values recommended for drinking water given by World Health Organization [2]. Increased total beta radioactivity was observed in water from reservoir which is an outflow from the sewage treatment plant and further radiation monitoring of waters in this reservoir is recommended.

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Temporal and spatial patterns of fallout radionuclides accumulation on Gulkana Glacier, Alaska Range

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Keywords: Fallout radionuclides, Cryoconite, Glaciers, Spatial patterns

Analysis of fallout radionuclides in cryoconite holes on Gulkana Glacier (Alaska Range) reveals the presence of five zones at different altitudes (1270, 1385, 1470, 1585 and 1680 m above sea level a.s.l.) that present different radiological features. The first zone has low radioactivity of fallout radionuclides, but the fourth zone is characterized by the highest activity levels of anthropogenic fallout radionuclides (^{137}Cs and Pu isotopes). The highest level of ^{210}Pb is observed in the fifth zone. Activity concentrations of all fallout radionuclides reach the record levels for northern hemisphere cryoconite. This work presents the first results of temporal (from 2000 to 2019 y) and spatial patterns of fallout radionuclides accumulation in high mountains in the Northern Hemisphere.

We suggest that a buried layer of contaminated ice that formed during atmospheric nuclear tests serves as a local secondary source of radionuclide contamination. Its melting is responsible for the formation of such zones.

This study was supported by the National Science Centre, Poland under research project No. 2018/31/B/ST10/03057.

On ^{210}Po, ^{210}Pb, ^{40}K, ^{137}Cs, ^{226}Ra and ^{234}Th in algae diet supplements - the assessed radiation hazard of aquatic superfoods

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Keywords: Polonium ^{210}Po, Lead ^{210}Pb, supplements, aquatic superfoods

Superfoods, i.e. unprocessed food of natural origin, are rich in various nutrients (vitamins, minerals, phytochemicals). Dietary supplements produced from spirulina (*Arthrospira platensis*) and chlorella (*Chlorella vulgaris*) achieved the greatest market success. However, it should be remembered that algae have a high bioaccumulation capacity, which means that raw materials for producing superfoods may contain many contaminants, including radioactive elements, which can significantly affect the safety of the foodstuffs used.

Activity concentrations of natural ^{40}K, ^{137}Cs, ^{226}Ra and ^{234}Th radioisotopes in algae dietary supplements were determined using gamma spectrometry. Alpha spectrometry has investigated the activity of ^{210}Po and ^{210}Pb. Activity concentrations ranged from 0.23 to 0.65 Bq/kg for ^{137}Cs, from 1.76 to 10.7 Bq/kg for ^{226}Ra, from 11.6 to 24.2 Bq/kg for ^{234}Th, and from 20.1 to 400 Bq/kg for ^{40}K. The highest annual effective dose for naturally occurring ^{226}Ra was obtained in chlorella from Japan. The risk of morbidity and mortality ranged from 10^{-13} to 10^{-9}. Activity concentrations of ^{210}Po and ^{210}Pb (Bq/kg dw) ranged from 0.07 to 14.5 (^{210}Po) and from 0.06 to 8.48 (^{210}Pb). The highest values of annual effective doses have been estimated for ^{210}Po in the recommended portion of Spirulina from China (59.7 μSv/year) and Diatomaceous earth (fossil shell flour) from the USA (50.4 μSv/year). The cancer morbidity and mortality risk ranged from 10^{-4} to 10^{-8}. The studied algae supplements can be considered radiologically safe foods.

Radiocarbon variations in the biosphere with solar activity

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Keywords: Solar activity, Solar proton events, Tree rings, Wines

The radiocarbon variations in the biosphere (tree rings and wines), associated with past solar activity, mostly represented by 11-year solar activity cycles (Schwabe cycles), and long-lasting minima in the solar activity (Grand solar activity minima) have been of concern as possible impacts of the Sun on the Earth climate. As the Sun has been modulating the intensity of galactic cosmic rays in the heliosphere, it has been expected that it could have an impact on the ^{14}C variations in the atmosphere and biosphere. An inverse correlation between ^{14}C levels in tree rings and Sun activity (sunspot numbers), a ^{14}C cycle with a period of about 100 yr (presently known as the centennial cycle or the Gleissberg cycle) was also proposed. The well-known Suess wiggles had a characteristic period of about 200 yr (also called the Suess cycle). In both cases, the amplitude of the ^{14}C variations was 10-20 ‰. The radiocarbon amplitude during the most prominent solar cycle with the 11-year period could be around 10-20‰, however, such short-term variations are difficult to observe because the atmospheric $^{14}CO_2$ is in equilibrium with a large oceanic reservoir of CO_2, which acts as a buffer, and therefore the expected ^{14}C amplitudes in biospheric samples would be around 2‰, only. However, high-precision ^{14}C data obtained during 1970s showed amplitude variations of ~3‰ in annual tree rings and wines (1900-1950), which were later confirmed in several other investigations, including the millennium record. Recently, another interesting phenomenon was investigated, when except of regular ^{14}C variations during the 11-year solar cycles, rapid ^{14}C increases up to 12‰ were found in tree rings, which could be associated with emission of solar. We shall review the present status of radiocarbon investigations which proved that cosmogenic radiocarbon has been an important tracer for studying solar activity impacts on the biosphere via solar activity cycles, especially the occurrence of Grand solar activity minima on a time scale of 50 ky. The solar phenomena (solar activity cycles and solar proton events) are an important part of the radiocarbon research for a better understanding of the Sun behaviour and its impact on the Earth environment, including climate change.

Environmental applications of radiocarbon measurement by AMS at the Centro Nacional de Aceleradores (Spain)

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Keywords: Radiological Surveillance, Diet, Ivory, Radiocarbon, AMS

Environmental applications constitute an important part of the global research involving radiocarbon. We present two different projects carried out at Spanish Centro Nacional de Aceleradores (CNA), one related to radiological surveillance and the other one related to forensic applications to control illegal ivory trading and poaching.

Our laboratory belongs to the Spanish Radiological Surveillance Web, supervised by Spanish Nuclear Safety Council (Consejo de Seguridad Nuclear), where radionuclides in a typical human diet are observed. This is the case of C 14, which is controlled since 2006. The presence of C14 in the environment can be the origin of detectable levels of this radionuclide in the human foods. Consequently, C14 would be transferred to cooked food and could reach the human body. In this work we present the results of levels of C14 in a human diet corresponding to a week (from Monday to Friday), four times in a year, since 2006.

The second application is related to the control of trading of elephant ivory. This is regulated by The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The legal situation of ivory depends on the time when the ivory originated and the moment when the animal was killed. C14 bomb peak dating offers a scientific tool to certificate the moment when the ivory was formed, in contrast to the stylistic analysis. In this work we present a compilation of results from the ivory samples analysed at CNA.

Tritium Distribution of Various Groundwater in Korea

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Keywords: Tritium Distribution, spring water, Mineral water, hot spring water

Water is important for the human life and proper drinking of the good water is helpful for healthy. Recent study of the bottled drinking water showed high concentration of HCO_3, Ca and low concentration of SO_4 was an optimum drinking water for bone health. The mineral content in groundwater was influenced by water-rock interaction and this interaction was correlated with groundwater residence time. To understand groundwater residence time, ^3H concentration of more than 100 three types of groundwaters (spring, mineral and hot spring) in Korea were analysed. The analytical results showed mean ^3H concentration was spring (3.19 TU)>mineral (2.84 TU)> hot spring(1.62 TU) order.

1-14-23

Fifty-five years of radiocarbon variations studies in Bratislava

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Keywords: Global fallout, Nuclear power plants, Fossil fuel CO_2, Atmosphere, Tree rings

Radiocarbon variation studies are reviewed with an emphasis on a better understanding of the impacts of the Bohunice nuclear power plant and fossil fuel CO_2 on the atmosphere and biosphere of Slovakia. The maximum $\Delta^{14}C$ levels in the air up to about 1200‰ were observed during the 1970s at the Žlkovce monitoring station, which after 2005 decreased to <30‰. A relative decrease in the atmospheric $\Delta^{14}C$ levels due to increasing levels of fossil CO_2 in the atmosphere has also been significant, for example, in Bratislava down to about -330‰, but after 2005 they were <50‰ below the Jungfraujoch European clean air level. The tree-ring data, averaging the annual $\Delta^{14}C$ levels for several stations in Slovakia, have been in agreement with the atmospheric data, as well as with the newly established clean-air station at Jasná in central Slovakia. Future ^{14}C levels will depend strongly on fossil CO_2 levels in the atmosphere, which will change the bomb ^{14}C era to the fossil CO_2 era. However, if fossil CO_2 levels in the future decrease, ocean warming could bring more $^{14}CO_2$ from oceans back to the atmosphere, which would develop a new steady- state distribution of carbon isotopes in the environment. A new ^{14}C record in the atmosphere-biosphere- hydrosphere during the Anthropocene is a great challenge for radiocarbon science, important for better understanding of environmental processes, climate change, and impacts of human activities on the total environment. This new era of radiocarbon research will also need new developments in radiocarbon analytical technologies, as further progress in accuracy and precision (<1‰) of results will be needed to meet the new radiocarbon challenges.

1-14-24

Chronological records in animal tissues

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Keywords: Radiocarbon dating, Animal tissues

Radiocarbon dating of recent and near-future biota samples faces an inability to distinguish these from the pre-bomb peak ones. If the samples in question are of animal tissues, such as protected species that are dated for legal purposes, a possible mitigation of this unfavourable trend is to exploit the chronological record of the tissue. The known chronology can anchor the sequence on radiocarbon calibration curve and thus reduce the ambiguity of the dating results. The samples were cleaned and dried. The combusted samples were graphitized with Zn as the sole reduction agent. The AMS measurement was performed on MILEA at the Nuclear Physics Institute. Several types of samples were investigated in this study. Eurasian lynx (*Lynx lynx*) is a medium-sized wild cat, critically endangered. We sampled the eye of a female lynx that died in the Czech zoo during 2020. Several layers were separated, including retina (identified as the youngest part), sclera, cornea and lens (inner parts identified as the oldest). *Testudo hermanni* is threatened medium-sized long-lived terrestrial species. Its shell grows throughout its life, creating separate lines resembling tree rings. The shell of recently deceased *Testudo hermanni* was sampled along the incremental lines from the center (the oldest part) to the edge of the scute (the youngest part). The multiple sampling can exclude the older intervals. Pangolin is likely most poached mammal in the world, at the edge of extinction. Its scale is a horny derivative of the epidermis mainly of keratin, considered as homologous with primate nails. We performed two sets of sampling on the scales of *Smutsia gigantea* with ambiguous results. Obviously, the chronology of the scales is either even more complex, or there is no one. Five scales from five pangolins were sampled at the free edge and from the edge of the inner part attached to the epidermis. Two scales from two pangolins were sampled at five different positions on the upper and bottom side of the scales as well. We shall discuss in detail radiocarbon results obtained for each set of samples.

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1-14-25

30 years of National Network for Environmental Radiological Surveillance in the Atmosphere and Terrestrial Environment

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Keywords: Environmental radiological surveillance, radioactivity measurement

The year 2023 marks the 30th anniversary of the start of the Spanish national network for environmental radiological surveillance in the atmosphere and terrestrial environment. This surveillance is the responsibility of the Nuclear Safety Council (CSN), the only Spanish body competent in matters of nuclear safety and radiological protection, and it is currently carried out through agreements between this body and 20 different entities, including 19 universities throughout the national territory.

During these 30 years, several changes have taken place in the different programmes that develop environmental radiological surveillance in Spain, as well as several national and international events. This study presents the evolution of these programmes from different points of view, including scope changes, time evolution of radionuclides, taking into account national and international events, data management, European Commission verifications under article 35 of the Euratom Treaty, quality assurance and communication to the public.

Particularly noteworthy is the development of an application, available on the CSN website (Keeper Gis Web), where the public can consult the data from this network, as well as from other environmental radiological monitoring programmes including those developed in the surroundings of nuclear power plants and radioactive facilities of the nuclear fuel cycle.

The values of certain radionuclides of interest, such as the downward trend observed in the "fallout" radionuclides or the evolution of the radioactivity background on certain matrices, temporarily interrupted by accidents such as Fukushima, are analysed in detail.

1-14-26

Bringing Innovation to Autonomous Exploration of Marine Radioactivity: The RAMONES Project

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Natural radioactivity in the marine environment has been present since the Earth's formation, while artificial radionuclides were introduced into the oceans in 1944. More recent direct sources, such as low-level liquid discharges from reprocessing plants, large-scale releases due to disasters (e.g. Fukushima hit by the tsunami in 2011), and smaller-scale radiological events feed the oceans. Exploration of submarine environments should consider the existence of radioactivity in terms of its short- and long-term impact on marine and coastal ecosystems, also in correlation to natural hazards, such as seismic activity over submarine faults. Significantly undersampled in oceans, radioactivity poses real risks to marine ecosystems and human population, urging for detailed, data-driven modelling.

The EU-funded RAMONES project aims to offer new and efficient solutions for *in situ*, continuous, long-term monitoring of radioactivity in harsh submarine environments. A new generation of submarine radiation-sensing instruments, assisted by state-of-the-art robotic vehicles and artificial intelligence is under development to offer the means towards understanding radiation-related risks near and far from coastal areas, while providing data to shape new policies and guidelines for environmental sustainability, economic growth and human health.

The main ambition behind RAMONES is to lay a radical new path to close the existing marine radioactivity under-sampling gap at large scales and foster new interdisciplinary research in threatened natural deep-sea ecosystems. RAMONES invest significant effort to provide tools for long-term, rapid deployments, propose new AI-driven and supported methodologies, and offer scaled-up solutions to researchers, policy makers and communities. RAMONES combine state-of-the-art equipment from various disciplines and advanced modelling in fine synergy, and design new and effective approaches for the marine environment to provide efficient response to natural and man-made hazards, shaping future policies for the global population.

RAMONES receives funding from European Union under Horizon 2020 FET Proactive Programme via grant agreement No. 101017808

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POSTER SESSION II

03 Radionuclide transport in the environment

04 Quality assurance and quality control

05 Natural radionuclides

06 Fukushima, Chernobyl and Test Ground

09 Modelling

10 Atmosphere

11 Marine environment

12 Marine sediments

POSTER SESSION II

03 Radionuclide transport in the environment

Bioconcentration factors (BCFs) and sediment distribution coefficients (K_ds) for ^{137}Cs in a sheltered Norwegian fjord system

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Keywords: Bioconcentration Factors, Sediment distribution coefficients, ^{137}Cs, Norwegian fjord system, Vefsnfjord

Areas in central Norway experienced significant radioactive contamination from the Chernobyl accident in 1986. Long-term monitoring conducted in the Vefsnfjord, located in Nordland County, has confirmed consistently elevated ^{137}Cs levels compared to open Norwegian sea areas. Although there has been a slight decrease in the temporal trends of ^{137}Cs in the Vefsnfjord, the levels have remained relatively stable over the past decade. As a result, the fjord serves as a suitable location for investigating the distribution of ^{137}Cs in the marine environment. The objective of this study is to evaluate the bioconcentration factors (BCFs) and sediment distribution coefficients (K_ds) for ^{137}Cs in samples collected in July 2022. The BCFs increased in the following order: *A. silus* (benthopelagic fish) ($6{\cdot}10^1$) < *B. glaciale* (mesopelagic fish) ($1{\cdot}10^2$) = *P. tarda* (shrimp) ($1{\cdot}10^2$) < *P. borealis* (shrimp) ($2{\cdot}10^2$) < *G. cynoglossus* (flatfish) ($3{\cdot}10^2$) = *F. vesiculosus* (brown seaweed) ($3{\cdot}10^2$) < *C. crispatus* (seastar) ($2{\cdot}10^3$). The corresponding BCFs recommended by IAEA (2004) is $1{\cdot}10^2$ for pelagic fish (BCFs are not derived for benthopelagic and mesopelagic fish) and $5{\cdot}10^1$ for both crustaceans (including shrimps) and macroalgae (including brown seaweed). Thus, the BCFs observed in the present study are similar to or higher than IAEA's recommended values. Notably, the highest BCF was observed in a seastar belonging to the phylum echinoderms, for which IAEA has not provided a recommended value. The K_d in the Vefsnfjord is determined to be $8{\cdot}10^4$, which is one order of magnitude higher than the value recommended for ocean margins by IAEA ($4{\cdot}10^3$). The geometric mean is given for brown seaweed (n=11) and sediments (n=4). Other samples are pooled and n=1. The findings of this study are discussed within a broader context. Specifically, the study addresses factors affecting the BCFs and K_ds in a sheltered fjord system, such as temporal and spatial variations in fresh water supply, salinity and pH, as well as potential disequilibrium in the ^{137}Cs partition between the dissolved and particular phases.

Radioactivity in agricultural crops and soils from the family farms in Croatia

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Keywords: radioactivity, alpha, beta and gamma emmiters in agricultural crops, HPGe, LCS

This work presents the results of the radioactivity measurements in selected agricultural crops and soils from family farms in Croatia, mostly following ecological production standards, as a part of Croatian Science Foundation project RiChFALL (Radioactivity in children food and novel methods for low level activity determination, 2020. – 2024.). Quantitative analysis of radionuclides which can be determined by gamma-spectrometry directly or through their progenies was done using high purity germanium detectors (HPGe), upgraded with active shielding (cosmic veto) to reach lower detection limits. Beta emitter Sr-90 was determined, after radiochemical separation, by Cherenkov counting using liquid scintillation counter (LSC). Alpha emitter Po-210 was determined by alpha-spectrometry after radiochemical preparation. In addition to activity concentrations of mentioned radionuclides in crops, to determine the transfer factors of nuclides, soils of different depths, on which the analysed agricultural products were grown, were also analysed. The comparison of activities based on type of crop and soil, will be shown. In order to determine if transfer of stable isotopes differs from transfer of radioisotopes, elemental analyses using XRF and ICP- OS techniques were performed for a selected part of samples. Preliminary measurements of crops showed activities of naturally occurring nuclides to be in range from 0.5 to few Bq kg^{-1} in dry mass, predominantly Ra-226 and progeny, Th-232 and progeny and rarely U-238,235 and their progenies. Cs-137 and Sr-90 were measured in most of crops with activity concentrations ranging from 0.5 to few Bq kg^{-1} for Cs-137 and from 0.1 to few Bq kg^{-1} for Sr-90, in dry mass. Po-210 was found to be below 1 Bq kg^{-1} of dry mass, expectedly exceptions are leafy vegetables. Preliminary measurements of soil samples showed activities of Cs-137 up to 20 Bq kg^{-1}, while for Sr-90 it ranged from 1 to 2 Bq kg^{-1} in dry mass. Determined Pb-210 (gamma-spectrometry) and Po-210 (alpha-spectrometry) activities were compared along soil vertical profile, with an expected gradual decrease from top to bottom layer. Po-210 was not in equilibrium with Pb-210 in all samples.

2-03-03

On the influence of soil organic matter on the downward migration of ^{137}Cs and ^{239,240}Pu

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Keywords: ^{137}Cs; ^{239,240}Pu, vertical migration; soil organic matter; secondary peaks

The influence of the content of soil organic matter (SOM) on the occurrence and quantitative characteristics of secondary peaks in the vertical distribution of ^{137}Cs and ^{239,240}Pu in the soil cores taken in the southern and north-western regions of Lithuania has been studied. An analysis of the vertical profiles of radionuclides in the soil in some cases evinces secondary maxima on the deep slope of their depth distribution. Particularly pronounced secondary maxima of ^{137}Cs and ^{239,240}Pu are observed in cases of anaerobic decomposition of organic matter in the soil. A positive correlation was found between the reserves of ^{137}Cs and ^{239,240}Pu in the secondary peaks of their distribution and the SOM in the upper layers of soil cores. Moreover, the positive correlation is higher in those cores where the decomposition of organic matter in the soil occurs under anaerobic conditions. This suggests that when modelling the migration behaviour of radionuclides in the soils of contaminated areas, SOM and anaerobic conditions should be considered as important physical factors. This once again proves out that places with a high level of groundwater and a large amount of organic matter tendentious to radioactive contamination can be responsible for the long-range transport of radionuclides from the source of contamination. Although our investigation should be regarded as a pilot one, it opens up the possibility of creating more objective models of the radionuclide downward migration into the soil and their spread beyond the contaminated zone.

Influence of soil microbiology on radionuclide transport and uptake into plants

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Keywords: Soil, Radionuclides, Microbial diversity, Root exudates, Plants

Deep geological repositories (DGR) will be used for the final disposal of highly radioactive waste. For the safety assessment of the DGR, it is important to consider accident scenarios such as the ingress of water, which might lead to a release of radionuclides (RNs) from the repository into the groundwater. RNs in groundwater can migrate to the surface soil where they can interact with indigenous microorganisms and plants, entering the food chain and posing a health risk to humans. The reliable modelling of the RN uptake into plants requires more than just transfer factors. A more detailed process understanding of the RN uptake into plants, including the effects of soil microorganisms, is necessary. RNs may affect the soil microbial community altering the natural community composition and interactions. Root exudates from plants and microorganisms can alter the speciation of RNs, affecting their bioavailability and mobility.

We study the impact of soil microorganisms on the RN transport and uptake into plants at the molecular level. The experiments discussed focus on studying the modulation of soil microbial diversity in the presence of RNs and selected root exudates. In addition, radiation-resistant soil microorganisms will be isolated to study their interaction with RNs and their effect on the degradation of root exudates. This will include characterization of the degradation products and their interactions with RNs. These findings will be used to elaborate radioecological models for the assessment of the RN transport and uptake into the food chain.

2-03-05

Transfer of sedimentary carbon into benthic organisms: Implications for disposal of radioactive waste

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Keywords: Radiocarbon, ^{14}C, *Chironomus riparius*, *Lumbriculus variegatus*, Radioecology, Microcosm study

Radiocarbon (^{14}C) is known as one of the important radionuclides that can be released into the biosphere from nuclear fuel cycle and radioactive waste repositories and thus can be readily taken up by organisms. It has long half-life (5730 years) and can distribute in forms of dissolved and gaseous species at global scale. In the present work, we investigated the proportion of sedimentary C (from field-collected peat and sediment) in benthic animals, chironomid larvae (*Chironomus riparius*) and blackworms (*Lumbriculus variegatus*), in a microcosm study. There was a large difference in ^{14}C/total C ratio between the atmosphere and up to 8000-year leftover peat after peat extraction. Two-pool isotope mixing model was used to estimate the contribution of sedimentary C in the selected animals. The isotopic abundance of ^{15}N was also used to further investigate the incorporation of the substrates (peat and sediment) in the selected animals. The findings revealed insignificant contribution of sedimentary C in the organisms, despite positive incorporation of the substrate into the animals suggested by the ^{15}N values. Such a minimum/zero contribution of C could be attributed to availability and preference of the fish food and other microorganisms with more enriched C, over the recalcitrant peat or the sediment with lower nutritional value. Other parameters such as assimilation efficiency, elimination rate, gut passage time and C turnover rate are important in the rate of uptake. These findings indicated that transfer of sedimentary C in the animals is relative to availability of old vs. modern sources of C as it was observed by the selective diets of the organisms. Further studies with a greater number of samples as well as sediment types are recommended for the future work.

2-03-06

Assessment of the influence of edaphic factors on the transfer of artificial radionuclides (cesium-137 and strontium-90) in the soil-agricultural plant system

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Keywords: artificial radionuclide, soil, edaphic factors, pepper plant.

To assess the influence of edaphic factors on the cesium-137 and strontium-90 transfer in the soil-agricultural plant system in arid territories, a model vegetation experiment had been conducted in controlled greenhouse conditions on soil samples with different types of radioactive contamination and contrasting physicochemical properties on the example of pepper culture (Capsicum annuum). Based on the results of correlation and factor analysis of experimental data, the most significant factors affecting the intensity of radionuclide transfer in the soil- agricultural plant system have been established: for cesium-137 – the content of available isotope forms and the gross K content; for strontium-90 – the content of available isotope forms, gross Ca content, and salt content. Regression models describing the dependence of the accumulation of cesium-137 and strontium-90 on the physicochemical properties of soils in the example of pepper culture have been developed. Determination coefficients describing the quality of regression models have high values: 0.80 – for Cs-137; 0.86 – for Sr-90, which makes it possible to apply them in practice.

The results obtained are compared to data about the influence of these factors on the transition of cesium-137 and strontium-90 in the soil-plant system reported in the literature.

Investigation of the transport and transfer behaviour of I-125 using a laboratory lysimeter with reference soil

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Keywords: I-125, final disposal leakage, migration, surface soil.

In many countries the storage of radioactive waste in deep geological formations is a planned option for final disposal. In case of unintentional release, radionuclides with very long half-lives, for example I-129, can lead to potential radiation exposure. For the assessment of long-term safety, processes such as the migration and accumulation of radionuclides in the far field around the repository, and thus in the surface soil layers of the geosphere, must be considered.

To get more detailed knowledge on the migration of I-129, long term lysimeter experiments with in-situ measurement of pH and Eh have been performed over a period of more than two years. The reference soil chosen is a dystric cambisol (RefeSol 01-A), mainly consisting of sand (approx. 73 %) with a low content of C_{org} (approx. 0.9 %), representing one typical soil type in Germany. After an equilibration period of one year, I-125 as a substitute tracer for the longlived I-129, has been added to the system, and its upward migration driven by evaporation was studied performing γ-measurements of both pore water and soil layers. Additionally, column experiments with the same reference soil and tracer were set up to get more information about the migration through the water-saturated zone.

The lysimeter experiment showed a considerable migration from the saturated zone to upper soil layers, with a maximum at a depth of 6-10 cm below surface. These results were supported by the column experiments.

In addition, experiments with fluctuating water levels are envisaged in order to obtain more detailed information on remobilization and sorption processes. Fur- thermore, the influence of microorganisms on these processes will also be investi- gated.

Migration of Technetium in German Reference Soils

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Keywords: Tc-99, final disposal, leakage, migration, top soil

When considering the long-term safety of a repository for radioactive waste, unintentional release followed by migration and accumulation of long-lived radionuclides in the far field, and thus in the surface soil layers must be taken into account. Risk assessments for public exposure over long periods of time require a deeper understanding of the complex mechanisms of radionuclide transport from the groundwater through the vadose zone into the biosphere.

Batch, column and lysimeter experiments were performed to examine the influence of soil characteristics on the transport and transfer behavior of the long-lived fission product ^{99}Tc. For these experiments, top soil material from four different German reference soils (dystric cambisol, stagnic luvisol, eutric cambisol, gleyic podzol) was used. Individual synthetic soil solutions were developed for the reference soils and the influence of the composition of these solutions in comparison to a 'standard' synthetic soil water on the migration of ^{99}Tc was investigated in detail.

As expected, technetium showed a low sorption tendency, but immobilization was also observed to a lesser extent. The clay and organic matter content of the soils as well as the ionic strength and nitrate concentration of the soil solutions appeared to be decisive factors for this. Together with the respective soils, the individual soil solutions represent realistic model systems for laboratory-scale soil experiments, which will be used in future research. Furthermore, the influence of microflora and the role of root exudates on the speciation and mobility of technetium will be investigated.

Liquid phase dependence of field distribution coefficients of stable elements between river water and bottom sediments

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Keywords: Distribution coefficients, River water, Sediment, Satble elements

Distribution coefficient (K_d) of radionuclides (RNs) between river water and bottom sediment is a key parameter for modelling migration of RNs in terrestrial environments. A field K_d, which is obtained by measurements of elemental concentrations in river water and sediment, is sometimes used for the modelling. Because, however, a field K_d can vary with a variety of environmental factors, understanding of the variation is necessary for a prediction of filed K_d. Especially, contributions of liquid and solid phases to the variation should be elucidated in first. In this study, we evaluated the relationships between filed K_d values and stable element concentrations in river water (C_{aq}) or sandy sediment (Q) collected from different four rivers in Japan. As the result, it was found that the logK_d values are linearly correlated with logC_{aq} with a slope of around −1 for all the elements examined (e.g., Cs, Sr, Sm etc.). This means that the variation of log$Q$ is negligible small compared with those of logC_{aq}. Thus, the field K_d for sandy sediments could be expressed as a function of dissolved element concentration in river water.

Acknowledgments
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Chemical implication of partition coefficient of ^{137}Cs between aqueous and suspended and phases in natural water

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Keywords: Partition coefficients, irrigation water, ^{137}Cs, sediment, chemical model

After the Fukushima Daiichi Nuclear Power Plant accident, terrestrial environment has been seriously contaminated by radiocesium. As a result, higher radiocesium levels in river/lake water have continued in the Fukushima area, although they exhibit gradual decline trends. To have better understanding of movement of radio- cesium in terrestrial environments, partition coefficient of ^{137}Cs between solid (suspended matter, sediments) and aqueous phases, K_d, has been introduced.
Although K_d is a tool to have better understanding of dynamic behavior of ^{137}Cs in natural water system, the K_d values in river waters, ranged from 2×10^4 to 7×10^6 L kg^{-1}, showed larger spatiotemporal variability. In this study, furthermore, very low K_d (20 L kg^{-1}) of ^{137}Cs was determined between Yugama crater water and sediment, Kusatsu-Shirane Volcano. It is important to elucidate factors controlling the partition coefficient of ^{137}Cs in natural water system. Previous study revealed that the logarithmic K_d of ^{137}Cs in river negatively correlated with logarithmic electro-conductivity and logarithmic suspended sediment (SS) concentrations, respectively. We, here, introduce a chemical model to explain variability of K_d of ^{137}Cs in natural water system. The chemical model contains complexation of stable cesium (^{133}Cs) with mineral and organic binding sites in SS, metal exchange reactions, and presence of colloidal species. The chemical model reveals that plots of the logarithmic K_d values versus logarithmic concentrations of $^{133}Cs^+$ are within a band of a slope of -1, which means that Cs is strongly associated with binding site in SS and a major chemical interaction between ^{137}Cs and binding site in SS is isotope exchange reaction between ^{133}Cs and ^{137}Cs rather than metal exchange reactions with other metal ions. The effect of the SS concentrations to K_d, may be explained by presence of colloidal ^{137}Cs, passing through filter, which is a potential dissolved species of ^{137}Cs in river water. The result suggests that better understanding of geochemical behaviors of stable Cs in natural water is important to know movement of ^{137}Cs in natural water systems.
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The use of Beryllium-7 as a tracer in-depth penetration study

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Keywords : Aims, Depth penetration, Beryllium-7, Gamma spectrometry, Results

This paper aims to study the depth penetration into the soil surface by Fallout Radionuclides (FRNs) as tracers. This approach is still not widely used in soil penetration studies until now and Beryllium-7 is used entirely as a short-term tracer in this study. Thus, in order to confirm the use of this tracer, a study was conducted in the catchment area of Timah Tasoh, Perlis and Bangi, Selangor which were selected as two study sites for both the rainy and dry seasons. This study involves taking soil samples by using a metal corer and taken to the Radiochemistry and Environment Laboratory (RAS), Nuclear Malaysia to carry out further procedures such as the preparation and finally the analysis data obtained from the analysis using Gamma Spectrometry counting system, consists of Hyper-Germanium detector (HPGe). Based on the analysis results shown in table 1 and table 2, the depth penetration values in the study site area of Timah Tasoh and Bangi have given different results as a whole. Nevertheless, the trend does not show the results of the analysis so significant to each other. Where, the shared values are between 2.98 kgm^{-2} to 4.98 kgm^{-2} and 3.43 kgm^{-2} to 5.06 kgm^{-2} , respectively. This study is also not much different in the value of depth penetration distribution with some study results that has been carried out by scientists from all over the world made as a comparative data. In conclusion, Beryllium-7 which acts as a short term tracer in this study has been successfully used to determine the value of depth penetration into the soil surface in different places and seasons.

POSTER SESSION II

04 Quality assurance and quality control

2-04-01

Development of reference material for the determination of alpha, beta and gamma emitting radionuclides in concrete waste generated from decommissioning of nuclear facility

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Keywords: Reference material, Radioactive waste, Concrete, QA/QC

Decommissioning of aging nuclear facilities is a part of the cycle process for the sustainable nuclear industry, and it is expected that the number of nuclear facilities to be dismantled domestically and abroad will increase. In the decommissioning process of nuclear power plants (NPPs), the largest amount of radioactive concrete waste contaminated with various alpha, beta, and gamma nuclides is generated.

In order to reduce the disposal cost of radioactive waste and meet regulatory standards for free release, it is essential to accurately evaluate the radioactivity remaining in radioactive waste. Quality assurance and quality control (QA/QC) of radioactivity measurement and validation of analysis can be evaluated through interlaboratory comparisions (ILCs) and proficiency test (PT) etc. using reference materials (RMs). Ideally, RM should have the same matrix and compenet content with sample, but it is difficult to secure RM uncer the same conditions.

Therefore, In the Korea Research Institute of Standards and Science (KRISS), a total of 7 nuclides (^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, and Pu) were selected to develop a new concrete RMs. These nuclides should be given priority when disposing of radioactive waste. The radioacitivity concetrations of ^{60}Co, ^{90}Sr, ^{134}Cs, ^{137}Cs, ^{152}Eu, ^{154}Eu, and Pu in the RM were in the range of 65-180 Bq/kg-dry and the expanded uncertainty was within 10% ($k = 2$).

2-04-02

A new Certified Reference Material IAEA-465 for radionuclides in Baltic Sea sediment

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Keywords: Radionucléides, Certifified Reference Materials, Baltic Sea sediments

The accurate and precise determination of radionuclide concentrations in marine samples is an important aspect of marine radioactivity assessment and applications of radionuclides in studies of oceanographic processes. To support and improve data quality, the IAEA Environment Laboratories (IAEA-EL) in Monaco regularly conduct characterization studies aimed to assign values to reference materials for radionuclides and other components in different matrices of marine samples as an integral part of the Sub-programme IAEA Reference Products for Science and Trade [1, 2].

The presentation shows all details on the production of IAEA-465, complying the relevant standard ISO 17034 and ISO Guide 35 [3,4] and for the first time the property values of some radionuclides with gamma emitters (^{40}K, ^{137}Cs, ^{210}Pb, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{232}Th, ^{235}U, ^{238}U) are scoped with Austria Accreditation Body Query Company (akkreditierung- austria.gv.at)

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2-04-03

Gross alpha and beta activity in non-saline waters using NM ISO 11704: method validation and application to bottled mineral and tap waters from Morocco

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Keywords: Gross alpha/beta activity, drinking water, method validation, ISO 11704, bottled and tap waters.

In this study, gross alpha and gross beta activities in 15 bottled mineral waters in Morocco were measured by Liquid Scintillation Counting following the standard method ISO 11704:2018. Method validation was carried out using standard approaches to confirm the performance parameters of the method, being used routinely in our laboratory. Gross alpha and gross beta activities were between minimum <DL (below detection limit) and maximum 0.211±0.015 and 0.151±0.008 Bq L-1 respectively. No significant correlation was found between activities and total dissolved salts (TDS) contents, ranging from 141 to 2078 mg L-

1. Tap waters collected from different regions within the country were also analyzed following the same procedure. Almost all the samples presented gross alpha and beta activities below the Moroccan admissible values (0.1 Bq L^{-1} for gtross alpha and 1 Bq L^{-1} for gross beta).

POSTER SESSION II

05 Natural radionuclides

2-05-01

Natural radioactivity concentrations and radiological risk assessment of pyroclastic products from Tajogaite volcano (La Palma, Canary Islands)

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Keywords: Gamma spectometry, Radiological risk, Pyroclastic rocks.

On 19 September 2021, Cumbre Vieja volcanic ridge (La Palma, Canary Islands, Spain) faced a flank eruption, naming the new Tagojaite volcano, which remained active for 85 days. This eruption has been considered the most devastating eruption of the last 100 years in Europe, according to the Copernicus European Union's Earth observation program. In this study, the levels of natural radioactivity of pyroclasts from this volcano were evaluated. A total of 45 samples, ranging in size from lapilli to ash, were collected from different locations on La Palma Island.

High-resolution gamma spectrometry was performed on pyroclastic samples to determine the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K. The average activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K were 60 ± 10 Bq/kg (range 31 - 81 Bq/kg), 19 ± 3 Bq/kg (range 10 to 26 Bq/kg) and 535 ± 79 Bq/kg (range 279 - 707 Bq/kg), respectively. These values were similar to those previously published for soils in Cumbre Vieja ridge [1].

The absorbed gamma dose rate (AGDR), radium equivalent activity (R_{aeq}), internal and external hazard indexes (H_{in} and H_{ex}), outdoor annual effective dose (AEDRout) and excess lifetime cancer risk (ELCR) were all determined to assess the radiation hazard derived from the pyroclastic products. The obtained mean values were 61 ± 10 nGy/h, 128 ± 21 Bq/kg, 0.4 ± 0.1, 0.12 ± 0.02, 75 ± 12 µSv/year and 0.26 ± 0.04, respectively. The average absorbed gamma dose rate (61 nGy/h) obtained in this study was higher than previously reported values for La Palma Island (44.7 nGy/h) and close to the worldwide average (59 nGy/h)[1,2].

The overall findings indicated no radiological threat to the population's health in the study area.

Acknowledgements. This study was supported by Spanish Ministry of Science and Innovation (BOE-A-2021-20262).

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2-05-02

Natural Radioactivity of Selected Mineral Deposits in Camarines Norte and Northern Palawan, Philippines

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Keywords: natural radioactivity, mineral deposits, Philippines

Philippines is recognized as one of the world's most mineral-rich countries, but its limited baseline data on natural radioactivity levels in its mineral deposits hinder the ability to monitor the environmental impact of mining activities. This study aimed to assess the natural radioactivity levels of selected mineral deposits in Northern Palawan and Camarines Norte, which are both previously identified with radioactive materials deposits. Concentrations of natural radionuclides (^{40}K, ^{238}U, and ^{232}Th) in granodiorite plutons (Darocotan and Bay Peak), olistostrome unit (Bacuit Formation), and beach deposits (El Nido, Erawan, Ombo, and New Canipo) in Northern Palawan, and granodioritic pluton (Paracale Granodiorite), ophiolitic suite (Cadig), iron skarn deposits (Larap, Nakalaya, and Pinagbirayan), and beach deposit (Mambulao) in Camarines Norte were measured, and radiological risk parameters were used to assess the potential impact of these deposits on the environment and human health. Results show that the Darocotan and Bay Peak granodiorites in Northern Palawan have higher average natural radionuclide concentrations compared to Paracale granodiorite and average upper continental crust (UCC). Erawan, Ombo, and New Canipo beach deposits also exhibited elevated ^{238}U and ^{232}Th than El Nido and Mambulao beach deposits and average UCC. The Bacuit Formation and Larap, Nakalaya, and Pinagbirayan iron skarn deposits had a higher average ^{238}U concentrations than average UCC. Meanwhile, El Nido and Mambulao beach deposits, Paracale granodiorite, and Cadig ophiolite had natural radioactivity levels below average UCC. Darocotan and Bay Peak Granodiorites, Bacuit Formation, Erawan, Ombo and New Canipo beach deposits, and Larap and Nakalaya iron skarns have been found to have radiological health risk parameter values that exceed recommended levels. These findings highlight the importance of baselining and continuous monitoring of areas with elevated natural radioactivity as these risks can be further exacerbated by future mining and human activities posing impacts on human health and the environment.

2-05-03

Preliminary Baselining of Natural Radioactivity in Selected Active Volcanoes in the Philippines

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Keywords: active volcano, baselining, radioactivity, gamma-ray, radon

Measurement of natural radioactivity from volcanoes, specifically, of ^{238}U, ^{40}K, ^{232}Th and ^{222}Rn radionuclides has been shown to provide tools to detect variation in volcanic activity and to indicate potential anomalous tectonic events. In order to establish background radioactivity from active volcanoes in the Philippines, this study conducted preliminary baselining of in-situ gamma-ray emissions and spot radon-222 gas measurements from both soil and spring waters using portable gamma-ray spectrometer and radon detector, respectively. Three active volcanoes in Luzon Island, Philippines – Taal, Bulusan and Mayon volcanoes – were measured for ^{238}U, ^{40}K, ^{232}Th and ^{222}Rn emissions during a low-level of unrest period from February to March 2023. All volcanic regions display constant background values for ^{238}U, ^{40}K, ^{232}Th activities, except for one hot spring discharge found in Bulusan volcano (Buhang hot spring). Hot spring waters and crater lakes display the relatively high radon measurements ranging from 1.257 – 2.979 Bq/L for Mt. Taal, 0.3044 – 1.550 Bq/L for Mt. Bulusan and 0.3533 – 0.5489 Bq/L for Mt. Mayon, in comparison with the surrounding vicinities. Elevated radon measurements up to 6528 Bq/m^3 are also recorded in areas near fissures and cracks with emissions of volcanic gases as compared to other areas. Future direction of this study is to further visit and assess the ambient conditions of other active volcanoes in the Philippines.

2-05-04

Application of ^{210}Pb as an environmental tracer for hydrological characterization of two shallow coastal lagoons in Uruguay

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Keywords: Lead-210, Polonium-210, Sedimentation rate, Environmental tracer, Coastal lagoon

The use of the radionuclide ^{210}Pb for dating sediments and estimating sedimentation rates has been widely employed in many environmental systems. This technique yields satisfactory results when used to study sediments that have incorporated this radionuclide in an ordered manner from the atmosphere.

Uruguay presents on its Atlantic coast a system of coastal lagoons and wetlands that stand out for their high biodiversity and are part of the Ramsar site "Bañados del Este" (Ramsar 290). This paper presents the application of ^{210}Pb as an environmental tracer to study the hydrological characteristics of two shallow coastal lagoons in eastern Uruguay in a semi-pristine state.

For this study, two sediment cores of 50 cm depth were obtained from areas with greater sedimentation in the Briozzo and Castillos lagoons. The activity concentration of ^{210}Pb total and ^{210}Pb excess was determined in each section of the sedimentary core by determining its daughter ^{210}Po through alpha spectrometry. The geochronology was confirmed by measuring the activity of ^{137}Cs using gamma spectrometry. The study also determined the variation of organic matter content with depth for each core. Furthermore, physical-chemical parameters such as pH, temperature, depth, turbidity, salinity, and dissolved oxygen were examined at each point in the lagoon.

The results obtained from the physical-chemical parameters, the organic matter content, and the radiometric characterization (^{210}Pb total, ^{210}Pb excess) confirm that both lagoons have significant hydrological differences. The Briozzo lagoon presents a high sedimentation capacity, which allowed for the calculation of sedimentation rates, radionuclide fluxes, and the estimation of the age of each section of the sedimentary core. In the Castillos lagoon, the total activity of ^{210}Pb with depth exhibits an abrupt exponential decay, preventing the estimation of dates or the calculation of accumulation rates. These results demonstrate that the Castillos lagoon is dominated by sediment resuspension processes.

2-05-05

Possibility of ^{210}Po and ^{210}Pb concentration prediction in mineral waters based on their total mineralization

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Keywords: mineral water, ^{210}Po, ^{210}Pb

Mineral water is water from a spring that contains various minerals, such as salts and sulfur compounds. Mineral water may usually be still or sparkling according to the presence or absence of added gases. The content of different minerals and heavy metals in water is controlled by the chemical properties of the specific metal and chemical conditions (i.e. pH, Eh, the occurrence of possible complexing agents).

Our study aimed to analyze ^{210}Po and ^{210}Pb concentrations in 40 mineral water samples from Poland, selected based on varied mineral content. Using data given by the mineral water producer (mineral content, water source, and some chemical properties), we also aimed to propose a multiple linear regression model that could help predict the prevalence of both radionuclides in commercially available mineral waters in Poland.

Both polonium and lead are particle-reactive elements and should be mostly filtered before water bottling. In this context, concentrations of both radionuclides should not be correlated with mineral content, creating many opportunities in statistical modelling. Additionally, effective doses and lifetime cancer mortality and morbidity risk coefficients connected with water consumption were calculated to check if annual mineral water consumption in Poland significantly increases the cancer risk due to radionuclides incorporation.

POSTER SESSION II

06 Fukushima, Chernobyl and Test Ground

Americium and plutonium isotopes in forest ecosystems of the Chornobyl Exclusion zone

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Keywords: Americium, Plutonium, Forest biogeocenosis, Speciation, Migration ability

The speciation of americium and plutonium isotopes in components of forest biogeocenoses in the Chornobyl Exclusion zone and processes of these radionuclides' inclusion in biogeochemical cycles of migration were studied. The sampling site was chosen in a pine forest located 6 km west of the Chornobyl NPP. The total biomass inventory for the local forest ecosystem was determined and the sampling of pine tree components, mosses, forest litter and soil was carried out.

It was found, that nearly 90 % of ^{241,243}Am and ^{238,239,240}Pu activity in the forest ecosystem is concentrated in the fermentative and decomposed humus horizons of the litter and in the upper 2 cm soil layer. The forest litter, which constitutes only 13 % of the forest biomass, has demonstrated the ability to retain up to 67 % of ^{241,243}Am and 70 % of ^{238,239,240}Pu inventory. The fraction of exchangeable ^{241}Am and ^{243}Am in the upper soil layer constitutes 12 – 35 % from their bulk content that exceeds significantly the corresponding value for Pu isotopes (1 – 3 %). Most of ^{241}Am accumulated in the biomass of the pine trees is concentrated in the wood (53 %), bark (21 %) and branches (18 %). The distribution of ^{241}Am inventory in the forest biogeocenosis indicates that only 6 % of its total activity is involved into biogeochemical cycles of migration.

The obtained results demonstrate that vertical migration of americium and plutonium in the soil profiles of the studied forest ecosystem is rather slow. The main part of the activity of these radionuclides is concentrated in the humus horizon of the forest litter. The fraction of exchangeable species of ^{241}Am and ^{243}Am exceeds significantly that of ^{238,239,240}Pu which indicates a much higher migration ability of americium and its enhanced potential accessibility for the intake into local trophic chains. Due to the processes of ^{241}Pu decay and physicochemical transformation of fuel particles, the inventory of ^{241}Am and its mobility will increase over time.

2-06-02

Transport of ^{137}Cs discharged by the Fukushima accident based on a Lagrangian particle tracking model

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Keywords: ^{137}Cs, Fukushima accident, Lagrangian particle tracking model

The Fukushima Dai-ichi nuclear power plant (FDNPP) accident caused by the great earthquake in March 2011 released a large amount of radioactive material into the atmosphere and ocean. Kumamoto et al. (2014) conducted observations along the longitude of 149°E in winter 2012 and reported the maximum concentration of cesium in the sub-surface layer of the subtropical region. The radioactive material released from the FDNPP is mainly pushed into the Pacific Ocean east of Japan along the Kuroshio current. Still, it can also enter below the surface through the formation of subtropical mode water and inflow into the East Asian Marginal Seas within a few years. The origin and mechanisms of the maximum subtropical sub- surface concentrations of cesium shown in observations are not clearly understood.

In this study, based on a Lagrangian particle tracking model, we simulated the dispersion of cesium (^{137}Cs) and identified their source (atmospheric deposition or direct oceanic release). The three-dimensional horizontal and vertical flow fields of the ocean circulation model (Modular Ocean Model version 5: MOM5) operated by the Korea Institute of Ocean Science and Technology (KIOST) were used to represent the transport of radioactive materials more realistically. Numerical simulations demonstrated that most of the ^{137}Cs found in the subtropical sub-surface layer had resulted from atmospheric deposition.

2-06-03

Comparison of cesium-bearing microparticles from marine and terrestrial sources

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Keywords: Fukushima accident, CsMPs, Ocean

Two years after the Fukushima accident, glassy water-resistant cesium-bearing microparticles (CsMPs) were first reported. CsMPs have been studied because (i) they have information on the condition in the reactor at the time of the accident, and (ii) there is concern about the exposure to the humans and the other organisms. Several types of CsMPs have been reported, which is assumed to reflect the difference in the accidental progress of each unit. It is also known that CsMPs were transported in the atmospheric plume at the time of emission and therefore have different deposition regions. Type-A CsMPs, are presumed to originate from Unit 2, deposited over a wide area including the Kanto region due to their small size (~0.1–10 μm). Type-B CsMPs, are presumed to originate from Unit 1, deposited in a limited area in the north direction because of their large size (50–400 μm). Matrix of Types-A and -B CsMPs is SiO_2 but Type-A CsMPs have higher concentration of volatile elements including Cs than Type-B CsMPs due to the difference in forming process. The presence of CsMPs emitted from Unit 3 in the ocean was confirmed by our research. The plume at the time of the emission of radionuclides from Unit 3 was in the ocean direction, which suggests that many CsMPs from Unit 3 deposited directly into the ocean. We will report the comparison of CsMPs from marine and terrestrial sources. The presence of CsMPs may be the cause of the overestimation of solid–water distribution coefficient for marine sediments and particulate matters and apparent high concentration factor of marine biota of radioactive Cs.

2-06-04

Tritium in seawater of the NW Pacific Ocean: possible effects after releases of contaminated water from the Fukushima site

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Keywords: Tritium levels, Coastal seawater, NW Pacific Ocean, Radiation doses

The large amount of decontaminated water has been stored after the ALPS treatment in more than 1000 large volume tanks at the Fukushima Dai-ichi nuclear power plant (FDNPP) site. The activity concentrations of several radionuclides (Cs-137, Cs-134, Co-60, Sr-90, Sb-125, Ru-106, Tc-99, and I-129) in treated water were <6 kBq/m^3 (except for C-14 of 60 kBq/m^3), i.e., they were below the Japanese regulation limits. In contrast to other radionuclides, H-3 concentrations in treated water, which cannot be removed by the ALPS system, were about 750MBq/m^3, and the total activity due to increasing volumes of the contaminated water could reach 1 PBq, which would be comparable to H-3 discharges to coastal waters during the FDNPP accident in 2011. Although the H-3 regulation limit is high (60 MBq/m^3), its total activity in stored water has been of concern for Japanese population if tritium water would be released to coastal waters. Tritium because of low energy of emitted beta-rays during its decay (E_{max} = 18.6 keV) does not contribute significantly to radiation doses (that is reflected in its high regulation limit), but its long half-life (12.3 years) would require waiting too long for its decay in contaminated water. As the production rates of contaminated water are very high, its storage (presently more than 1.3 million tons) and waiting for H-3 decay is not an acceptable solution. As H-3 is a part of the water molecule (HTO), it is difficult to get rid of H-3 from water by using common chemical separation methods. There are several methods available for the removal of tritium from water, for example, distillation, cryogenic distillation, electrolysis, and catalytic exchange, but their implementation for treatment of million cubic meters of water is a difficult task. Therefore, Japanese authorities were examining several concepts of releases of H-3 either to the atmosphere or into seawater. Possible impacts of releases of H-3 to the marine environment will be discussed, including its availability as a potential tracer for future oceanic transport studies.

2-06-05

Current radioactive fallout contamination along a trans-European gradient assessed using terricolous lichens

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Keywords: ^{137}Cs, bioindicators, lichens

Lichens are considered to be good indicators of contamination of the terrestrial environment. In this study, we investigated the level of ^{137}Cs accumulated by *Cladonia arbuscula* and *Stereocaulon alpinum* along a longitudinal gradient from northern Norway, across Sweden to southern Poland. Additionally, we compared isotope contents between the selected lichen species, and investigated the correlation of the ^{137}Cs content accumulated by C. *arbuscula* with ^{137}Cs fallout after the Chernobyl disaster. Even though more than 30 years have passed since the event being the primary source of radioisotopes in Europe, there is still increased activity of ^{137}Cs in *Cladonia arbuscula* and *Stereocaulon alpinum* occurring in the area where surface ground deposition of radioisotopes released after the Chernobyl accident was the highest. The statistically significant correlation between the activity of ^{137}Cs in *Cladonia arbuscula* and reported ^{137}Cs deposition in Scandinavia and Poland was $r = 0.66$, $p < 0.05$ and indicates the possibility of using this species for the biomonitoring of radioisotope contamination. The good agreement between our spatial maps of ^{137}Cs activity in lichens and maps of post- Chernobyl deposition confirms the possibility of mapping environmental contamination even if the fallout took place many years ago.

The field research leading to these results received funding from the European Union's Horizon 2020 project INTERACT (grant agreement No. 730938). The work of Paulina Wietrzyk-Pełka was supported by the Foundation for Polish Science (FNP, scholarship

agreement No. START 92.2020). The laboratory research received funding from the National Science Centre, Poland project PRELUDIUM, grant No. 2017/27/N/ ST10/02230.

Bio-availability of radio-caesium in mesoplankton collected from Fukushima coastal waters of 2018 and 2020

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Keywords: Food chain transfer, Marine plankton, ^{137}Cs, biota

Accident originated Cs-137 was introduced from the Fukushima Dai-ichi Nuclear Power Station (1FNPS). Marine plankton off Fukushima was contaminated by radio-caesium and was concerned to transfer along food chain in ecosystems. The concentration factor of caesium for plankton was 13, and comparatively rapid turnover with relatively short life-span, the radioactivity level was expected to be decreased early on after 2011. However, the measured ^{137}Cs radioactivity levels in mesoplankton were greater than expected. In this study, the concentrations of ^{137}Cs radioactivity and stable Cs were determined in plankton collected during 2018 and 2020. After measurement of the total radioactivity, the sample was subjected to H_2O_2 digestion, and the ^{137}Cs and Cs concentrations in the residue were determined to derive labile fraction. During examination, the anomalous radioactivity originated from terrigenous ^{137}Cs-rich particle and caesium bearing micro particle other than plankton was found. After exclude non-biota and refractory fraction, the ^{137}Cs transfer along food chain was examined by model simulation by using the labile fraction as bio-available caesium for filter feeder and planktivorous fish off Fukushima.

The content of tritium in the plant cover of the 'Balapan' site at the Semipalatinsk Test Site

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Keywords: Semipalatinsk Test Site, nuclear tests, plant cover, H-3.

The environment currently contains both naturally occurring and man-made tritium (H-3). When nuclear and fusion testing started, the amount of H-3 being 60–190 times its natural level was released into the Earth's atmosphere. Much of H-3 was produced during nuclear tests conducted at the former Semipalatinsk Test Site (STS). Despite much research undertaken, the STS territory, from the perspective of H-3, is still of special interest because its concentrations in individual areas exceed the level of radioactive waste.

The paper presents the description of the plant cover and the content of H-3 in there at the 'Balapan' site where underground nuclear tests were conducted in boreholes. H-3 activity concentration was determined by carrying out a beta-spectrometric analysis with a liquid scintillation spectrometer. The content of H-3 in the plant cover of the study area was found to reach up to $n \times 10^5$ Bq/kg. That said, maxima are associated with near-mouth sites of warfare boreholes.

2-06-08

Transport of ^{137}Cs discharged by the Fukushima accident based on a Lagrangian particle tracking model

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Keywords: ^{137}Cs, Fukushima accident, Lagrangian particle tracking model

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In this study, based on a Lagrangian particle tracking model, we simulated the dispersion of cesium (^{137}Cs) and identified their source (atmospheric deposition or direct oceanic release). The three-dimensional horizontal and vertical flow fields of the ocean circulation model (Modular Ocean Model version 5: MOM5) operated by the Korea Institute of Ocean Science and Technology (KIOST) were used to represent the transport of radioactive materials more realistically. Numerical simulations demonstrated that most of the ^{137}Cs found in the subtropical sub-surface layer had resulted from atmospheric deposition.

Presence of Fukushima derived radionuclides in the Arctic Ocean.

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Keywords: Fukushima, ^{137}Cs,^{129}I, Arctic, Pacific

On 11 March 2011, the Fukushima Daiichi Nuclear Power Plant (FDNPP) was seriously damaged spilling radioactive particles along the North Pacific Ocean (NPO). In the NPO the FDNPP derived radionuclides were transported with the water masses reaching the Arctic Ocean (AO). Complementary, the ^{129}I signal from the Nuclear Fuel Reprocessing Plants (NFRPs) located in the North Sea, Atlantic Ocean, travels along the North Atlantic current into the AO. Therefore, we propose the use of a dual tracer technique for NPO and AO water masses based on the use of ^{137}Cs and ^{129}I, with two main sources, FDNPP (^{137}Cs) and NFRPs (^{129}I), The combined use of both can be used to differentiate the origin of the water masses, time scales and ages in the AO. We present ^{137}Cs and ^{129}I concentrations of water samples of 63 stations from Japan Sea to AO collected from 23 July to 10 October 2017 on board the R/V Xuelong icebreaker during the 8th Chinese Arctic Research Expedition. ^{137}Cs results ranged from $9.68 \cdot 10^6$ at/kg in Japan Sea to $4.55 \cdot 10^6$ at/kg in the AO. ^{129}I concentrations ranged from $9.68 \cdot 10^6$ at/kg in Japan Sea $1.73 \cdot 10^9$ at/kg in the AO. Both radionuclides show concentrations above the background values in the vicinities of the coast of Japan, $1.4 \cdot 10^6$ at/kg for ^{137}Cs and for ^{129}I $1.07 \cdot 10^7$ at/kg.

Our results show a peak of ^{137}Cs in the Bering Strait and AO, confirming presence of FDNPP derived radionuclides inside the AO. A high peak of ^{129}I from the Atlantic NFRPs is also detected in the Bearing Sea. Both peaks allow to discriminate the inflow and outflow of AO water masses into the NPO. Moreover, this input of the FDNPP discharges in the AO will provide a new opportunity to use those derived radionuclides as tracers in the NPO and the NPO-AO connection and the AO circulation in the following years.

POSTER SESSION II

09 Modelling

Airborne radionuclide activity concentration forecast using SARIMA and Exponential Triple Smoothing algorithms

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Keywords: ^{7}Be, Gross Beta, aerosol, SARIMA, ETS

Radionuclide activity concentrations associated to aerosols are routinely measured both to monitor their presence in the environment, and to exploit their role as radiotracers that provide useful information on atmospheric circulation.

Several approaches can be used to forecast future activity concentrations, exploiting several time series analysis algorithms. One of the most common techniques is Seasonal Autoregressive Integrated Moving Average (SARIMA) where a given value in the time series is obtained as a linear combination of the previous values, along with a linear combination of previous forecast errors from past points in the time series. Several studies performed in different locations have shown that this algorithm can successfully predict future activity concentrations. Exponential Triple Smoothing (ETS) are a family of forecasting algorithms where predicted values are obtained as weighted averages of previous observations, the importance of the weights decreases exponentially for older points. The latter technique has been proven to be quite successful in several fields, but is not so popular in environmental radioactivity studies.

In this work we obtain several forecasting models for activity concentrations of ^{7}Be and Gross Beta associated to aerosols in Mallorca (Spain), using both SARIMA and ETS algorithms. A dataset comprising monthly values measured between 2004 and 2014 is used to construct these models, dividing it in training and test subsets. The best models are selected using the training datasets according to their corresponding Akaike and Bayesian Information Criteria (AIC and BIC), while the goodness of the models is verified computing the Adapted Mean Absolute Percentage Error (AMAPE) for the test subset.

The ETS algorithm shows similar pretictive power to SARIMA, although the former is easier and faster to implement.

Evaluation of Response Function for the Beta Detector System using Monte Carlo Simulation

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Keywords: Beta Detector System, Semiconductor, beta radionuclide, Monte carlo simulation

In this research, we evaluated the feasibility of detecting the beta radionuclides such as ^{90}Sr and ^{90}Y using the semiconductor detector instead of Liquid scintillation counter. Usually, the analysis of ^{90}Sr and ^{90}Y requires the chemical separation and liquid scintillation counter (LSC). In liquid scintillation counter, the beta radionuclides can be detected using the sample mixed with scintillation cocktail and photomultiplier tube. In Korea, the Quantulus 1220 is the best-selling LSC, but its production was stopped. The 300SL can be used instead of Quantulus 1220, however, the minimum detectable activity of 300SL is higher than Quantulus 1220. Therefore, it is necessary to develop the new detector with similar performance compared Quantulus1220. There are several possible options of semiconductor for beta radionuclides detection. In this research, we simulated the response function of the semiconductor detector such as CZT detector using Monte Carlo code and compared with experiment. And we designed the system using the results.

2-09-03

Dispersion of particle-reactive elements caused by the phase transitions in scavenging

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Keywords: Dispersion, Multifraction suspended particulate, Scavenging, Ssorption-desorption processes

A generalized model of scavenging of the reactive radionuclide ^{239,240}Pu was developed, in which the sorption-desorption processes of oxidized and reduced forms on multifraction suspended particulate matter are described by first-order kinetics. One-dimensional transport-diffusion-reaction equations were solved analytically and numerically. In the idealized case of instantaneous release of ^{239,240}Pu on the ocean surface, the profile of concentrations asymptotically tends to the symmetric spreading bulge in the form of a Gaussian moving downward with constant velocity. The corresponding diffusion coefficient is the sum of the physical diffusivity and the apparent diffusivity caused by the reversible phase transitions between the dissolved and particulate states. Using the method of moments, we analytically obtained formulas for both the velocity of the center mass and apparent diffusivity. It was found that in ocean waters that have oxygen present at great depths, we can consider in the first approximation a simplified problem for a mixture of forms with a single effective distribution coefficient, as opposed to considering the complete problem. This conclusion was confirmed by the modeling results for the well-ventilated Eastern Mediterranean. In agreement with the measurements, the calculations demonstrate the presence of a maximum that is slowly descending for all forms of concentration. The ratio of the reduced form to the oxidized form was approximately 0.22-0.24. At the same time, ^{239,240}Pu scavenging calculations for the anoxic Black Sea deep water reproduced the transition from the oxidized to reduced form of ^{239,240}Pu with depth in accordance with the measurement data.

Radiological environmental impact assessment by Ecolego. Potential reach of accidental discharges from Zaporizhzhia nuclear power plant

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Keywords: Radiological environmental impact assessment (REIA), nuclear emergency, Zaporizhzhia nuclear power plant (NPP), Ecolego software

Zaporizhzhia is the largest nuclear power plant (NPP) in Europe, with a total gross capacity of 6000 MW_e divided into six pressurised water reactor (PWR) type VVER V-320 model. It is located in south-eastern Ukraine and controlled by the Russian army since 2022, although it is still operated by Ukrainian staff. As a consequence of the military conflict in the area, the facility suffered minor damages. For this reason, all of the six reactors have been shot down for several months, four in cold shutdown and two in hot shutdown. However, despite this shutdown, several aspects may jeopardize the cooling of the reactors leading to an accident with leakages out of the nuclear facilities.

Since Zaporizhzhia is located near farm fields, eventual leakages may entail a risk for human health. For this reason, we are carrying out an evaluation of the potential radiological environmental impact of an accident in Zaporizhzhia NPP using Ecolego. This software is a tool for creating dynamic models and performing both deterministic and probabilistic simulations, in order to conduct safety and risk assessments in nuclear facilities.

To assess the potential radiological impact two possible discharges has been considered, a release into the atmosphere and a loss of coolant accident (LOCA).

In both cases, both spatial and temporal scopes have been studied along the different environmental compartments.

2-09-05

CHAINING MODELS FOR THE ASSESSMENT OF THE ECONOMIC IMPACT OF A NUCLEAR ACCIDENT ON FORESTRY AND AQUATIC ACTIVITIES

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Keywords: 137Cs, transfer modelling, post-accident ecconomical onsequences

The objective of the AMORAD-II project (ANR-11-RSNR-002) was to reduce the uncertainties related to the prediction of radiological consequences in the case of a nuclear accident. Numerous data have been used to calibrate and validate different modelling tools designed to predict the transfer of radionuclides following releases into the sea or after atmospheric deposition, and how they are redistributed. Numerical models were chained for the first time in order to represent the transfer of ^{137}Cs released by a nuclear accident (nuclear power plant along the Loire river) over a continuum watershed-ocean, each model providing the outputs for the next one. Models pX and ldX (IRSN) were used to simulate the short and long term distance deposits of ^{137}Cs (for a given meteorological scenario). The WATERSED (BRGM) model combined with a new module for radiocesium was used to simulate the redistribution of ^{137}Cs within the soils, and from the soils to the rivers. CASTEAURX (IRSN) modelled the transfer from the rivers to the sea, and STERNE (IRSN) the transfer of dissolved ^{137}Cs in the Atlantic sea and to the fishes. The simulation was done over 20 years after the accident to evaluate the long-term trend and consequences. Finally, ARPAGON model (IRSN), initially created for simulating the economic costs directly associated to an accident, was specifically developed to evaluate the losses due to the market costs for the sectors of agriculture, wood production and sea fishing, and the costs due the loss of ecosystem services relating to hunting, gathering and drinking water supply. Over the 20 years, the losses related to hunting and gathering ecosystem service from the forest areas and stop of drinking water supply are all estimated higher than those related to agricultural products. Those associated with fisheries are around 1/10 of this last one. This case study shows the importance of considering non-market costs for aid decision-making in the field of post-accident management of a nuclear accident.

RADEKOR: Speciation and transfer of radionuclides in the human organism especially taking into account decorporation agents – a joint project

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Keywords: Biokinetics, gastrointestinal tract, speciation, cytotoxicity

In case radionuclides (RN) enter the food chain and are incorporated by humans, they pose a possible health risk due to their radio- and chemotoxicity. To precisely assess the health risk after oral incorporation of RN with food and beverages and to apply effective decontamination methods, it is mandatory to understand the molecular and cellular processes of RN biokinetics. Within the German joint research project RADEKOR, quantitative excretion analysis of Ra-containing food and biokinetic modeling of orally incorporated Am(III) are performed, combined with molecular speciation studies of RN (Ra(II), Eu/Am/Cm(III), U(VI)) in artificial fluids of the alimentary tract of humans and cytotoxicity studies with respective human and rat cell lines both in the absence and presence of decorporation agents such as DTPA (diethylenetriaminepentaacetic acid). Aim of the project is to expand the knowledge of processes underlying RN interactions within the human alimentary tract on a cellular and molecular scale to establish a precise biokinetic model as well as to contribute to the development and improvement of nuclide specific decontamination methods.

This joint project is funded by the German Federal Ministry of Education and Research (grant number 02NUK057A-E).

2-09-07

Various approaches to calculate radon exhalation rate for estimation of CO_2 flux from soil and their verification by experimental measurements

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Keywords : Radon, CO_2, exhalation rate

The current requirements for the reduction of the fossil CO_2 content in the atmosphere require a monitoring of CO_2 dynamics to distinguish its anthropogenic emissions from natural emissions from sources such as soil which is the largest terrestrial reservoir of carbon on Earth. Direct measurements of CO_2 flux are associated with various limitations due to disruptions of physical processes connected with a CO_2 transport in soil or due to a modification of biochemical processes connected with its production in soil. A promising method of obtaining a CO_2 exhalation rate, also as a solution to the above problems, is the use of a radon gas which is released from the soil together with CO_2. This method requires to know the ^{222}Rn exhalation rate and its concentrations in soil together with CO_2 concentrations. It is called the radon calibrated method (RCM), which enables to calculate the CO_2 exhalation rate with potential application of its estimation for larger areas or territorial units.

In this contribution, we deal with a verification of various approaches of calculation of the radon exhalation rate from soil using the most common theoretical equations. These values are subsequently used in RCM and both results (i.e. the exhalation rate of ^{222}Rn and CO_2) are compared with measured results using an accumulation chamber in the locality of FMPI CU in Bratislava. Because meteorological parameters are routinely measured at the measurement site, this allows us to study variations of concentration and exhalation of radon and CO_2 depending on soil moisture and temperature. In a short-term perspective the results of exhalation rate and concentration show strong fluctuations according to the weather. On the other hand, in a long-term perspective we found a very good agreement of measured results with the calculated values for some of tested relations.

This work was supported by the Scientific Grant Agency of the Ministry of Education, Science, Research and Sport of the Slovak Republic and the Slovak Academy of Sciences (VEGA project No. 1/0019/22 and No. 1/0086/22) and the Slovak Research and Development Agency (project No. APVV-21-0356).

Distributions and inventory of ^{137}Cs released from multiple sources in a general circulation model

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Keywords: ^{137}Cs, Global fallout, Reprocessing Plant, Fukushima Dai-ichi Nuclear Power Plant accident, Ocean general circulation model

Radioactive cesium (^{137}Cs) is distributed in the world's oceans as a result of global fallout from atmospheric nuclear weapons tests, releases from fuel reprocessing plants, inputs from the Fukushima Daiichi Nuclear Power Station (F1NPS) accident. In order to detect future radionuclide contamination, it is necessary to establish a baseline global distribution of radionuclides such as ^{137}Cs and to understand the ocean transport processes that lead to that distribution. To this end, the International Atomic Energy Agency (IAEA) has created the database of observations of radioactivity in seawater. To aid in the interpretation of these observations, we have conducted a suite of simulations of the distribution of ^{137}Cs using a global ocean general circulation model (OGCM). The simulated ^{137}Cs activity concentrations were found to be in good agreement with available observations, especially in the North Pacific and the North Atlantic Oceans where the measurement densities are relatively high. The F1NPS accident increased the inventory by 20% in the North Pacific Ocean in 2011. In the North Atlantic, inventories reached a maximum in the late 1970s due to discharge from reprocessing plants. ^{137}Cs activity concentration from atmospheric nuclear weapons tests are expected to be detectable in the global ocean until at least 2030. These results of this simulation will be useful for planning future observations to fill gaps in the database.

POSTER SESSION II

10 Atmosphere

2-10-01

Radioxenon as a potential atmospheric tracer for climate studies

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Keywords: Radioxenon, effluents, atmospheric transport

Radioxenon released into the atmosphere from industrial sources has potential for use as a unique environmental tracer. The International Monitoring System (IMS) for the Comprehensive Nuclear-Test- Ban Treaty has stations deployed globally that monitor for radionuclide signatures of nuclear explosions which have been operating for many years. While well below levels related to health and safety concerns, these very sensitive IMS stations routinely detect radioxenon emissions from industrial sources such as medical isotope production and nuclear reactors. This radioxenon background can be used to understand global environmental transport. The Source Term Analysis of Xenon (STAX) project has using radioxenon emission data collected from industrial facilities along with atmospheric transport modeling to better understand the environmental transport and the global background of radioxenon observed at IMS monitoring stations. We will discuss how radioxenon is currently used for nuclear explosion monitoring and may be applied to other applications, for instance environmental and climate studies.

Ireland's Updated National Radiation Monitoring Network

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Keywords: Aerosol, gamma dose rate, monitoring,

Ireland's National Radiation Monitoring Network (NRMN) was set up in the 1980s for gamma dose rate, aerosol and precipitation monitoring. An upgrade of the network was required to ensure compliance with international regulations.

One of the main focuses was the significant improvement of particulate aerosol monitoring, as it's the main tool in characterising and quantifying radionuclides during an event. The following improvements were made:

- The expansion in the number of sites,
- Increase in the number of high- and low-volume aerosol samplers,
- Deployment of automated aerosol radioactivity measurement systems,
- Revision of procedures for the measurement gamma emitters and total beta activity of air filters,
- New and enhanced collaboration with various organisations,
- Modern and more resilient telemetry systems providing robust data pathways for secure emergency response and access to real-time data were rolled out. New communication pathways reduce the need for staff intervention in the field.

Improvements to the NRMN architecture and operational capacity were designed to increase its functionality and response capabilities in emergency situations.

The objective is to present lessons learned, challenges and outcomes of the project on the renewal of the radiation monitoring structure in Ireland that might be beneficial for countries planning the extension of their national networks.

Two years of continuous monitoring of ^{7}Be and ^{210}Pb in rainfall collected at the IPEN campus, São Paulo, Brazil

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Keywords: Be-7, Pb-210, Natural Radionuclides, Rainfall.

The naturally occurring radionuclides ^{7}Be and ^{210}Pb are produced in the atmosphere and used as tracers of a wide variety of processes that occur in the Earth's atmosphere and surface. The cosmogenic radionuclide ^{7}Be (T1/2 = 53.3 d), is produced in the upper atmosphere by cosmic ray spallation of oxygen and nitrogen; ^{210}Pb (T1/2 = 22.3 y), a natural radionuclide from ^{238}U series can be found in the atmosphere, as a product of ^{222}Rn decay that emanates from the ground. Both natural radionuclides can be used as tracers for heavy metals and pollutants in the environment, tracer of soil erosion, transport processes in watershed and sedimentation in lakes, among other examples. The activity concentration results of these radionuclides in rainfall, when combined with meteorological information, help to understand how aerosol particles are transported in the air and removed from the atmosphere by the action of rainfall. The objectives of this work were to determine the activity concentrations of the natural radionuclides ^{7}Be and ^{210}Pb in rainfall samples over a period of two years, from January 2021 to December 2022, in each rainy event that occurred on the IPEN campus, located in the city of São Paulo, Brazil. Be-7 activity concentrations were measured by non-destructive gamma-ray spectrometry using a coaxial Be-layer HPGe detector with 25% relative efficiency and associated electronic devices and live counting time varying from 80,000 s to 300,000 s; ^{210}Pb activity concentrations were measured by gross beta counting in a low background gas flow proportional detector, after radiochemistry procedure. The annual rainfall indices for 2021 and 2022 were 1093 mm and 1391 mm, respectively. Activity concentrations for ^{7}Be ranged from 0.459 ± 0.038 Bq L^{-1} to 8.96 ± 0.57 Bq L^{-1} and for ^{210}Pb from 0.015 ± 0.001 to 0.98 ± 0.01 Bq L^{-1} in the studied period. The results obtained of ^{7}Be and ^{210}Pb in rainfall were correlated to seasons, precipitation, temperature, and sunspot number for ^{7}Be. The higher values obtained for the concentrations were in winter and spring time presenting good correlations with the amount of precipitation and sunspot number and a clear seasonal variation.

Back-tracking of radioactive aerosols in the atmosphere with high temporal resolution

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[1]*National radiation protection institute (SÚRO), Prague, Czech Republic*

Keywords: Radioactive aerosols,Online measurement, HPGe detector, Inverse atmospheric modeling, Beryllium

Monitoring of radioactive aerosols is carried out routinely by various monitoring networks around the world. Although atmospheric research was not the primary reason why these networks were built, the data they provide can be very well used to investigate a variety of atmospheric processes.

In recent years, numerous studies have been conducted to link aerosol measurements and the back-trajectories of associated air parcels to identify the contributing meteorological factors to observed radionuclide concentrations. Such studies are often limited by the temporal resolution of the underlying monitoring data caused by rather long sampling intervals (~week), during which the wind direction can change significantly.

To overcome this issue, SURO has developed an online monitoring system that can detect airborne radioactivity at the mBq/m^3 level. The measurement is carried out using the HPGe detector positioned directly above the aerosol filter during sampling. The high sensitivity of this experimental setup enabled the reconstruction of the concentration time series of aerosol associated with ^{7}Be on a time scale of several hours.

Furthermore, the history of each air parcel was thoroughly investigated, and the influence of the aerosol and humidity along a given trajectory on the observed ^{7}Be activity was examined.

2-10-05

Greenhouse gas Observations at a middle-sized European city, Debrecen, Hungary: CO_2, CH_4 mole fraction, stable isotope ratio and radiocarbon measurements in different seasons

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Keywords: radiocarbon, carbon dioxide, methane, isotope ratio, greenhouse gas

The increasing level of atmospheric greenhouse gases and the effect of this trend, the climate change, is one of the greatest environmental issues of the modern era. The rapid, increasing trend of greenhouse gas levels after industrialization is related to urban environments, where industrial and traffic, transportation- related activity and emissions are concentrated. In response to this, the European system, the ICOS (Integrated Carbon Observation System) was established and started the ICOS cities program, where coordinated greenhouse gas observations are carried out besides the regional background measurements and samplings. Similarly to this program, atmospheric air samples were collected at the Institute for Nuclear Research, Debrecen. During the sampling campaigns in three different seasons (winter, spring and summer), a minimum of 23 samples were collected in the morning and afternoon during weekdays and weekends. The samples are processed within a collaboration between Utrecht University, where the stable isotope composition of CO_2 and CH_4 were measured, and the Institute for Nuclear Research, Hungary, where the mole fraction of CO_2 and CH_4 and radiocarbon ratio of CO_2 were measured. Based on the isotope composition results and stable isotope fingerprint of carbon dioxide and methane sources, the possible emission sources of these gases can be differentiated. We can estimate the fossil CO_2 contribution in urban areas using radiocarbon. The preliminary results show that there is a great fossil contribution to the CO_2 fraction, on the other hand, a great local biological contribution was observed in the CH_4 fraction in every season.

2-10-06

An attempt to measure the $^{237}Np/^{239}Pu$ atom ratios on air filters collected in the early 1960s in Vienna, Austria

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Keywords: $^{237}Np/^{239}Pu$, air filters, bomb peak, AMS

In the early 1960s air filters were collected at meteorological observatories in Vienna, Austria, in order to determine the amount of aerosol bound γ-emitting fission products like $^{141}Ce+^{144}Ce$, ^{103}Ru and $^{95}Zr+^{95}Nb$ present in ambient air (Schönfeld et al. 1960). Some years later ^{137}Cs and $^{239+240}Pu$ concentrations of selected filters were measured (Irlweck et al. 1981). In the last years we found it worthwhile to investigate the left-over filters (mainly from 1964-66) with regard to Pu atom ratios, and the more "exotic" ^{236}U and ^{233}U isotopes by using accelerator mass spectrometry (AMS) (Wallner et al. 2022).

As there are still filters available, we now turned to the determination of the $^{237}Np/^{239}Pu$ atom ratios preserved in these aerosols. As appropriate Np spikes (^{236g}Np and/or ^{235}Np) are not yet easily accessible, we tried an approach without spikes: Different chemical separation procedures were checked with regard to a constant ratio of the Np and Pu yields by α-spectrometry. So at least a good approximation of the $^{237}Np/^{239}Pu$ atom ratio should be possible for these samples representing pure nuclear weapons fallout undisturbed by mixing or dilution processes.

Schönfeld T, Liebscher K, Karl F, Friedmann C, 1960, Nature 185, 192-193.
Irlweck K, Friedmann Ch, Schönfeld T, 1981, Mitteilungen der österr. Sanitätsverwaltung 82, Heft 5, 81-84.
Wallner G, Uguz H, Kern M, Jirsa F, Hain K, 2022, JENVRAD 255, 107030

Analysis of Gross Beta activity concentration associated to aerosols in Mallorca (Spain) based on Multifractal Detrended Fluctuation Analysis (MFDFA)

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Keywords: Gross Beta, aerosol, MFDFA

Radioactivity in the atmosphere is measured as a key part of most surveillance programmes, which also provide useful information that allows to better understand atmospheric transport and the characterization of air masses. The obtained time series are complex and typically endowed with autocorrelation at different time scales, their proper analysis is then challenging.

Multifractal Detrended Fluctuation Analysis (MFDFA) is a numerical algorithm designed to understand the dynamical characteristics of complex time series, it deals with the identification of correlations and the scaling properties of time series data. MFDFA has been used to analyse a wide variety of data from different fields (biomedical, meteorological or economical) providing insights into the spatial and temporal distribution of the analysed parameters, and helping to identify patterns, trends, and anomalies in the data.

Given its proved ability to properly describe the properties of contaminants and tracers in the atmosphere, it is to expect that MFDFA can also be useful in environmental radioactivity studies. It is applied in this work to analyse a series of weekly gross beta activity concentrations measured in Mallorca (Spain) between 2006 and 2019. The fluctuation function, generalised Hurst exponent, multifractal scaling exponent and the singularity spectrum are obtained for this time series. Results are compared to typical values obtained for other atmospheric tracers in other studies.

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Back-tracking of radioactive aerosols in the atmosphere with high temporal resolution

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Keywords: Radioactive aerosols,Online measurement, HPGe detector, Inverse atmospheric modeling, Beryllium

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In recent years, numerous studies have been conducted to link aerosol measurements and the back-trajectories of associated air parcels to identify the contributing meteorological factors to observed radionuclide concentrations. Such studies are often limited by the temporal resolution of the underlying monitoring data caused by rather long sampling intervals (~week), during which the wind direction can change significantly.

To overcome this issue, SURO has developed an online monitoring system that can detect airborne radioactivity at the mBq/m^3 level. The measurement is carried out using the HPGe detector positioned directly above the aerosol filter during sampling. The high sensitivity of this experimental setup enabled the reconstruction of the concentration time series of aerosol associated with ^{7Be} on a time scale of several hours.

Furthermore, the history of each air parcel was thoroughly investigated, and the influence of the aerosol and humidity along a given trajectory on the observed ^{7}Be activity was examined.

POSTER SESSION II

11 Marine environment

2-11-01

Building a database from radioisotopes measurements: the case of ^{234}Th in seawater

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Keywords: Radioisotopes, database, Thorium-234.

Radioisotopes serve as tracers to study biological and physical processes, together with the impact that human activity has on them. Databases are a basic tool for storing data in a structured form and facilitating their consultation. The fast development of sampling and analysis techniques has incremented the amount of available measured data, including radioisotope concentrations. Hence the creation of open-data, well-structured and user-friendly databases is vital in Environmental Sciences. Moreover, AI databases are a fast-emerging database approach that should be considered when designing a new database. In the field of radioecology, databases can be used to collect information on radioisotopes measurements, doses or related parameters, in different environmental compartments. IAEA's MARIS or GEOTRACERS are examples of databases that collect open-access radionuclide data measured in marine environments.

Building a functional database requires great effort and meticulous work. Some of the main problems present in existing databases are the usability and the management of large amounts of data. As a case study, we are working on a compilation of ^{234}Th measurements in seawater, a radioisotope that traces carbon fluxes and carbon export in the ocean. Based on our case study, we present a guide of recommendations for database building on environmental radioactivity. The key points detected are the designing of a robust structure, that allows to add new inputs if required, the need for constant updates and the incorporation of AI techniques to improve efficiency or functionality. This improves the access of the scientific community to global data for analysis and for using emerging technologies to process large amounts of data.

2-11-02

Radiological impact of the submarine volcano Tagoro (Canary Islands) on coastal ecosystem from 2011 to 2020

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Keywords: Tagoro, Submarine volcano, radiological impact, Canary Islands

Volcanic eruptions are a source of natural radionuclides that are incorporated into the environment and can be used as tracers of various volcanic processes. Imbalances in the ^{238}U, ^{235}U and ^{232}Th series can provide relevant information for the analysis of time scales and dynamics of magmatic processes, for dating volcanic eruption, or as a precursor signal for volcanic eruptions. In addition to this relevant role as tracers of volcanic processes, it is important to assess the radiological impact of radionuclides released in volcanic eruptions on the environment and the nearby population. However, there are not many studies on the radiological impact of volcanic eruptions that assess radiological risk, and even fewer are found on these radiological impact's effects on marine environmental ecosystems when the eruption is submarine. The monitoring of natural radioactivity levels in the environment of the submarine volcano of the Canary Island of El Hierro during the eruption (October 10, 2011 to March 5, 2012) is analysed. What is more, its subsequent radiological impact later years (2013-2020) on the coastal ecosystem through water, sediments, and biota (algae) is studied.

2-11-03

Distributions of ^{137}Cs in the Southern Sea of Korea: Preliminary results of onboard measurement in 2022

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Keywords: ^{137}Cs, onboard measruement, Southern Sea of Korea

Cesium-137 (^{137}Cs; half-life = 30 years) is one of the artificial gamma-decay nuclides which has been produced from human activities related to nuclear facilities and reactors. In marine environments, ^{137}Cs have been widely used as a tracer for water mass transport and sedimentation rates. We measured the horizontal and vertical distributions of ^{137}Cs in seawater and other oceanographic parameters (i.e., temperature and salinity) during September 30 to October 5, 2022 in the Southern Sea of Korea (SSK). In this study, we applied the onboard measurement of ^{137}Cs by the nickel potassium ferrocyanide (KNiFC) co- precipitation (< 12 hours) and High Purity Germanium (HPGe) detector (~ 8 hours of counting time) equipped in a ship-based mobile laboratory. ^{137}Cs activities ranged from 1.35 to 2.60 dpm L^{-1}, with a chemical recovery of 97% ± 5% (n > 30). These ^{137}Cs activities were similar to those observed in the past from the SSK (2014-2021) which was measured by traditional methods (i.e., AMP co- precipitation). Our results suggest that the onboard measurement of ^{137}Cs can be used in the event of an accident requiring urgent monitoring in the ocean.

2-11-04

16 years of actinides studies in marine samples in the frame of the IAEA-CNA collaborating agreement

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Keywords : AMS, CNA, actinides, IAEA

The *Centro Nacional de Aceleradores* (CNA, Sevilla, Spain) signed the first collaborating agreement with the International Atomic Energy Agency (IAEA) Environment Laboratories (Monaco) in 2007. Since then, both institutions have enjoyed a fruitful collaboration. The IAEA expertise on radiochemistry has motivated and allowed the development of a novel procedure for the AMS analysis of ^{237}Np, ^{236}U and ^{239,240}Pu in low-volume seawater samples, and its application to solid matrixes is an ongoing project (Lérida et al, these proceedings). A synergy with active IAEA sampling projects has been fulfilled, and comprehensive datasets on ^{236}U, ^{237}Np have been produced in different marine regions of the world. Besides, ^{236}U and ^{239,240}Pu has been determined in a variety of IAEA reference materials. In this work, we will present an overview of the studies performed in the frame of the IAEA-CNA collaboration agreement.

V. Lérida, I. Levy, M. López-Lora, E. Chamizo, *Sequential extraction of actinides from sediment samples for the analytical determination of ^{237}Np by AMS*, these proceedings.

2-11-05

Distributions of radiocesium and plutonium in the Korean seas and North Pacific after the Fukushima accident, 2011-2014

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Keywords: Radocesium, Plutonium, Fucushima accident, Pacific Ocean

The distributions of artificial radionuclides, radiocesium (^{137}Cs and ^{134}Cs) and plutonium isotopes ($^{239+240}$Pu and ^{238}Pu), in the surface water around the Korean seas (East/Japan Sea and Yellow Sea) in 2011–2012 and in three sections in the North Pacific between 2011and 2014 were examined. The ^{137}Cs activities in the surface water in the Korean seas in 2011 (immediately after the Fukushima nuclear power plant (NPP) accident on 17 March 2011) were comparable or not significantly different relative to those in 2012 and 2010. However, ^{134}Cs, which had been not detected in the study area before the Fukushima accident (under the detection limit of 0.1 mBq kg^{-1} level), was detected rapidly in 2011 after the accident (in about 60% of the 72 samples) and gradually disappeared due to its short half-life ($t_{1/2}$ = 2.06 years) in 2012 (detected in about 16% of the 24 samples). In addition, the highest activities of radiocesium and Pu isotopes appeared locally in some stations of the Korean Strait region (located between Korea and Japan), within 1–2 months immediately after the accident. This suggests that the radioactive nuclides released immediately after the Fukushima accident were significantly introduced through the atmosphere, based on recent studies conducted in neighbouring areas. We also show that the spatial distribution of radiocesium in the North Pacific moved east-ward from 2012 to 2014, and we attempt to quantify the residence time of radiocesium (^{137}Cs) in the Korean seas based on the long-term

(tens of years scale) temporal trends of ^{137}Cs activity data, which have been collected since the 1960s and 1970s. The estimated retention time of ^{137}Cs in the East/Japan Sea and Yellow Sea were 25±0.6 and 8.0±0.1 years, respectively. These results are expected to be used as a preliminary study for a potential future event of a marine radioactive accident (which, of course, cannot be predicted) and as basic data for predicting the influences of radionuclide releases in the ocean.

2-11-06

First radionuclide survey in marine environment off the Mauritius coast: levels and distributtion of naturally occurring radionuclides and ^{137}Cs in seawater,sediments and biota

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Radionuclide studies in the marine environment for small island developing states, such as Mauritius Island, are essential as inhabitants depend highly on marine resources as their primary sources of protein. This study presents the first records for the distribution of radionuclides (^{210}Po, ^{234}U, ^{235}U, ^{238}U, ^{40}K, ^{228}Th, ^{228}Ra, ^{210}Pb, ^{226}Ra and ^{7}Be) in different compartments of the marine ecosystem (seawater, sediment, macro-algae, sea cucumber, oysters and fish) of Mauritius Island and ^{210}Po annual dose assessment.

The calculated K_ds for ^{210}Po and U isotopes were lower than the reported average worldwide and ithe marine sediments were found poor in ^{40}K (10 to 95 Bq/kg) due to their biogenic carbonate composition. With respect to biota samples, biota sediment accumulation factor (BSAF) values (2.6 - 71.7) of ^{40}K showed that macro-algal samples readily bio-accumulated ^{40}K. Macro-algae also displayed the highest levels of ^{210}Pb (48.1±42 Bq/kg). High levels of ^{210}Po were observed in oyster *Saccostrea* sp samples collected at two sites. The calculated BSAF values suggested that macro-algae and fish could be considered as good bio-sensors for ^{40}K whereas oysters for ^{210}Po. The annual effective doses from ^{210}Po obtained through consumption of fish and oysters ranged from 0.19 mSv/year to 0.21 mSv/year and 0.07 mSv/year to 0.12 mSv/year, respectively which were below the annual effective dose due to natural radiation sources.

POSTER SESSION II

12 Marine sediments

2-12-01

Environmental radiological risk assessment of algae from Algiers coastline

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Keywords: Risk assessment, algae, gamma spectrometry, ERICA tool, Algiers coastline

Abstract:
During recent years there has been increased interest for knowledge on the concentration and the distribution of natural radionuclides in the marine environment. The latter is required not only to provide useful information to radiological monitoring programmes, but also to assess the radiological risk for marine biota and seafood consumers. In Algeria, there are no studies that surveyed the quantities of radionuclides in algae and their potential effects on human health.

The main objectives of this preliminary work are the study of radionuclides distribution in algae species as well as the assessment of the linked environmental radiological risk.

Brown, red, and green algae were collected from five different parts of Algiers coastline on May 2022.
Algae species were identified at laboratory and an amount of 100 g dry weight of each species were taken for analysis.
The radionuclides that were analyzed by gamma spectrometry were ^{238}U daughters (^{234}Th, ^{226}Ra, ^{214}Pb and ^{214}Bi), ^{232}Th daughters (^{212}Pb, ^{208}Tl and ^{228}Ac), ^{7}Be and ^{40}K.
Activity concentrations (Bq·kg^{-1} d.w.) were found to be in the range of 138.75±6.41-1858.95 (^{40}K), 6.36±3.78-35.51±9.54 (^{7}Be), 0.58 ±0.14-5.08±0.76 (^{226}Ra), 0.61±0.21-3.02±1.47 (^{232}Th).
ERICA tool was used for the radiological risk assessment.
The total dose rates for algae species were found lower than 7µGy·h^{-1} and the annual effective dose was found to be: 2.95·10^{-3} mSv·y^{-1}.
The results indicate that algae from Algiers coastline do not pose a radiological health risk.

2-12-02

Spatial distribution of radionuclides in marine sediments from Djibouti seamounts (Alboran Sea, Western Mediterranean)

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Keywords : Natural radionuclides, ^{137}C, marine sediments, Alboran Sea.

In the present study, sediment grab samples from two seamounts of the Djibouti Banks area – Avempace and Herradura - located on the Motril Marginal Plateau (northern Alboran Sea) were investigated to determine the radioactivity of natural (^{226}Ra, ^{232}Th, ^{210}Pb, ^{40}K) and artificial (^{137}Cs) radionuclides. Changes in sediment features on seamounts can be related with both source and oceanographic conditions, but also geochemical interactions can be involved once particles are settled oralong the water column. The particular interest of this area is that the influence of fluvial supplies is scarce and almost all the sediments belong to the aeolian dust inputs that are transported, deposited and reworked by the bottom current. In this setting, the Sahara and northern North Africa or Sahel regions are the most likely areas providing dust particles to the Mediterranean Sea.

The tops of the Avempace and Herradura seamounts are relatively flat, and they occupy water depths of 200–500 m. In general, both seamounts presented similar average radiological load and the results showed that the spatial distribution of radionuclides was relatively uniform in the surface sediments from these two banks. For the anthropogenic ^{137}Cs, the radioactivity ranges from 1.8-6.9 Bq/Kg and can be mainly attributed to the significant supply of aeolian dust from North Africa to the Alboran Sea.

2-12-03

On the prevalence of ^{242m}Am in sediments collected from the vicinity of a Swedish nuclear facility

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Keywords: Sediments, nuclear facility, americium

^{242}Am ($T_{1/2}$=16 h) and ^{242m}Am ($T_{1/2}$=141 y) are a product of the neutron capture of ^{241}Am, and the capture cross sections for the thermal neutrons are 562 and 62 barns, respectively. ^{242}Am disintegrates with beta emission (83%) to ^{242}Cm ($T_{1/2}$=163 d), is one of the dominating alpha emitters in nuclear fallout in terms of activity and decays in a couple of years after the fallout. ^{242}Cm can also exist in a supported state with ^{242m}Am and ^{242}Am and can be used to determine the activity of ^{242m}Am in the environment. ^{242m}Am decays via internal transition to ^{242}Am, which again will produce ^{242}Cm. This supported fraction of ^{242}Cm to a total ^{242}Cm is usually less than 0.01% of the spent nuclear fuel. When compared to ^{243,244}Cm isotopes, ^{242m}Am (measured via supported ^{242}Cm) gives reliable information on the burn-up history of the nuclear fuel.

Swedish nuclear facility Studsvik is located on the shore of the Baltic Sea, close to Tvären. This is a semi-enclosed bay with a max. depth of 80 m and can be effectively used to study the distribution and mobility of rare actinides. In our study, we collected multiple sediment cores from Tvären Bay to understand the historical discharges of Studsvik nuclear facility and actinides distribution in these specific conditions. The presentation shows spatial distribution, inventories, and activity ratios of ^{242m}Am in relation to other actinides radionuclides.

2-12-04

Anthropocene dating by radionuclide analysis of estuarine sediments from northern Spain.

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Keywords: Plutonium, Sediments, Dating, Anthropocene, Radiochemistry

The Anthropocene Epoch is the proposal of a new geological time division used to describe the most recent interval in Earth's history when human activity started to have a significant impact on the planet's climate and ecosystems. In particular, this epoch is considered to begin when thermonuclear weapons tests in the atmosphere caused radioactive signals to be present in the global stratigraphic record beginning in 1952, a peak between 1963 and 1964, and a decline since then due to the partial nuclear test ban treaty. Among the artificial radionuclides, $^{239+240}$Pu is considered the primary marker of the Anthropocene due to its global distribution, ubiquitous presence in all environments, long half-life and its low mobility in sediments and ice. Moreover, the Pu profiles of cores are compared with the corresponding ^{137}Cs profiles and ^{210}Pb dating.

In this work, several cores of estuarine sediments from northern Spain up to depths of 50 cm were analysed. A radiochemistry method for plutonium determination based on borate fusion pretreatment, UTEVA extraction chromatography separation, electrodeposition and alpha spectrometry was applied. The $^{239+240}$Pu profiles were represented and ratios ^{238}Pu/$^{239+240}$Pu were obtained for samples with activities above the limit of detection. $^{239+240}$Pu activities ranged from 0.1 to 1.5 Bq/kg.

2-12-05

Gamma emitter radionuclides as tracers of sediment dynamics in beach areas: a comparison between in situ and lab-based gamma spectrometry measurements

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Keywords: Gamma spectrometry, In-situ measurements, Sediment dynamics, tracer

Natural radionuclides are a useful tool to study the sediment dynamics in coastal areas. In this study, the activity concentration values of ^{226}Ra, ^{228}Ra and ^{40}K were analysed on two beaches with different sedimentary dynamics on the Island of Gran Canaria (Spain) using gamma spectrometry. Measurements were carried out using the KATERINA in situ detector from the Hellenic Centre for Marine Research and a Canberra Extended Range (XtRa) Germanium spectrometer belonging to the University of Las Palmas de Gran Canaria. In one of the beaches, Las Canteras Beach, the sediment dynamics and the use of natural radionuclides ^{226}Ra, ^{228}Ra and ^{40}K as tracers of erosion and accumulation periods are well documented in the literature. Therefore, the results were useful to improve the calibration of the KATERINA detector for in situ measurements of the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K. Moreover, both types of measurements were applied to do a first study using the activity concentration of ^{226}Ra, ^{228}Ra and ^{40}K to trace the sediment dynamics of the second beach, La Laja beach. The comparison of the results obtained for both beaches also helped to further comprehend the weakness and strengths of each methodology.

2-12-06

Determination of sedimentation rates using Pb-210 and Cs-137 at a renaturalised salt marsh of the Wadden Sea

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Keywords: Wadden Sea, Cs-137, supported and unsupported Pb-210

Due to the installation of electric power lines to offshore wind farms, impairments of the natural balance in the Wadden Sea of the German North Sea coast have to be compensated. To this end, in the Lower Saxony part of the Wadden Sea National Park in East Frisia near the village of Neßmersiel (ferry port to the island of Baltrum), culturally influenced salt marshes that are in an unfavourable state of conservation are to be upgraded accordingly. This includes removing material and remodelling the terrain, restoring more frequent flooding and different standing times of the water in order to preserve biodiversity and protect the population of the highly specialised flora and fauna. These measures are being scientifically monitored by the Ludwig Franzius Institute of Hydraulic, Estuarine and Coastal Engineering (LuFI) at Leibniz University Hanover. The Institute of Radioecology and Radiation Protection (IRS) at Leibniz University Hanover supported this with radiometric investigations. For this purpose, several drill cores were taken on the salt marsh in December 2022. These are now being examined for Cs-137 and Pb- 210 by means of gamma spectrometry within the framework of two bachelor theses in order to be able to draw conclusions about sedimentation age and rate.

2-12-07

Sediment Profiles from Anoxic Regions off the Namibian Coast

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Keywords: Sediment cores, anoxic areas, natural radinuclidea an elementalprofiles

During two scientific surveys organized in 2014 and 2015, in total 21 sediment cores were collected along the Namibian coast from 18º to 26º latitude and at different distances from the shoreline. The Namibian coastal region is part of the northern Benguela upwelling system, one of the four major eastern boundaries coastal upwelling ecosystems of the world. It is characterized by strong wind-driven upwelling conditions, extensive areas of bottom waters containing minimum amounts of oxygen (< 2 mL/L), affected by intensive sulfuric eruptions and/or dominated by marine phosphate deposits. The radiometric characterization of sediments from such a dynamic system provided necessary information on areas of net sedimentation that are ideal for collecting sediment cores for studying temporal evolution of potential anthropogenic contaminants during the last century by ^{210}Pb dating method. Obtained data suggested that sediment cores can be associated with a sedimentary area only by the analysis of the uppermost layer which consequently significantly simplifies the work, allowing to concentrate efforts on cores from which valuable information can be gained.

Locations affected by anoxic conditions were identified within sedimentary areas and were further investigated. The detailed study of one sediment core affected by anoxic conditions presented in this study shows that radionuclides mostly used for ^{210}Pb dating (^{210}Pb and ^{226}Ra) are not affected by variable enhancements or depletions in the sediments due to the redox conditions. The ^{210}Pb dating technique can be thus applied with confidence in coastal sediment cores affected by anoxic conditions. The U profile shows enrichment along the core consistent with a y reduced form of uranium which is present in anoxic conditions in the areas with high productivity and/or deposition of organic matter. Specific profiles of some heavy metals (manganese, cadmium, zinc and cooper) significantly influenced by anoxic conditions can be used as the ideal fingerprint of the conditions of the sediments in the investigated area.

2-12-08

^{241}Am in the bottom sediments of the southern Baltic Sea

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Keywords: Baltic Sea, sediments, artificial radionuclides, americium ^{241}Am

Based on obtained results of ^{241}Am in dated sediments, we studied the history of isotope accumulation in the sediments and evaluated their contamination level and distribution in the sediment cores. The fieldwork and sampling collection in the presented project were performed during a cruise on the r/v Oceania that belongs to the Polish Academy of Sciences (IO PAN). Sediment cores were collected from various locations in the southern Baltic Sea; the Bornholm Deep, the Gdansk Deep, and the Gotland Deep.

An analytical method for determining Am was adapted to analyse ^{241}Am in environmental and biological samples, which relies on the sequential use of ion exchange (Dowex 1x8) and extraction chromatography (UTEVA and TRU) to obtain a pure radioactive source of ^{241}Am. The procedure was developed using the tracer ^{243}Am isotope and alpha spectrometry. The accuracy was tested using reference materials IAEA-300, IAEA-384 and IAEA-385.

The results showed in bottom sediment samples taken in 2010, the activity concentrations of ^{241}Am in the Gdańsk Deep ranged from 0.009±0.003 (k=2) to 0.938±0.070 Bq·kg^{-1} and in the Gotland Deep from 0.024±0.004 to 2.57±0.19 Bq·kg^{-1}. For bottom sediment samples collected in 2019, ^{241}Am activity concentrations in samples from the Bornholm Deep ranged from 0.030±0.012 to 0.85±0.06 Bq·kg^{-1}, in the Gdańsk Deep from 0.24±0.017 to 1.59±0.12 Bq·kg^{-1} while in the Gotland Deep was from 0.017±0.002 to 2.25±0.16 Bq·kg^{-1}.